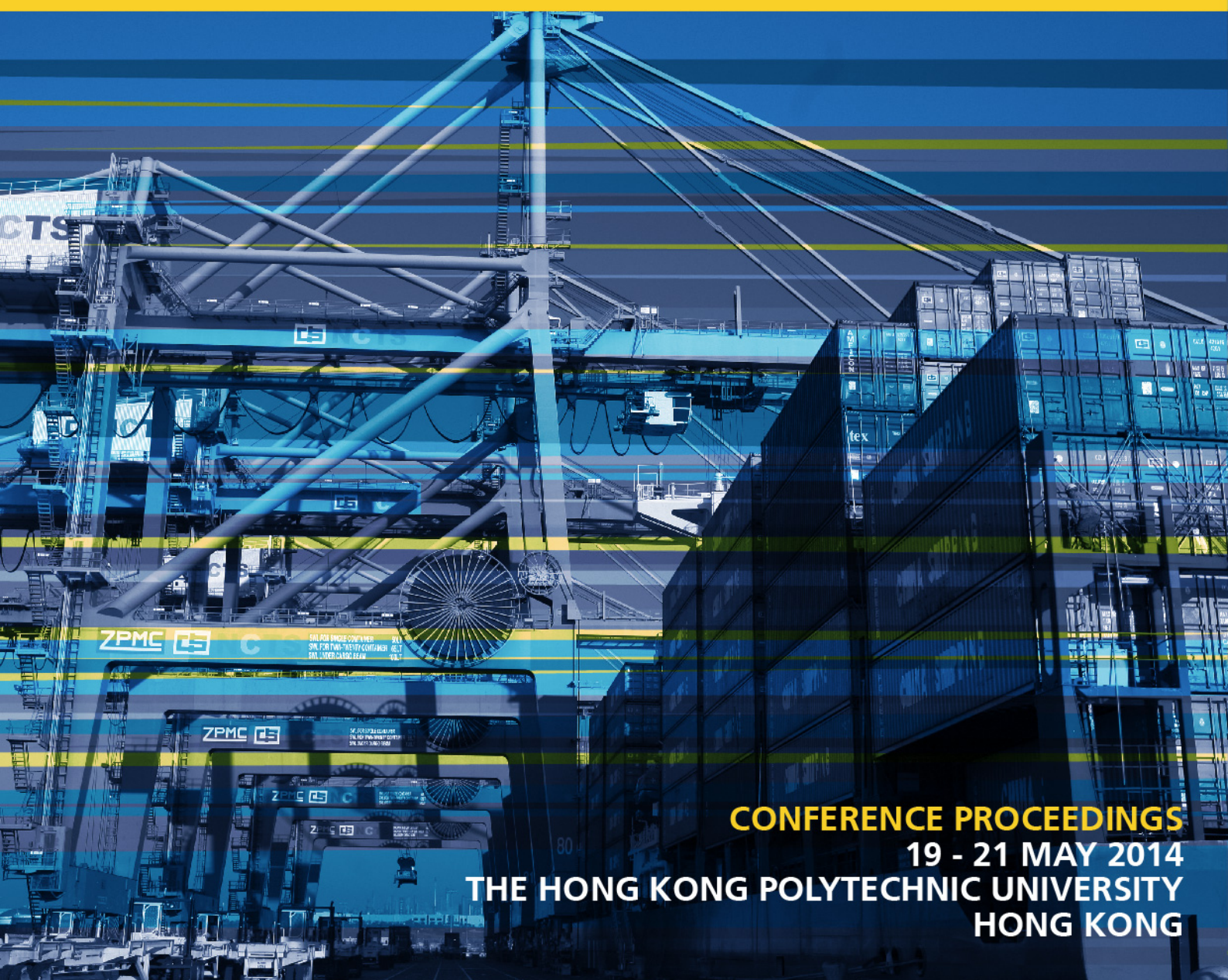


IFSPA 2014

INTERNATIONAL FORUM ON SHIPPING, PORTS AND AIRPORTS (IFSPA) 2014

SUSTAINABLE DEVELOPMENT IN
SHIPPING AND TRANSPORT LOGISTICS



CONFERENCE PROCEEDINGS

19 - 21 MAY 2014

**THE HONG KONG POLYTECHNIC UNIVERSITY
HONG KONG**

Proceedings of the
International Forum on Shipping, Ports and Airports (IFSPA) 2014

Sustainable Development in Shipping and Transport Logistics

19 – 21 May 2014

Hong Kong

Edited By:

Chin-Shan Lu

Petrus Choy

Kee-hung Lai

Y.H. Venus Lun

Tsz Leung Yip

Proceedings of the International Forum on Shipping, Ports and Airports (IFSPA) 2014

19 – 21 May 2014

Copyright © 2014

C.Y. Tung International Centre for Maritime Studies

Department of Logistics and Maritime Studies

The Hong Kong Polytechnic University

All rights reserved.

No part of this publication may be reproduced, transmitted, transcribed, stored in a retrieval system, or translated into any language, in any form or by any means without written authorization from The Hong Kong Polytechnic University.

ISSN: 2312-6388

The organizers and editors of this publication assume no responsibility or liability for the statements or opinions expressed in papers or presentations by the contributors to this conference or proceedings.

August 2014



The **International Forum on Shipping, Ports and Airports (IFSPA)** is an annual international conference jointly organised by the C.Y. Tung International Centre for Maritime Studies and the Department of Logistics and Maritime Studies of The Hong Kong Polytechnic University. It aims to invite international academics and practitioners to discuss and exchange views on issues related to global maritime and aviation economics, policy and management. The conference also serves as a good platform for networking and promoting academic-industry collaboration.

The roots of IFSPA can be dated back to 2006 when it was started as a workshop with the objective to promote high-quality research papers. Since then it has experienced significant successes and has attracted more than 700 participants from different countries and regions of the world.

Preface

The Seventh International Forum on Shipping, Ports and Airports (IFSPA) 2014 was successfully held from 19 to 21 May 2014, in Hong Kong. The proceedings contained a collection of 70 papers presented during the Conference. The topics covered include shipping economics, port strategy, airport management, logistics development, environmental issues in logistics, port efficiency and competition, and maritime safety and security.

The theme of IFSPA 2014 was “Sustainable Development in Shipping and Transport Logistics”. It aimed at providing an interactive platform for international academics to discuss important issues related to shipping, ports, and airports. It also advocated the adoption of interdisciplinary business approach for maximisation of competitive advantage, economic benefits and sustainable developments of transport, logistics, shipping and trading industries worldwide. This year the Forum comprised 5 Keynote Sessions, 4 Special Sessions and 18 Parallel Sessions. During the event, world-famous scholars and industry leaders shared with participants their insights on issues relevant to maritime and trade economics, policy and management. More than 120 delegates came from different parts of the world including Australia, Belgium, Canada, Germany, Egypt, Japan, Korea, Taiwan, India, the Netherlands, Norway, Italy, Thailand, the U.K., and the U.S.

Led by the C.Y. Tung International Centre for Maritime Studies of The Hong Kong Polytechnic University, IFSPA is an annual international event devoted to maritime, aviation and logistics studies to discuss and exchange views on contemporary issues facing the sectors, and further advance academia-industry cooperation. Through participation from relevant international and regional organisations, the increased pool of participants has enabled IFSPA to become an important event in the transport logistics sector. We are pleased that the event has secured significant support from local governmental agencies and institutions to assist with its coordination and implementation. Conference participants now include the world’s leading maritime and aviation experts and professionals.

The Conference gratefully acknowledges the support from our Conference Sponsors including Faculty of Business of PolyU, Orient Overseas Container Line Ltd., Tai Chong Cheang Group, Pacific Star Group and Chinese Maritime Research Institute, especially Routledge for exhibiting at IFSPA 2014.

The IFSPA 2014 Organising Committee greatly appreciates the invaluable contribution from the invited speakers, paper authors, paper reviewers, conference co-organizers and partners.

Finally, we thank members of the Organising Committee and Conference Secretariat who had offered both moral and technical support to the conference and this proceedings. In particular, we would like to thank Xinyu Sun, Justin Wong and Violette Wong.

The Editors

Chin-Shan Lu
Petrus Choy
Kee-hung Lai
Y.H. Venus Lun
Tsz Leung Yip

Hong Kong, August 2014

IFSPA 2014 Organizing Committee

Conference Chairman Chin-Shan Lu

Co-Chairs
Petrus Choy
Kee-hung Lai
Y.H. Venus Lun
Tsz Leung Yip

Committee Members
Chung-Lun Li
Hong Yan
Hengqing Ye
Zhou Xu
Meifeng Luo
Sarah Wan
Yulan Wang
Peter Wong
Kelvin Pang
Johnny Wan
Girish Gujar

Secretariat
Xinyu Sun
Violette Wong
Justin Wong
Fiona Zhang

Conference Sponsors and Partners

The Organizing Committee would like to express our deep appreciation to the support of the following companies and organizations.

Conference Sponsors

Faculty of Business, The Hong Kong Polytechnic University

Orient Overseas Container Line Ltd.

Tai Chong Cheang Group

Pacific Star Group

Conference Co-organisers

Chinese Maritime Research Institute

IMC-Frank Tsao Maritime Library and Research & Development Centre

Logistics Research Centre

Shipping Research Centre

Conference Partners

Hong Kong Air Cargo Industry Services Limited

Hong Kong Association of Freight Forwarding & Logistics

Hong Kong Logistics Association

Hong Kong Shipowners Association

Hong Kong Shippers' Council

Modern Terminals Limited

Routledge

Taipei Port Container Terminal Corporation

The Chartered Institute of Logistics & Transport in Hong Kong

List of Keynote Speakers

IFSPA 2014 is proud to have invited the following worldwide prestigious scholars and practitioners as Keynote Speakers for this event:

- Professor Rommert Dekker
Erasmus University Rotterdam, The Netherlands
- Dr Anne Graham
University of Westminster, United Kingdom
- Professor Chandra S. Lalwani
University of Hull, United Kingdom
- Ms Vivien Lau
Hong Kong Air Cargo Industry Services Limited, Hong Kong
- Professor Chung-Yee Lee
The Hong Kong University of Science and Technology, Hong Kong
- Mr Michael Lee
Chinese Maritime Research Institute, Taiwan
- Professor Becky P.Y. Loo
The University of Hong Kong, Hong Kong
- Mr Kevin Suen
Taipei Port Container Terminal Corporation, Taiwan
- Mr James S.C. Tai
Orient Overseas Container Line (OOCL) Limited, Hong Kong
- Mr Arnold Wu
BNP PARIBAS, Hong Kong

List of Paper Reviewers

The Organizing Committee would like to express heartfelt thanks to the following scholars for their invaluable inputs to the peer-review process of the academic papers submitted to IFSPA 2014.

Michele Acciaro	The Kühne Logistics University, Germany
Bhagrav Adhvaryu	Centre for Environment Planning and Technology University, India
Sataporn Amornsawadwatana	The University of the Thai Chamber of Commerce, Thailand
Victor Oladapo Atere	University of Central Lancashire, United Kingdom
Ruth Banomyong	Banomyong Thammasat University, Thailand
Stephen Cahoon	Australian Maritime College, Australia
Pierre Cariou	Marseilles Business School, France
Yu-Chun Chang	National Taiwan Ocean University, Taiwan
Poti Chao	Chiang Mai University, Thailand
Shih-Liang Chao	National Taiwan Ocean University, Taiwan
Haibo Chen	Ningbo University, China
Yenming Chen	National Kaohsiung University of Science & Technology, Taiwan
Petrus Choy	The Hong Kong Polytechnic University, Hong Kong
Qing Ding	Huazhong University of Science & Technology, China
Branislav Dragovic	University of Montenegro, Montenegro
César Ducruet	University of Paris 1 Panthéon-Sorbonne, France
Islam El-Nakib	Arab Academy for Science, Technology and Maritime Transport, Egypt
Lixian Fan	Shanghai University, China
Walter S.L. Fung	The Hong Kong Polytechnic University, Hong Kong
Xianghua Gan	The Hong Kong Polytechnic University, Hong Kong
Qiang Gong	Southwestern University of Finance and Economics, China
Stephen Gong	The Hong Kong Polytechnic University, Hong Kong
Girish Gujar	The Hong Kong Polytechnic University, Hong Kong
Pengfei Guo	The Hong Kong Polytechnic University, Hong Kong
Gaofeng Huang	University of Oxford, United Kingdom
Mukul Jain	Indian Railway Traffic Service, India
Liping Jiang	University of Southern Denmark, Germany
Jasmine Siu Lee Lam	Nanyang Technological University, Singapore
Joseph Yui Yip Lau	Hong Kong Community College, PolyU, Hong Kong
Zheng Lei	Cranfield University, United Kingdom
Gang Li	Xi'an Jiaotong University, China
Leon Li	The Hong Kong Polytechnic University, Hong Kong
Luke Ming Kun Li	Shanghai University, China
Chiung-lin Liu	National Taiwan Ocean University, Taiwan
Nan Liu	Zhejiang University, China

Shumin Liu	Inha University, Korea
Manoj Lohatepanont	Chulalongkorn University, Thailand
Cherie Lu	Chang Jung Christian University, Taiwan
Y.H. Venus Lun	The Hong Kong Polytechnic University, Hong Kong
Meifeng Luo	The Hong Kong Polytechnic University, Hong Kong
Olaf Merk	The Organisation for Economic Co-operation and Development, France
Prakash Metaparti	The Hong Kong Polytechnic University, Hong Kong
Haruo Mimura	Kobe University, Japan
Toshinori Nemoto	Hitotsubashi University, Japan
Adolf K. Y. Ng	University of Manitoba, Canada
Baozhuang Niu	Sun Yat-Sen University, China
Anthony Pang	The Hong Kong Polytechnic University, Hong Kong
Kelvin KL Pang	The Hong Kong Polytechnic University, Hong Kong
Bart Van Riessen	Erasmus University Rotterdam, The Netherlands
Michael Roe	Plymouth University, United Kingdom
Kimitoshi Sato	Waseda University, Japan
Kuo-Chung Shang	National Taiwan Ocean University, Taiwan
Maja Skuric	University of Montenegro, Montenegro
Dongping Song	Plymouth University, United Kingdom
Xinyu Sun	The Hong Kong Polytechnic University, Hong Kong
Christa Sys	University of Antwerp, Belgium
Sik Kwan Tai	City University of Hong Kong, Hong Kong
Ailie Kit Yee Tang	Centennial College, Hong Kong
Vinh Van Thai	Nanyang Technological University, Singapore
Johnny Wan	The Hong Kong Polytechnic University, Hong Kong
Sarah Wan	The Hong Kong Polytechnic University, Hong Kong
Jin Wang	Liverpool John Morres University, United Kingdom
Wen-Yao Grace Wang	Texas A&M University at Galveston, USA
Xiaoxia Wang	Beijing Jiaotong University, China
Yuhong Wang	Edinburgh Napier University, United Kingdom
Yulan Wang	The Hong Kong Polytechnic University, Hong Kong
Hon Shu Wong	The Hong Kong Polytechnic University, Hong Kong
Peter Wong	The Hong Kong Polytechnic University, Hong Kong
Jun Wu	Beijing University of Posts and Telecommunications, China
Yen-Chun Jim Wu	National Sun Yat-Sen University, Taiwan
Yibin Xiao	University of Electronic Science and Technology of China, China
Jingjing Xu	Plymouth University, United Kingdom
Su Siu Xu	The University of Hong Kong, Hong Kong
Zhou Xu	The Hong Kong Polytechnic University, Hong Kong
Bibo Yang	The Hong Kong Polytechnic University, Hong Kong

Chung-Shan Yang	Chang Jung Christian University, Taiwan
Hangjun Yang	University of International Business and Economics, China
Yi-Chih Yang	National Kaohsiung Marine University, Taiwan
Zaili Yang	Liverpool John Moores University, United Kingdom
Hengqing Ye	The Hong Kong Polytechnic University, Hong Kong
Raymond Yeung	The Hong Kong Polytechnic University, Hong Kong
Jingbo Yin	Shanghai Jiaotong University, China
Tsz Leung Yip	The Hong Kong Polytechnic University, Hong Kong
Qingcheng Zeng	Dalian Maritime University, China
Ling Zhu	The Hong Kong Polytechnic University, Hong Kong

Contents

The Spatial-temporal Analysis of Airport Foreign Firms' Agglomeration Trends – The Case of Shanghai Hongqiao International Airport <i>Yonglei Jiang, Liangwen Qiu, Lu Wang, Ruijia Zhao, Zhongzhen Yang</i>	1
Market Structure and Airline Pricing: Evidence from the Chinese Airline Industry <i>Jiaqiang Song, Hangjun Yang, Qiang Wang</i>	9
Risk of Abuse of Dominance in Airport Slots for 'Better' European Airports? <i>Steven Truxal</i>	19
The Implications of Market-based Measures on the Mitigation of Aircraft Engine Emissions <i>Cherie Lu, Ming-Tao Chou</i>	34
Investigating International Forwarders' Preferences toward Air Cargo Services and Their Purchasing Behavior <i>Jin-Ru Yen, Tsung-Sheng Liang, Chia-Ping Tsou, Chia-Yu Li</i>	43
Online Container Transport Planning with Decision Trees based on Offline Obtained Optimal Solutions <i>Bart van Riessen, Rudy R. Negenborn, Rommert Dekker</i>	50
The Supply Chain Perspective on Slow Steaming <i>Sara Elzarka, Maha Morsi</i>	61
Becoming a Major Hub in the Distribution of Wine: Hong Kong as a Gate to Asian Markets <i>Yui-yip Lau, Adolf K.Y. Ng, David Guerrero</i>	70
High-speed Rail and Airline Cooperation under the Multinomial Logit Model: Model and Properties <i>Kimitoshi Sato, Yihsu Chen</i>	84
Investigating the Change in Firm Performance using Balanced Scorecard: An Empirical Study of Logistics Service Providers in Egypt <i>Islam El-Nakib</i>	93
Effective Bundle Double Auctions for Carrier Collaboration <i>Su Xiu Xu, Meng Cheng, Shuyan Lin, George Q. Huang</i>	105
Application of Fuzzy Quality Function Deployment on the Service Quality Improvement for International Logistics in Shipping Company <i>Yi-Chih Yang, Chi-Yu Sung</i>	116
The Optimization Model for the Location of Water Emergency Supplies Reserve Bases and the Configuration of Salvage Vessels <i>Jing Lu, Yun-fei Ai, Li-li Zhang</i>	132

Competitive Strategies in Bilateral Oligopoly —The Case of Coastal Coal Transport Market in China <i>Jing Lu, Xiaolin Jiang, Jing Li</i>	143
GARCH Models Application in Volatility of Dry Bulk Freight Index <i>Feier Chen, Lei Dai, Shijie Chen, Hao Hu, Chunxia Lu, Yifei Zhao</i>	154
Combining Multi-Stage DEA and Fuzzy AHP to Evaluate the Efficiency of Major Global Liner Carriers <i>Shih-Liang Chao</i>	162
Optimizing the Performance of Urban Consolidation Centers <i>Xiaolei Wang, Lei Guo</i>	170
Northeast Asian Transport Corridors: Potential and Development under the Greater Tumen Initiative <i>Varvara Krechetova</i>	181
Production Strategy with Green Technology Input under Cap and Trade Policy <i>Zhenyu Luo, ChangSong Ma, Jialu Pan, Yun Cao</i>	190
Supply Chain Network Optimization with Piecewise Linear Cost Function of CO2 Emissions <i>A-Young Choi, Joon-Ho Na, Jian-Hua Ji</i>	197
Under the Carbon Emissions and Cap-and-Trade Manufacturers Pricing Strategy Research <i>Changsong Ma, Yinfeng Du, Zhenrui Wu, Linlin Huang, Ying Luo</i>	206
Integration of Pricing and Production for Single Product with the Mandatory Carbon Emissions Policy <i>Huawei Duan, Qin Luo, Xinyu Xu, Jing Mao</i>	214
Pricing Strategy Research for Enterprises under Carbon Constraint Policy with Two Products <i>Hua He, Li Zhang, Ruiyu Wang, Shucheng Zhou, Liang Ming</i>	222
Predicting Consumers' Behavioral Intention of Adopting Green Logistics Service Providers <i>Chiung-Lin Liu, Ting-Yu Chang</i>	230
The Impact of the External Integration Capabilities of Taiwan's 3PLs on Their Performance <i>Chiung-Lin Liu, Pei-Yu Lai, Chun-Wei Chiang</i>	240
Supply Chain Security: An Empirical Study of Drinking Milk Producers in Egypt <i>Islam El-Nakib</i>	248
Sustainable Shipping Management Strategy: Vessel Sharing in Liner Shipping Alliances <i>Xiwei Zhao, Jasmine Siu Lee Lam, Xuan Qiu</i>	259
An Evaluation of the Success Factors for Ship Management Companies using Experts' Knowledge <i>Jun-woo Jeon, Gi-Tae Yeo, Vinh V. Thai, Tsz Leung Yip</i>	269
The Antecedents and Consequences of Supply Chain Service Capabilities in the Context of Container Shipping <i>Chung-Shan Yang</i>	280

The Link between Corporate Social Responsibility, Corporate Reputation, and Organisational Performance: Evidence from the Liner Shipping Industry <i>Kuo-Chung Shang, Chin-Shan Lu, J-R Lin, Chih-Ching Chang, Kung-Don Yu</i>	295
Bi-level Optimization Model for Last Mile Retail Cargo <i>Shao-Jian Qu, Mark Goh, Robert de Souza</i>	306
Impact Factor Analysis of Container Terminal Shipline Operating Efficiency <i>Yi-Chih Yang, Yao-Lang Hong</i>	311
Green Port Performance Index for Sustainable Ports in Egypt: a Fuzzy AHP Approach <i>Sara Elzarka, Sara Elgazzar</i>	322
A State-run Company: Bane or Boon? A Case of the Korea Shipping Corporation, 1950 – 1968 <i>Sung-june Kim</i>	332
Twenty Box to Reduce Empty Container Positionings <i>Ulrich Malchow</i>	343
Competitiveness of Global Ports: The Kaohsiung and Dubai Experience <i>Shiva Madani, Booi. H Kam</i>	353
Research on Prosperity Index Constructing for Maritime Transport Market <i>Yifei Zhao, Tatsuo Yanagita</i>	365
Shipping Market Integration – The Case of Sticky Newbuilding Prices <i>Roar Adland</i>	376
Determinants of Ship Berthing Safety at Port Dock <i>Wen-Kai K. Hsu, Chiu-Fang Chiu</i>	383
Impact of Port Disruption on Supply Chains: Petri Net Modeling and Simulation <i>Jasmine Siu Lee Lam, Tsz Leung Yip</i>	394
Examining the Linkages between Service Capabilities, Dynamic Capabilities, and Competitive Advantage in Container Shipping <i>Szu-Yu Kuo, Pei-Chun Lin, Chin-Shan Lu</i>	405
Study of Principal Operational Performance Indicators of Various Indian Ports for Imported Steam Coal <i>T. Bangar Raju, B. V. Ramalingeswar Rao</i>	424
Logistics Innovation Networks for Ports' Sustainable Development: The Role of the Port Authority <i>Marcella De Martino, Luisa Errichiello, Alessandra Marasco, Alfonso Morvillo</i>	435
Issues Involved When Introducing Shore Power: A Critical Mixed Methods Study in the Port of Kaohsiung <i>Po-Hsing Tseng, Nick Pilcher</i>	445
Energy Saving Effect of Roof Shade at Reefer Container Storage Yard <i>Takeshi Shinoda, Muhammad Arif Budiyo</i>	455

Development of Equipment for Ballast Water Treatment by Filtration Technology <i>Takeshi Shinoda</i>	461
Container Seaports Connectivity: A “Concept” Analysis <i>P. Paflioti, T.K. Vitsounis, I. Tsamourgelis, M.G.H. Bell</i>	467
The New Mode of Container Trailer Transportation Management in Chinese Ports Area with the Development Trend of New Energy Consuming and E-commerce Technology <i>Kai Luo, Pin Xu, Bo Ma, Apollo Zhou, Julian Guna</i>	492
Evaluating the Effect of Logistics Learning Capability for International Distribution Center Operators in Taiwan <i>Ching-Chiao Yang, Hui-Huang Tai</i>	498
Development of Ship’s Safety Management Evaluation Tool for Maritime Safety Information System – A Case Study of Korean Flag Ship and Shipping Company <i>Hwa Young Kim, Gyei Kark Park, Sung Woo Lee, Gun Woo Lee</i>	510
An Analysis of the Profitability of Container Shipping Lines <i>Wei-Ming Wu</i>	519
An Analysis of the Environmental Efficiency of Chinese Container Ports based on CO2 Emissions <i>Na, Joon-Ho, Ji, Jian-Hua, Choi, A-Young</i>	528
Law and Economics of Port Finance –Whether Port Developers can Benefit from a Low Interest Rate Environment from Financing Port Assets under the Basel Accord <i>Owen Tang</i>	537
The Implication in the Opening of Northern Sea Route on Maritime Sector of Malaysia Economy <i>N.S.F. Abdul Rahman, R. Rasdi</i>	544
A Case Study on Slow Steaming Speed of Tanker Vessel – A Conceptual Paper <i>R. Md Hanafiah, Irwin U J Ooi, N.S.F. Abdul Rahman</i>	554
Optimization of Yard Truck Scheduling and Routing Model with Time-Space Network <i>Feng-Ming Tsai, Yu-Ming Chang</i>	562
A Study of Cruise Passengers’ Repurchase Behaviour <i>Lirn T.C., Weng H.K</i>	569
A Structural Equation Analysis of Vessel Traffic Controllers’ Fatigue Factors <i>Jin-Ru Yen, Yu-Ying Wang, Chih-Ching Chang, Chao-Yang Chang</i>	577
Development of Ship Finance Center: Case of Singapore <i>Sun Xi, Jasmine Siu Lee Lam</i>	584
An Improvement of Productivity in Container Terminal by Simulation Modeling: Case of Bangkok Port <i>Pantakan Saengaram, Veerachai Gosasang, Nuttapon Boonchokchuay</i>	592
The Impact of Information Sharing and Risk Pooling on Bullwhip Effect Avoiding in Container	599

Shipping Markets

Shaorui Li, Yujie Shi, Chin-Shan Lu, Yi Liao

Is New Emission Legislation Stimulating the Implementation of Sustainable (Retrofitting) Maritime Technologies? 609

Laurence Stevens, Christa Sys, Thierry Vanellander, Edwin van Hassel

A Duopoly Game for Capacity Expansion in Shipping 619

Meifeng Luo, Ying Kou

Port Investments on Coastal and Marine Disasters Prevention: An Economic and Policy Investigation 633

Yi-bin Xiao, Xiaowen Fu, Adolf K.Y. Ng, Anming Zhang

Impact of Government Policies on FDI in Indian Port Sector 654

Girish Gujar, Hong Yan, Rachna Gangwar, Mukul Jain

Vessel Collision Frequency Estimation in Archipelagic Waters 664

Yajun Li, Junmin Mou, Xi Chen, Guozhu Hao

The Development of a Slow Steaming Decision Support System for a Service Route in Trans-Pacific Trade 672

Eugene Y.C. Wong, Henry Y.K. Lau

The Impact of Panama Canal Expansion and Clean-Lines Strategy on Unit Emission of Trunk Route Deployments in International Container Shipping 676

Hui-Huang Tai, Dung-Ying Lin

Impact of Different Factors on the Risk Perceptions of Employees in Container Shipping Companies 689

Chia-Hsun Chang, Jingjing Xu, Dong-Ping Song

Service Preference and Short Sea Shipping 705

Yenming J. Chen, Mark Goh, Jau-Wen Wang

The Spatial-temporal Analysis of Airport Foreign Firms' Agglomeration Trends – The Case of Shanghai Hongqiao International Airport

Yonglei Jiang^{*1}, Liangwen Qiu¹, Lu Wang², Ruijia Zhao¹ and Zhongzhen Yang¹

¹College of Transportation Management, Dalian Maritime University

²China Academy of Civil Aviation Science and Technology

**Corresponding author*

Abstract

Due to the fast development of globalization, civil aviation has become the power of regional economic and international trade. As the important hub of international communication, foreign firms have been attracted to locate at the vicinity of airports to enjoy the preferable location advantages, and gradually the airport foreign industrial agglomeration showed up. This paper takes Changning District in Shanghai City, which is the location of Shanghai Hongqiao International Airport (SHA), as the study area to analyze the agglomeration trends of foreign firms. Firstly, the information of new foreign firms between 2001 and 2011 is collected, and their locations are fixed with a GIS software. Secondly, the agglomeration patterns of airport foreign firms are analyzed with Unbalanced Index and Industrial Gravity Center. Finally, according to the trends of industrial shares, the types of airport foreign firms of SHA are identified.

Keywords: Airport foreign industry; industrial agglomeration; Shanghai Hongqiao International Airport (SHA)

1. Introduction

Since the 1990s, the sustainable development of China's foreign trade has acted as a spur for foreign firms to enter China in the form of opening branch companies or representative offices. In order to be the correspondent with the head office and the international market promptly, and explore the markets as well as enjoy the excellent supporting facilities and serves, these foreign firms attach great importance to the location factor of traffic accessibility (including both internal and external ones). Considering all the aforementioned, the location of foreign firms shows widely different patterns. And some foreign firms gradually formed the agglomerations in the airport zone.

Since the complement of system reform, China Civil Aviation has been experiencing significant developments. Due to the characteristics of fast and efficiency, civil aviation has become one of the most important transport modes for international communication of regional economic, and gradually acts as a region's engine of growth. Accompanied with the great improvement of civil aviation, airport industry agglomerations have gradually appeared in main airport cities of China. And recently, more airport cities are planning to establish airport economic zones to attract foreign investments. So it is necessary to identify and analyze the tempo-spatial agglomeration characteristics of airport foreign firms.

The main structure of this paper is as following: section 2 is the literature review; section 3 introduces the data source and methods; section 4 takes Shanghai Hongqiao International Airport (SHA) as example to analyze the agglomeration characteristics of airport foreign industries; section 5 is the conclusion.

2. Literature Review

Due to the foundation of free trade zone of Shannon International Airport in Ireland, the economic of region around the airport showed a steeply increase. And this phenomenon firstly caught attention of researches. Later Conway (1965) firstly advanced the concept of "Fly-in", and the problems like location characteristics

of airport industries gradually appealed to researches. Testa (1992) pointed that the Service industries, including advertisement, law, data processing, accounting and public relations needed to communicate with customers instantly and frequently, and they preferred locating in the airport economic zones. After the investigation of industries at airports around regions of several airports in Europe, the U.S.A. and Japan, Weisbrod *et. al.* (1993) divided the airport around region into four types, and according to the degree of airport directivity, the industries was also divided into four types. This conclusion has widely become the main classification basis of airport region and airport industries. Taking the airports in the southeast region of Scotland as example, Caves & Gosling (1999) found that firms from the industries of electronic, medicine, IT (Information Technology) and fiancé were inclined to locate in industrial parks near airports. Kasarda (2001) found that in the U.S.A., the network sales, electronic commerce centre and the R&D departments also prefers to locate in airport economic zones.

The outstanding development of both China's civil aviation and airport economics caught attention of the domestic researchers, and the scope definition of airport economic zone and the classification of airport industries has become one of the hottest topics. Liu (1998) thought that the abroad airport around region could be divided into 3 levels including 9 functions (the airport service, logistics, communication, industrial technology, business, information, rehabilitation & entertainment, culture, art & sports and academic research). In Cao's (2009) opinion, the airport economic should be an airport-centered economic space, where the industries with different degree of relation with civil aviation clustered together. Zhang *et.al.* (2011) took the airports in Yangtze River Delta Region as example, collected the information of firms in airport around regions, and tried to definite the scopes of airport economic regions of each airport. Further, Zhang & Chen (2012) analyzed the evolution of airport industrial structures of main hub airports in Yangtze River Delta Region with specific firm-level data. From the viewpoint of industry chain of civil aviation, Zhao & Cao (2013) tried to point out which industries were suitable to be attracted into airport economic regions.

All these studies took the region around an airport and its firms as study scope, tried to define the scope and classification of airport economic region, analyze the structural characteristics of airport industries. Due to the lack of firm-level data, most studies took the macro-scale data to analyze. Especially, nobody concentrated on the study of foreign airport industries' characteristics in developing countries. This paper will take the foreign firms in SHA-around region as example to tempo-spatially analyze the characteristics of airport foreign firms' agglomerations from the firm level.

2. Data Source and Methods

2.1 Data source

2.1.1 Study area

In order to analyze the agglomeration characteristics of airport industries, the research results of Weisbrod *et. al.* (1993) and Zhang *et. al.* (2011) and the administrative areas of Shanghai City are taken as reference, Changning District is taken as the airport economic zone of SHA. Changning District is located in the west of central urban area of Shanghai City, and SHA is located at the west of Changning District. The longest distance between SHA and any site of Changning District is 10km. The geographical locations of Changning District and SHA are shown in Fig 1.

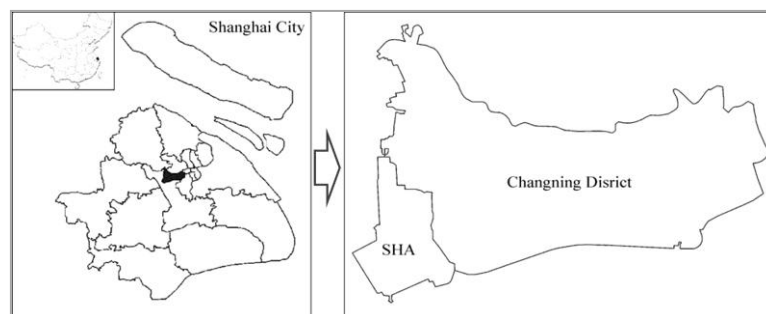


Fig 1. Geographical Locations of Changning District and SHA

2.1.2 Data collection

Firstly the list of new foreign firms of Changning District is collected between 2001 and 2011, and the geographical location is fixed with Google; secondly, the product or service and the second level classification of each foreign firm are identified with Google and <Classification of National Economic Industries> (GB/T4754-2002) respectively; finally the information of foreign firms are loaded on the digital map of Changning District drawn with Mapinfo8.5. After processing, we find that there are 1930 foreign firms from 70 kinds of second level industries. The location of the foreign firms is shown in Fig 2. In addition, this paper chooses the number of foreign firms and the spatial location instead of the industrial output to analyze the agglomeration because of the unavailable data.

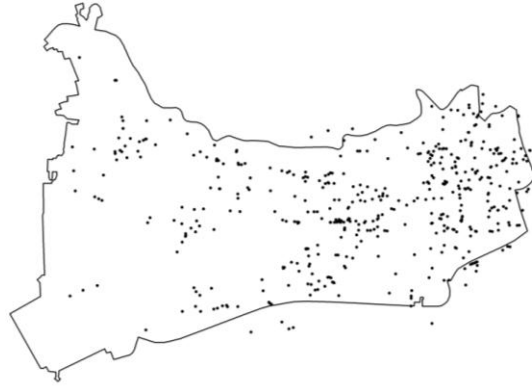


Fig 2. Spatial Location of Foreign Firms in Changning District

2.2 Methods

In order to study the agglomeration characteristics of foreign industries in Hongqiao Airport Economic Zone, this paper firstly use buffer analysis to divide the study area; secondly, the Unbalanced Index and the Industrial Centre are employed to analyze the tempo-spatial evolution of foreign firms' agglomeration in the airport economic zone; finally, the methods of Accumulative Share is used to identify the different trends of airport economic foreign industries.

2.2.1 Buffer analysis

Buffer analysis takes entities with the shapes of point, line or surface as the center to build polygonal buffers within a given width, and is usually employed to ascertain the sphere of influence or service of spatial objects (Fang *et.al.* (2013)). In order to analyze the agglomeration characteristics of foreign firms in the airport economic zone, the point buffer is employed, which means that SHA and 1 km are taken as the center and given width to divide Changning District into different buffers (sub-regions). The structure of foreign firms in each buffer will be analyzed then.

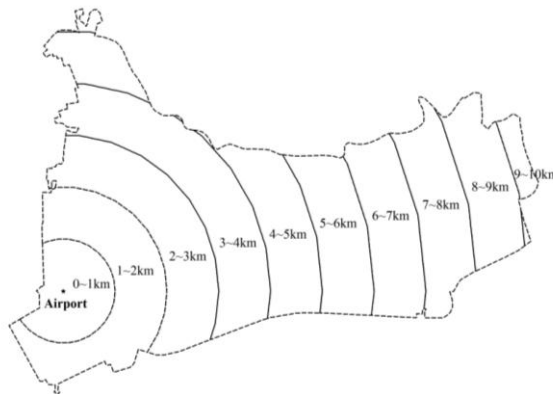


Fig 3. Buffer Results

2.2.2 Unbalanced Index

Based on the buffer analysis, the Unbalanced Index (Zhou, 1995) is applied to assess whether the location of foreign firms in airport economic zone shows the agglomeration trends, and the equation is as following:

$$U = \sqrt{\frac{\sum_{i=1}^n \left(\frac{\sqrt{2}}{2} (x_i - y_i) \right)^2}{n}} \quad (2.1)$$

Where, U = Unbalanced Index, the higher of the value means the strong trends of industry agglomeration; n =the number of buffers; x_i = the proportion of the number of foreign firms in the i^{th} buffer; y_i = the proportion of the area of the i^{th} buffer.

2.2.3 Center of gravity analysis

The spatial agglomeration of airport foreign industries can be explored with the center of gravity method (Zhao *et. al.*, 2011), and the equation of center gravity's coordinates is as following:

$$\bar{x} = \frac{\sum_{i=1}^n M_i x_i}{\sum_{i=1}^n M_i}, \bar{y} = \frac{\sum_{i=1}^n M_i y_i}{\sum_{i=1}^n M_i} \quad (2.2)$$

Where, \bar{x} = the horizontal coordinate of center gravity; \bar{y} = the vertical coordinate of center gravity; M_i = the number of foreign firms in the i^{th} buffer; (x_i, y_i) = the centroid coordinates of the i^{th} buffer.

2.2.4 Accumulative share trends

In an airport economic zone, the structure of foreign industries may show different trends: some shows the trends of highly agglomeration, some may cluster faster, others may gradually move out of the zone and turn out to be non-airport industries. Considering these hypothesis, we supposed that there should be four kinds of industries: Highly concentrated, More concentrated, Stable concentrated and Non-Airport industry (Fig 4).

(1) Highly concentrated

These kinds of industries hold much higher shares than others, and they are the main industries in the airport economic zone, which relies strongly on the location condition.

(2) More concentrated

The share of these kinds of industries increases sustainably, and the airport is becoming more important.

(3) Stable concentrated

The impact of the factor of airport seems stable to this kinds of industries, and the shares of these industries are comparatively stable.

(4) Non-airport industries

The share of these industries decreases gradually, which means they are non-airport industries.

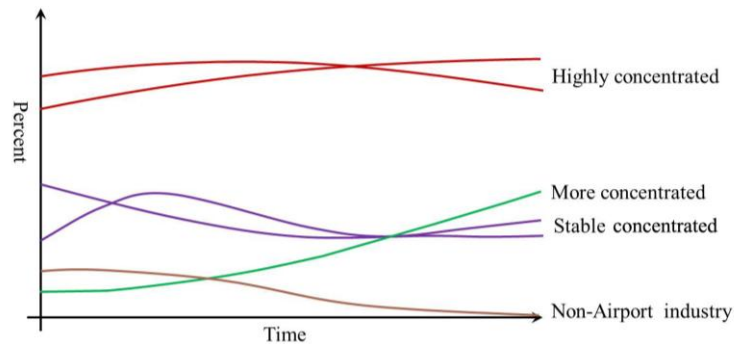


Fig 4. Theoretical Classifications & Trends

3. Agglomeration Characteristics of Foreign Industries

3.1 Agglomeration characteristics of the whole industries

Based on the buffer division and the number of foreign firms of each buffer, the spatial locations of the foreign firms are counted and shown in Fig 5. Different from the conclusion of Weisbrod *et. al.* (1993) and Zhang *et. al.* (2011), the foreign firms do not mainly scatter within the region with 6 km radius, but cluster in the buffers between 5 km and 9 km, and there are seldom foreign firms in the region within 2 km radius. According to the land use planning of Changning District, Hongqiao Foreign Trade Center and Zhongshan Park (commercial center) are located in the buffers of 5-7 km and 8-9km respectively. Hongqiao Foreign Trade Center is a national-level development zone with the function of foreign trades, and Zhongshan Park is a city-level one which aims to develop the contemporary commerce and multimedia industry. And that explains the spatial agglomeration characteristics of foreign firms.

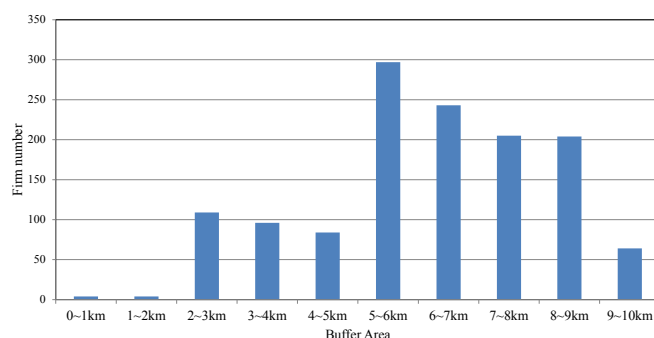


Fig 5. Number of Foreign Firms in each Buffer

3.2 Tempo-spatial characteristics of airport foreign industries

3.2.1 The temporal characteristics

With the method of Unbalanced Index, the temporal characteristics of foreign airport industries are shown in Fig 6. The value of Unbalanced Index is increasing from 2001 to 2011, especially in a linear growth from 2002 to 2009, which means the foreign firms in Hongqiao Airport Economic Zone keeps clustering.

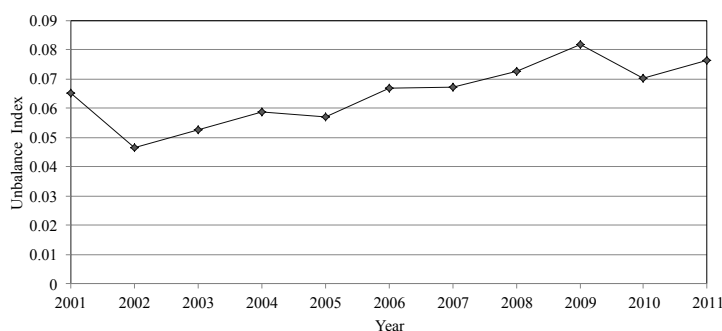


Fig 6. Value of Unbalanced Index from 2001 to 2009

3.2.1 The spatial characteristics

The spatial agglomeration characteristics of foreign industries in Hongqiao Airport Economic zone is shown in Fig 7. The gravity center of foreign industries in the 4-5 km buffer gradually moved to the 6-7 km buffer from 2001 to 2009, and then stably stayed at the site of 6 km. The movements of the gravity center reflect that the foreign airport industries in Hongqiao Airport Economic Zone has experienced the expansion stage (2001-2009), and now entered the stage of stably agglomeration (2010-2011). Further, in coincide with the conclusion of section 3.1, the coordinates of gravity center also reveal that Hongqiao Foreign Trade Center is the agglomeration center.

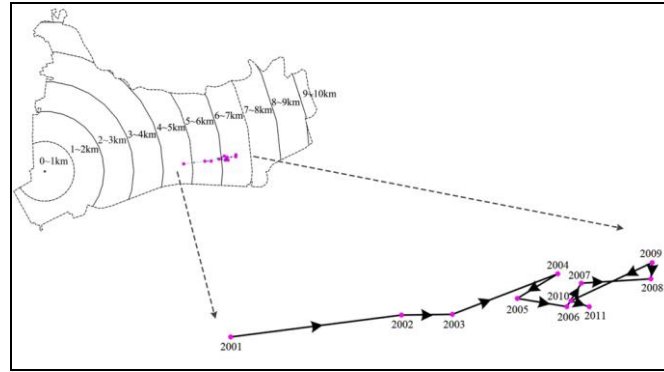


Fig 7. Movements of Industrial Gravity Centers

3.3 Identification of Hongqiao Airport foreign industries

Although the foreign industries in Hongqiao Airport Economic Zone are clustering sustainably, the identification of airport foreign industries and their characteristics seems important for the development of airport economic. So the accumulative share method is used to identify the airport foreign industries from the 70 second-level ones, and the results are shown in Fig 8 to 10.

(1) Highly concentrated industries

As shown in Fig 8, according to the lines of accumulative shares and the theoretical curve of highly concentrated industries, of the 70 industries, the shares of “Commercial Service Industry”, “Software Industry” and “Catering Industry” are much higher than others, and they are the highly concentrated airport foreign industries. In addition, the “Commercial Service Industry” owns the highest share, which is nearly a quarter of the whole industry, and most of them belong to “Investment advisory industry” and “Exhibition Industry”. All these can be ascribed to the development policies of Commerce-driven and foreign trade leading of Changning District.

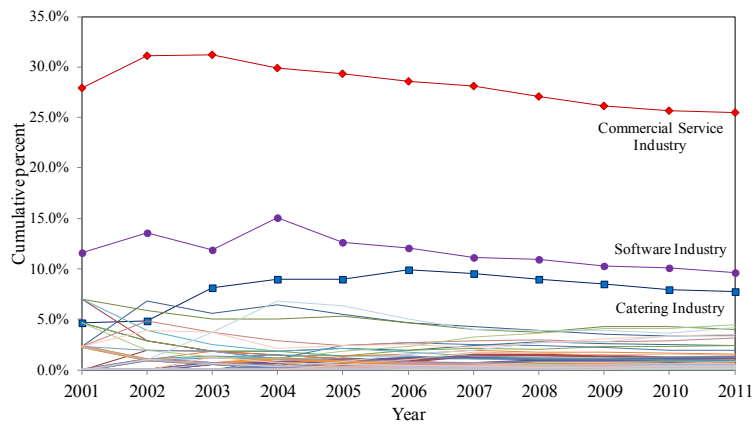


Fig 8. Highly Concentrated Foreign Industries

(2) More concentrated foreign industries

There are 7 industries following the trends of “More concentrated foreign industries”, and 2 industries (“Manufacture of General Purpose Machinery”, “Handling and Other Transport Services”) show the fast increase rate (Fig 9). “Manufacture of General Purpose Machinery” is the fundamental industry of Machinery, and developed countries lead this industry as well as have higher market share all over the world. In order to expand the market and keep in touch with head offices, the foreign firms of “Manufacture of General Purpose Machinery” prefer locating at Hongqiao Airoport Economic Zone. Firms of “Handling and Other Transport Services” are closely linked with the airport, and the fast development of airport economic boosts their agglomeration.

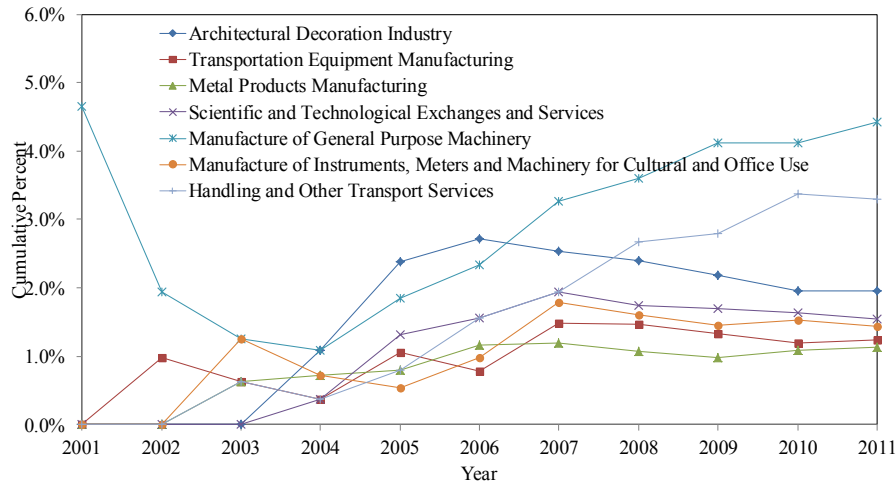


Fig 9. More Concentrated Foreign Industries

(3) Stable concentrated

The cumulative shares of 5 industries are comparatively stable (Fig 10). The products of these 5 industries are sophisticated and professional equipment or services, and they have an exclusive group of customers. However, most of these firms are branches, they need to contact with the head offices frequently, so their locations are fixed in the airport economic zone.

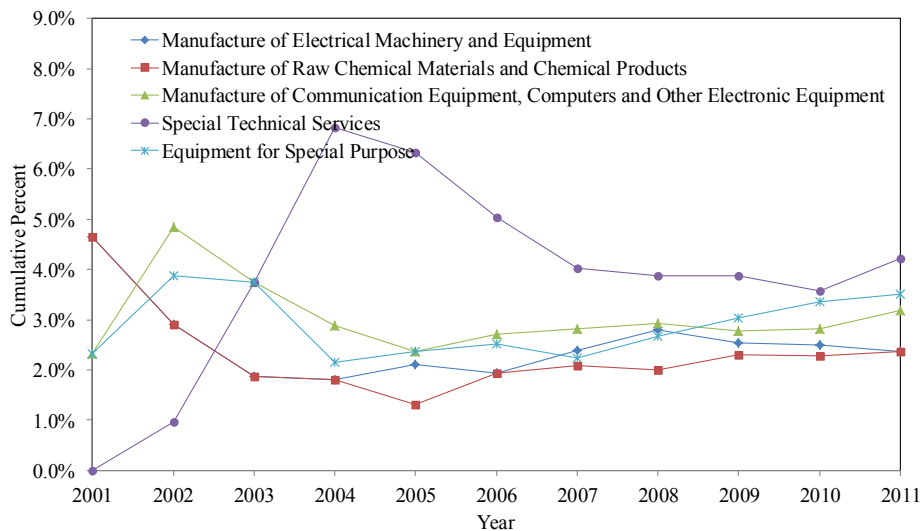


Fig 10. Stable Concentrated Industries

4. Conclusions

This paper took SHA as an example, and Changning District of Shanghai City as the airport economic zone to analyze the foreign firms' agglomerations from 2001 to 2011. All the foreign industries prefer clustering in the 5-9 km buffers, and experience center movements to the 6-7km buffer. With the accumulative shares, 3 "highly concentrated" airport foreign industries, 7 "more concentrated" airport foreign industries and 5 "stable concentrated" airport foreign industries were identified.

Acknowledgements

This research is financed by the Key Projects of Philosophy and Social Sciences from the Department of Education (11JZD049), Social Sciences Foundation from Liaoning Province (L13CJY049), and the Fundamental Research Funds for the Central Universities (3132013079).

References

- Cao, Y., Xi, Y. and Li, W. (2009), The formation of airport economy from the view of new Economic Geography, *Exploration of economic problems* 2: 49-54.
- Caves, R. E. and Gosling, G. D. (1999), Strategic airport planning.
- Conway, H.M.C (1965), The Fly-in Concept.
- Fang, Z., Guo, S. and Wang, Z. (2013), Analysis on the Micro-agglomeration of Exhibition Enterprises - A Case of Liuhua Area in Guangzhou, *Economic Geography* 33(8): 91-96.
- Kasarda, J. (2001), From airport city to aerotropolis, *Airport World*.
- Liu, W. (1998), Study on the development of foreign airport area, *Foreign Urban Planning* 1: 31-36.
- Testa, W. A. (1992), Job flight and the airline industry: the economic impact of airports on Chicago and other metro areas, *Federal Reserve Bank of Chicago* (No. 92-1).
- Weisbrod, G. E., Reed, J. S. and Neuwirth, R. M. (1993), Airport Area Economic Development Model, The PTRC International Transport Conference, Manchester, England.
- Zhang, L., Chen, W. and Song, Z. (2011), Scope Determination of the Airport Industrial Zone: A Case Study of the Yangtze River Delta, *Progress in Geography* 30(10): 1255-1262.
- Zhang, L. and Chen, W. (2012), Evolution of Industrial Structure in Airport Economic Zone: Taking Hub Airports in the Yangtze River Delta as Examples, *Progress in Geography* 31(12): 1685-1692.
- Zhao, S., Zhang, F., Xu, G. and Zhang, D (2011), Analysis of Population Distribution Spatial and Temporal Evolution Characteristics in Guanzhong Zones Based on GIS, *Resource Development & Market* 27(08): 701-704.
- Zhao, B. and Cao, Y.C. (2013), The Selection of the Airport Industry based on the Industrial Transfer. *Commercial Research* 430(2): 58-63.
- Zhou, Y (1995), *Urban Geography*, Beijing: Commercial Press 122-127.

Market Structure and Airline Pricing: Evidence from the Chinese Airline Industry

Jiaqiang Song, Hangjun Yang, and Qiang Wang

School of International Trade and Economics, University of International Business and Economics, China

Abstract

Airline pricing has consistently been the pivot of Chinese airline industry reform. With the gradual deregulation on pricing, Chinese airlines have obtained more freedom to set airfares. Meanwhile, they face emerging challenges from the rapid development of the high-speed rail (HSR) network in China. In this study, we analyze the factors affecting Chinese airline prices in different market structures (i.e., monopoly, duopoly, and more than two competitors) based on route-level data among provincial cities by adopting the generalized method of moments. Airline prices in all the markets follow a J-curve pattern. We find that the route distance is a positive factor affecting airfare in all market structures, whereas the existence of parallel HSR service can reduce price significantly. We also determine that factors such as flight number, market share, competitive flights within 1 h, plane size, and peak times have distinctive effects under different market structures.

Keywords: Airline pricing, market structure, Chinese airline industry, high-speed rail

1. Introduction

In the context of regulation, airfare was usually made only on the basis of distance, even if the cost varied significantly from one airline to another. During that period, price was set below cost in short-haul markets and above cost in long-haul markets (Graham et al., 1983). After deregulation on aviation, airlines could take into account all the relevant pricing information and make decisions on their own to achieve operation objectives through complicated pricing mechanisms.

A considerable body of literature on airline pricing behavior emerged after the US deregulation. Many papers investigated the influencing factors of American airfares, for example, Graham et al. (1983), Koran (1983), Borenstein (1989), Hurdle et al. (1989), Morrison and Winston (1990), Brueckner et al. (1992), Evans et al. (1993), Evans and Kessides (1993), Peteraf and Reed (1994), Dresner et al. (1996), Borenstein (2005), Dender (2006), and Dixit and Gundlach (2006).

Research on the airline industry usually employs self-collected data from websites. These data contain information about booking time, departure time, origin and destination cities, travel time, plane size, and etc. Researchers are able to identify how fares vary based on the above information, which is also called dynamic pricing. For instance, Dresner and Tretheway (1992) studied international airline markets; Gillen and Hazledine (2006) investigated the Canadian airline market; Roos et al. (2010) explored the Australian airline market; and Bergantino and Capozza (2011) examined the Italian airline market.

In this paper, we report the results of our empirical analysis of the influencing factors of airline pricing under different market structures based on data from Chinese airlines. Our paper contributes to the literature in four ways. First, we investigate China's airline market, which is the second largest in the world. However, empirical studies on airline pricing of Chinese airlines are extremely rare. Second, to the best of our knowledge, no literature that conducted research by comparing different market structures, except that of Peteraf and Reed (1994), explored the influencing factors of airfares of American monopoly routes. Therefore, our paper sheds light on this issue by contrasting monopoly routes, duopoly routes, and routes with more than two competitors and obtains some distinct conclusions. Third, the heterogeneity of airlines in previous literature mainly lies in the difference between legacy airlines and low-cost carriers (e.g., Dresner et al., 1996; Tretheway and Kincaid, 2005). In contrast, our paper considers the unique features of the Chinese aviation

market and makes comparative analysis from the perspective of airlines' ownership. Fourth, the rapid development of HSR in China has a significant effect on the Chinese airline industry. As a consequence, we incorporate the competition from HSR as a variable to examine its effects on airfares quantitatively.

The remainder of the paper is structured as follows: In Section 2, we briefly review the related literature. We discuss the industry setting and data in Section 3 and outline our empirical model in Section 4. The results are reported in Section 5. Finally, we offer concluding remarks in Section 6.

2. Literature Review

In the literature, the main factors affecting market structure associated with airline pricing include market share, Herfindahl–Hirschman Index (HHI), and the number of airlines. Dixit and Gundlach (2006) consider the market share to estimate the factors affecting price-cuts when discount airlines emerged, and find that the market share of the major airlines in the hub airport and in the city-pair markets is positively and significantly related to price-cuts. However, their relationship is nonlinear. The price-cutting responses of the major airline to the entry of discounters tended to increase at a decreasing rate as the market power of the major airline increased in its relevant city-pair markets but then decreased after a certain level of market power.

Many scholars use HHI to measure market structure. Graham et al. (1983) study how HHI affects fares and show that market concentration appears to have a positive effect on fares in the relatively less concentrated markets, but not much incremental effect on markets with HHI greater than 0.5. Evans et al. (1993) determine that concentration can increase price. Hurdle et al. (1989) analyze the effect of concentration on yields by adopting HHI to measure concentration. All the regressions suggest that market structure matters considerably. Dresner et al. (1996) examine the effect of HHI on yields based on the data of the top 200 US domestic routes. They determine that the coefficient of concentration is positive and significant only in the southwest low-cost carrier regression, but insignificant when all low-cost carriers were included. Gillen and Hazledine (2006) regress the average lowest price per kilometer as the dependent variable on HHI and other explanatory variables and determine that HHI is a moderately significant determinant of the average prices.

Some scholars consider the effects of both market share and HHI. Borenstein (1989) estimates the importance of route and airport dominance in determining the degree of market power exercised by an airline. The results indicate that an airline's share of passengers on a route and at the endpoints significantly influences its ability to mark up price above cost. The route HHI increases the 20th percentile fare, but reduces the 80th percentile. However, the high markups of a dominant airline do not create a noticeable “umbrella” effect from which carriers with smaller operations in the same markets can benefit. Evans and Kessides (1993) test whether the observed dominance of most city-pair markets and airports in the US domestic airline industry by single carriers confers any pricing power on the dominant firms. Using market share and HHI to evaluate market power, they show that market share at the route level seems to confer no pricing power, but the route concentration has a positive correlation with price. Bergantino and Capozza (2011) explore the effect of market structure and airlines pricing behavior via a sample of southern Italian routes. The results indicate that the market's concentration levels have a significant role in defining fare levels. Both market share and HHI have a positive and significant effect on fares, which is robust across regressions.

Certain authors analyze the effect of the number of competitive airlines. Morrison and Winston (1990) estimate how the number of potential and actual competitors affects fares, and find that the number of competitors can reduce fare. Brueckner et al. (1992) employ the total number of rival carriers of the observed carrier in the market to examine the effects of competition. All the market competition coefficients are negative and significant, which means diminishing returns to market competition. Specifically speaking, the addition of the first competitor to a monopoly market lowers fares by 7.7%. The addition of a second or third competitor reduces fares by a further 3.4%, whereas the addition of an extra competitor beyond three lowers fares by a further 0.6%. Moreover, the addition of a potential competitor to the market lowers fares by 1.6%.

Evans and Kessides (1993) study the impacts of both market share and the number of airlines, and find that the largest change in price is generated by moving from monopolies to duopolies where prices decline by 3.3%, and adding a third and a fourth competitor only decreases price by 1.5% and 0.5%, respectively. This

finding also indicates that monopoly control of routes mainly confers pricing power, and even a small number of firms at the route level are able to control pricing. Peteraf and Reed (1994) focus on monopoly markets, and show that monopolist's fares vary with potential entrants' cost, market share has a positive effect on fares over and above that of airport share and route share, and small airports exhibit economies of scope.

Tretheway and Kincaid (2005) published a review of the literature concerning the effect of market structure on airfares. They examine the literature on hub premiums, the effect of low-cost carriers on average fares, factors affecting entry by potential carriers into routes, and how the incumbent respond to low-cost carrier entry. Dender (2006) investigates the effects of market structure and network features on prices. The results are in line with earlier work, that is, average fares are lower at airports dominated by Southwest Airlines and higher at hub airports.

Other scholars evaluate the government policy and its welfare effects. Koran (1983) analyzes the welfare effects of airfare deregulation in the USA. Airfare deregulation resulted in an increase in consumer's surplus of between USD 15 and 20 per round trip although airline profits were left unchanged. Consumer surplus increased because the regulated fares had been above the optimal level. With deregulation, fares decrease by more than enough to offset the deterioration in service quality. Producer surplus remained substantially unchanged because the decrease in fares was roughly matched by a decline in average costs associated with the lower service quality. Dresner and Tretheway (1992) measure the effect of a change in government policy on prices by using a two-stage indirect least squares model, and find that liberalization can lead to a significant decrease in fares on international air routes.

Market structure has always been the key point of research in the previously mentioned literature and research methodology also improves continuously. In the early work, ordinary least squares of cross-sectional data were often adopted and instrumental variables were also incorporated to address the endogeneity problem. Afterward, some researchers employ simultaneous equation models, and estimate price by means of two-stage or three-stage ordinary least squares. Meanwhile, the method of panel data analysis is applied as well, including random effect model and fixed effect model.

3. Industry Background and Data

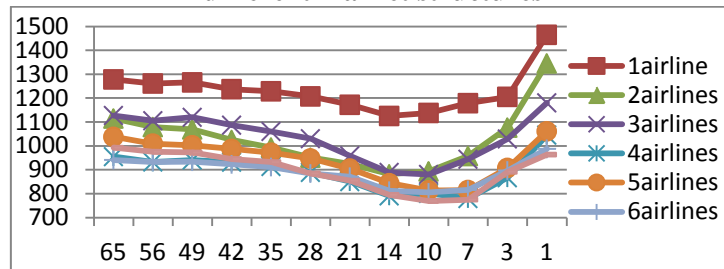
Airline pricing has always been the pivot of the Chinese airline industry's reform. Governmental administration on airline pricing has undergone many changes, from direct regulated pricing in the planned economy mechanism, gradual lift of the control over fares, and trial of multi-fare systems to the issuance of ban on discount. The Chinese airline industry has undergone the most profound and thorough transformation from 2002. At the beginning of 2002, the reform of the air traffic system was accomplished. In October, the six airline groups were set up after the restructuring of airlines and separated from the Civil Aviation Administration of China (CAAC), which implemented span-management to domestic airline pricing. In April 2004, the National Development and Reform Commission (NDRC) released the reform plan of domestic airline pricing, which stipulated that the guidance pricing of the government would be executed, that is, NDRC and CAAC would determine the benchmark price of air transport and floating range based on the average cost, market supply and demand conditions, and social tolerance capability. Hence, the administration on airfares turned from direct control mode to indirect control mode by the in-charge pricing department. The specific measures were provided as follows: domestic short-haul flights adopted market-adjusted prices, and the floating range rule was not applicable to them. Except for the previously mentioned lines, the markup was not allowed to exceed 25% of the benchmark price (i.e., RMB 0.75 per passenger-kilometer) and the floor price should not be less than 45% of the benchmark, but the floor price rule was not for leisure travel routes and exclusive operating lines. These rules show that airlines obtained pricing autonomy to a great extent and Chinese civil aviation entered into a competitive era because of the deregulation. Afterward, NDRC and CAAC issued the Opinion with regard to the Promotion of Civil Aviation Development by the State Council, which provided that, from 20 October 2013, the price floor limitation would be cancelled for those lines adopting governmental guidance pricing so that airlines could set airfares independently but the markup rule still existed. For those domestic routes that were jointly operated by two or more airlines facing the competition from ground transportation, the pricing method changed to market-adjusted from governmental guidance pricing. Airlines could make prices in accordance with market supply and demand conditions and,

thus, gained greater autonomy of pricing.

The aforementioned variation of regulation methods reflects the complications of the air passenger pricing mechanism. Furthermore, relevant studies regarding Chinese airline pricing behavior have always been insufficient compared with the USA and some European countries as a result of inaccessible data. Given this, the paper conducts quantitative analysis with regard to the determinants of airline pricing in China.

We employ a self-collected dataset of minimum available airfares offered online by the major domestic city pairs on 12 August 2013 with different leading days before departure, involving 65, 56, 42, 35, 28, 21, 14, 10, 7, 3, and 1 day. Therefore, we define a dataset composed by 9,936 observations in total on 828 flights of 194 city pairs. The major cities in the sample include Beijing, Shanghai, Tianjin, Chongqing, and all provincial cities, which could generally reflect the Chinese aviation context on the whole. Figure 1 shows the relationship between airfare variation and booking time, which seems to follow a J-curve pattern. The lowest price is available approximately in the last 1 or 2 weeks before departure.

Fig 1. Lowest available fare (in RMB) versus booking time prior to departure (in days) under different market structures



As shown in Table 1, routes have several types of market structures. Monopoly routes concentrate between the eastern and western regions, within the western region, and between the central and western regions of China. More than 70% flights fly to or from undeveloped western provincial cities where demand is relatively low. Duopoly routes concentrate between the central and eastern regions and between the central and western regions of China, and 57% of flights fly to or from the central cities with demand higher than monopoly routes. Routes served by three or more airlines concentrate between the eastern and western regions, within the eastern region, and between the eastern and central regions of China, and 76% flights fly to or from the developed eastern provincial cities with large demand.

Table 1. Market Structure and Fly Area of Sample Flights

	Monopoly routes		Duopoly routes		Routes with three or more competing airlines	
	Sample size	Proportion	Sample size	Proportion	Sample size	Proportion
Flights within the eastern region	36	8.11%	228	15.97%	1,716	21.70%
Flights between the eastern and central regions	48	10.81%	540	37.82%	1,380	17.45%
Flights between the eastern and western regions	108	24.32%	228	15.97%	2,916	36.87%
Flights within the central region	48	10.81%	24	1.68%	36	0.46%
Flights between the western and central regions	96	21.62%	252	17.65%	1,116	14.11%
Flights within the western region	108	24.32%	156	10.92%	744	9.41%

Table 2 shows the descriptive statistics. The mean number of flights on each route is 12.09; the average airfare is RMB 956; and the average flight distance is 1,375 km. Large planes, small planes, and medium planes

account for 8.9%, 0.98%, and 90.12%, respectively. The rival airlines number is 1.17 within 1 h before or after the departure time. Of all routes, 21.95% face the competition from HSR. The average market share for all the airlines is 34.78%, and the average leading days (i.e., booking time before departure) is 27.85.

Table 2. Descriptive Statistics for Major Variables

Variable	Mean	Std. Dev.	Variable	Mean	Std. Dev.
Flightnum	12.0902	0.0971	ComFlights1hour	1.1707	0.0152
Price	965	4.1537	HSR	0.2195	0.0042
Distance	1,375	5.9602	MarketShare	0.3478	0.0022
Large	0.0890	0.0029	Leadingdays	27.5833	0.2099
Small	0.0098	0.0010			

4. Empirical Model

In the literature, the main factors affecting market structure associated with airline pricing include market share, HHI, and the number of airlines and flights. The factors taken into account by different authors differ. The main factor for Dixit and Gundlach (2006) is market share. For Graham et al. (1983), Evans et al. (1993), Hurdle et al. (1989), Dresner et al. (1996), and Gillen and Hazledine (2006), the principal factor is the HHI of routes. Borenstein (1989), Evans and Kessides (1993), and Bergantino and Capozza (2011) considered market share and HHI as main factors. Brueckner et al. (1992) take into account the total number of airlines primarily. Evans and Kessides (1993) and Morrison and Winston (1990) considered market share and the number of airlines. Peteraf and Reed (1994) studied factors that might affect the price of American monopoly routes. As such, researchers generally accepted that market structure produces effects on airline pricing, but some problems also exist. For instance, market share and HHI are more likely to be highly correlated. By calculating the dataset of the flights of the main cities of China, we obtain a correlation coefficient of 0.64, which indicates that they have multicollinearity. The number of airlines is from one to seven in the sample dataset collected in our paper, covering monopoly market, duopoly market, and oligopoly market with more than two competitors. The services provided by airlines are of high homogeneity and the most remarkable difference lies in low-cost carriers and full-service legacy carriers. Consequently, airfare plays a significant role in their competition. The pricing strategies employed by airlines may vary to a large extent under different market structures. For example, monopoly airlines may take advantage of its market position to manipulate price, whereas airlines in the competitive market can only adjust price in line with the demand rather than control the price.

With the first HSR running between Beijing and Tianjin in August 2008, China entered into the era characterized by the rapid development of HSR. As of the end of 2012, the running mileage of China's HSR added up to 9,536 km and ranked first in the world. The journey time for two adjacent provincial cities would be shortened to approximately 1 or 2 h. The rapid expansion of HSR brings great challenges to China's airline industry. Zhang et al. (2013) mentioned that all the flights between Zhengzhou and Xi'an and part of the flights between Wuhan and Guangzhou have already ceased service because of the operation of HSR. This finding proves that HSR can divert some passengers to decrease airlines' load factor. As a result, airlines have to lower price to retain passengers. Hence, this paper incorporates the existence of parallel HSR services as a dummy variable to evaluate the effect of competition from HSR.

In this paper, we conduct a comparative analysis of three market structures. We designate fares as dependent variable and route distance, number of competitive flights, market share, competition from intra-industry and inter-industry, plane size, departure time, booking time prior to departure and its square, and characteristics of airlines as explanatory variables. Notably, endogeneity may exist between airfares and the number of routes and flights because the routes served by many airlines tend to belong to big cities and the purchase power of passengers is relatively strong so the price is much higher accordingly. In turn, the increase in flights may also decrease average operation cost and enforce competition to lower price. Hence, we define people and income as instrumental variables of Flightnum to address the endogeneity problem. Based on the two-stage least squares method, we consider the following empirical specification:

$$\begin{aligned} \ln \text{Price} = & \beta_0 + \beta_1 \ln \text{Distance} + \beta_2 \text{Flightnum} + \beta_3 \text{MarketShare} \\ & + \beta_4 \text{ComFlights1hour} + \beta_5 \text{HSR} + \beta_6 \text{PlaneSize} + \beta_7 \text{Workinghours} \\ & + \beta_8 \text{Leadingdays} + \beta_9 \text{Leadingdays}^2 + \beta_{10} \text{BigThree} + \varepsilon \end{aligned} \quad (1)$$

where $\ln \text{Price}$ is the log of the lowest available price; $\ln \text{Distance}$ is the log of the route distance; Flightnum represents the number of flights operating on a given route; and MarketShare represents the market share of an airline on a given route. ComFlights1hour represents the number of competitive flights within 1 h before or after a specific flight, which is used to identify the competition from intra-industry. HSR depicts the competition from HSR, with a dummy variable equal to 1 in case of the presence of HSR and 0 otherwise. PlaneSize is a dummy variable of aircraft size. In this study, we use medium plane as the benchmark. As such, the dummies for large and small planes are Large and Small , respectively. Workinghours is a dummy variable for flights from 9 A.M. to 5 P.M. to measure the difference between peak times and nonpeak times. Leadingdays is the booking days prior to departure. BigThree refers to the three state-owned airlines, namely, Air China, China Southern Airlines, and China Eastern Airlines and is a dummy variable for these airlines, which is distinguished from other domestic airlines.

5. Results

Since there are endogeneity and heteroscedasticity issues, we employ the generalized method of moments. The regression results are given in Table 3, which show that route distance has an important effect on airfares. No matter what the market structure is, a positive and significant association between route distance and price is observed. Airfares increase by approximately 0.66% to 0.79%, with route distance increasing by 1%. The relationship between flight number and price is apparently positive in the monopoly market, whereas negative in other markets. This finding suggests that excessive competition will not emerge because monopoly airlines possess all the market power in monopoly markets. The demand of monopoly airlines with many flights is large, which contributes to higher price. In competitive markets, the increase in flight number will not only enforce competition but also bring economies of scale to airlines to reduce operation cost and price.

The relationship between market share and price is positive in the market with three or more competing airlines. By contrast, the relationship is negative in the duopoly market, which indicates that the competition in the duopoly market might be fiercer relative to competitive markets. As shown in Figure 1, airfares in the duopoly market fluctuate more than other market structures, particularly in the early booking periods, because the dominant airline lowers fares to secure higher load factor. Hence, although its market share is large, its price is lower. As far as a competitive market is concerned, airlines with higher market share have more favorable departure time to attract more passengers and to charge higher prices.

The relationship between flight number within 1 h before or after departure time and price is negative in monopoly and duopoly markets. The price in the monopoly market decreases more compared with the duopoly market. Meanwhile, for the competitive markets, the relationship between flight number within 1 h before or after departure time and price is positive. The more the rival airlines, the higher the price, which indicates that substitute flights are evidently unable to lower price. The route on which three or more airlines operate has strong demand. As such, the effects due to high demand exceed substitution effects. For all the markets, the existence of parallel HSR services produces a negative effect on airfare, which suggests that competition from HSR can decrease price significantly.

The coefficient of large planes is negative in monopoly markets, positive in markets with three or more airlines, and insignificant in duopoly markets. As discussed above, adopting large planes is unable to produce a pricing advantage for the monopoly airline in the monopoly market, and the monopoly airline has to charge a lower fare to maintain a certain load factor. However, in competitive markets, passengers tend to choose large planes because the demand on such routes is high and large planes are generally more comfortable so that the airline can increase price accordingly. In contrast, the coefficient of small planes is positive and significant in all markets. Compared with medium planes, the operating cost per passenger is higher. Small planes generally have a supplementary role on the route. Hence, the price is relatively higher.

The coefficient of the dummy variable of flights between 9 A.M. and 5 P.M. is positive in all markets, which

implies that a premium effect during peak times exists. In all markets, the coefficients of leading days and the square of leading days are negative and positive, respectively. Therefore, the relationship between leading days and airfare is nonlinear. The regression results exhibit a J-curve effect, that is, the price is higher in the earlier booking time, decreases as the departure date approaches, then decreases to the lowest level at some particular point in time, and then increases with the close of departure. The J-curve effect has been observed in other studies with notable differences, however. Bergantino and Capozza (2011) find that the turning point of airfare turns up earlier (the lowest price is available roughly 47 days prior to departure) based on the study of the flights in the European airline market. Gillen and Hazledine (2006) show that airfares will increase precipitously in the last 2 weeks preceding takeoff by analyzing the airline markets in USA and Canada. Roos et al. (2010) find that airfares will evidently increase in the last week of departure date on the grounds of Australian airline market.

In monopoly markets, the coefficient of the big three state-owned airlines is negative, which indicates that, in monopoly markets, endemic airlines tend to set a higher price by exploiting their monopoly power, whereas for the big three airlines, their main revenues and profits do not rely on minor monopoly routes because of the large market share. Hence, the price for monopoly routes is lower than those on which endemic airlines operate to earn their major profits. In other markets, the coefficient of the big three airlines is positive, which shows that they have the pricing advantage in competitive markets.

Table 3. The Effect of Each Variable on Airfares

Explanatory variable	One airline	Two airlines	Three to seven airlines
lnDistance	0.7461918(28.20)***	0.6566826(48.61)***	0.7132134(84.91)***
Flightnum	0.2992741(3.71)***	-0.0198927(-2.29)**	-0.0187913(-22.73)***
MarketShare		-0.1919215(-3.82)***	0.1104027(4.48)***
ComFlights1hour	-1.091506(-11.26)***	-0.1207585(-4.31)***	0.064611(14.83)***
HSR	-0.1206307(-1.71)*	-0.1778877(-7.56)***	-0.0963512(-11.44)***
Large	-0.1931272(-3.49)***	0.0116336(0.21)	0.1203949(11.05)***
Small	0.0685868(1.86)*	0.2687052(10.50)***	0.1166768(4.25)***
Workinghours	0.2005497(6.12)***	0.0753156(5.09)***	0.0833187(13.48)***
Leadingdays	-0.0044683(-1.91)*	-0.0101572(-7.70)***	-0.0010389(-1.83)*
Leadingdays ²	0.0000822(2.44)**	0.0001813(9.19)***	0.0000527(6.15)***
BigThree	-0.1479276(-2.93)***	0.1161043(6.03)***	0.0567858(7.73)***
Constant	1.260355(5.50)***	2.369409(22.77)***	1.719928(27.68)***
R^2	0.6707	0.6918	0.5179
Wald	3,559.96	3,561.53	10,006.31
Observations	444	1,404	7,908

Note: ***Significant at 1%, **significant at 5%, *significant at 10%.

After a long history of regulation and deregulation, at present, the Chinese airline industry is composed of the big three state-owned carriers, many endemic and private airlines with distinct ownership, which is unique to the Chinese market. Hence, we take into account the nature of ownership of airlines in Eq. (1) and conduct a more detailed comparative analysis for the three forms of airlines under different market structures.

Table 4 shows the estimate results for airlines of different ownership in the monopoly market. Both route distance and flight number can increase price whatever the ownership is. Of all the routes, only the monopoly routes served by endemic airlines are faced with HSR competition. The coefficient of HSR is negative, which shows that HSR can evidently decrease price. Endemic airlines tend to set a lower price for small planes relative to medium ones. On the contrary, private airlines charge a higher price for small planes, which shows that private airlines attach more importance to utilizing small aircraft to earn profits. The premium effect for the big three airlines during peak times is remarkable. The J-curve effect for endemic airlines is more conspicuous. By contrast, for the other two forms of airlines, the J-curve effect is not obvious and presents a smooth upward trend.

Table 4. Estimate for Airlines of Different Ownership in Monopoly Markets

Explanatory variable	Big three airlines	Endemic airlines	Private airlines
InDistance	0.8337418(11.32)***	0.5836242(20.36)***	1.283678(7.88)***
Flightnum	0.8969907(1.65)*	0.4713916(7.38)***	0.3896257(3.79)***
MarketShare	—	—	—
ComFlights1hour	−0.3212465(−0.63)	—	—
HSR	—	−0.5782365(−6.76)***	—
Large	−0.1030546(−1.37)	—	—
Small	—	−0.1397954(−3.10)***	0.3714709(14.04)***
Workinghours	0.7246558(2.38)**	−0.0011827(−0.04)	—
Leadingdays	−0.0019955(−0.27)	−0.0059904(−2.24)**	−0.0028796(−0.64)
Leadingdays ²	0.0000547(0.50)	0.0000863(2.10)**	0.0000807(1.34)
Constant	−0.8760259(−0.58)	2.415191(15.45)***	−2.668873(−2.14)**
R^2	0.58333	0.7772	0.6887
Wald	1,767.2	2,985.06	321.12
Observations	228	168	48

Note: ***Significant at 1%, **significant at 5%, *significant at 10%

Table 5 shows the estimate results for airlines of different ownership in the duopoly market. Route distance can increase airfare and HSR can decrease it significantly. Flight number can reduce the price of private airlines, but will not significantly affect other forms of airlines. The coefficient of market share, big three airlines, and private airlines is negative and of endemic airlines is insignificant. The coefficient of competitive flight number, big three airlines, and endemic airlines is negative and for private airlines is insignificant. The premium effect for the big three airlines and private airlines during peak times is evident. All the airlines exhibit the J-curve effect.

Table 5. Estimate for Airlines of Different Ownership in Duopoly Markets

Explanatory variable	Big three airlines	Endemic airlines	Private airlines
InDistance	0.6923264(37.31)***	0.6514321(26.20)***	0.7854106(1.80)*
Flightnum	−0.0066381(−0.83)	0.0074081(0.29)	−0.3661996(−2.03)**
MarketShare	−0.4257296(−5.38)***	0.1525228(1.54)	−0.7816895(−3.35)***
ComFlights1hour	−0.1504108(−5.79)***	−0.2264838(−3.08)***	0.3025948(0.73)
HSR	−0.1653429(−6.26)***	−0.4127379(−8.22)***	—
Large	0.0256928(0.45)	—	—
Small	—	0.2746499(8.13)***	—
Workinghours	0.1057091(5.75)***	0.0280739(1.16)	0.2871219(2.71)***
Leadingdays	−0.0079785(−4.80)***	−0.0123201(−5.87)***	−0.0147181(−3.95)***
Leadingdays ²	0.0001431(5.63)***	0.0002112(6.86)***	0.0003003(5.49)***
Constant	2.278172(18.32)***	2.243101(10.08)***	2.449511(0.70)
R^2	0.7678	0.6343	0.7821
Wald	2,792.08	1,138.28	487.69
Observations	696	624	108

Note: ***Significant at 1%, **significant at 5%, *significant at 10%

Table 6 shows the estimate results for airlines of different ownership in competitive markets with three or more airlines. Both route distance and competitive flight number can increase price substantially. The premium effect for the big three and endemic airlines' large plane is conspicuous and for private airlines' small plane is insignificant. Market share can upgrade the price of the big three airlines, but do the opposite to endemic and private airlines. The price for the big three and endemic airlines during peak times is apparently higher, but insignificant for private airlines. All the airlines do not present the J-curve effect.

Table 6. Estimate for Airlines of Different Ownership in Competitive Markets

Explanatory variable	Big three airlines	Endemic airlines	Private airlines
InDistance	0.7129824(61.81)***	0.7293571(53.28)***	0.6461402(23.86)***
Flightnum	-0.0190587(-16.36)***	-0.0220271(-13.64)***	-0.0208924(-8.35)***
MarketShare	0.2466445(8.17)***	-0.2085617(-3.51)***	-0.3579196(-3.02)***
ComFlights1hour	0.0668005(11.74)***	0.0593575(6.75)***	0.0880299(6.65)***
HSR	-0.0757787(-6.83)***	-0.1100269(-7.49)***	-0.1798236(-5.30)***
Large	0.1196445(8.33)***	0.1368589(6.64)***	–
Small	0.0717022(1.56)	0.1157046(3.04)***	0.1640009(2.63)***
Workinghours	0.090556(10.48)***	0.0800287(7.28)***	-0.0065002(-0.34)
Leadingdays	-0.0009964(-1.28)	-0.0014448(-1.49)	-0.0002286(-0.15)
Leadingdays ²	0.0000436(3.68)***	0.0000719(4.98)***	0.000044(1.84)*
Constant	1.73367(20.54)***	1.707374(16.52)***	2.327565(10.64)***
R^2	0.5199	0.5165	0.4661
Wald	5,535.07	4,108.15	897.28
Observations	4,380	2,712	816

Note: ***Significant at 1%, **significant at 5%, *significant at 10%

By contrasting Tables 3, 4, 5, and 6, we determine that competitive flight number will increase price in the monopoly market and lower price in the competitive market. The market share of the big three airlines can increase price in the competitive market and reduce price in the duopoly market. The competitive flight number can increase all the airlines' price in the competitive market, whereas in the duopoly market, it will reduce the price of the big three and endemic airlines. The premium effect for a large plane in the competitive market is conspicuous. The J-curve effect is most significant in the duopoly market.

6. Conclusion

In the paper, we examine the determinants of airline pricing under different market structures using data on China's major routes. The empirical results show that the influencing factors of airfares under different market structures not only have something in common but also display some remarkable differences. In all markets, the relationship of route distance and price is positive. On average, price will increase by 0.66% to 0.79% as the distance increases by 1%. The price for the flights that fly from 9 A.M. to 5 P.M. is higher, i.e., the premium effect during peak times. Compared with medium planes, the price for small planes is higher. Competition from HSR reduces airfares dramatically in all markets. Booking days preceding departure exhibits the J-curve effect and the minimum price level is observed in the 1 or 2 weeks before departure. In the monopoly market, the larger the number of flights, the higher the price, whereas in the other markets, the exact opposite trend is observed. In the competitive market with three or more airlines, market share can increase price. By contrast, in the duopoly market, market share will reduce price. The competitive flight number within 1 h before or after departure time can decrease price in monopoly and duopoly markets, and price decreases in the monopoly market are much more than in the duopoly market. By contrast, in the competitive market, the larger the number of competitive flights, the higher the price. In the monopoly market, the price for large planes is relatively lower, whereas in the competitive market, the price for large planes is evidently higher. The price set by the big three airlines in the monopoly market is conspicuously lower, whereas in the duopoly and competitive markets, the big three airlines possess remarkable pricing advantage.

Furthermore, we obtained some interesting results by distinguishing airlines based on their ownership nature under three market structures. By comparison, we show that route distance affects airfare positively. Flight number affects all airlines positively on monopoly routes, but negatively on competitive routes. In the duopoly market, flight number produces negative effects on private airlines, whereas for other airlines, the effect is unclear. The market share of the big three airlines can increase and decrease price significantly in competitive and duopoly markets, respectively. For endemic airlines, the effect is not evident. The competitive flights within 1 h before or after departure can increase airfare on the competitive routes. The effect is insignificant in

the monopoly market, however, a negative effect on the big three and endemic airlines was observed in the duopoly market. Competition from HSR can reduce the price of all airlines in all markets. The premium effect of large planes on competitive routes is significant, but not on other routes. On monopoly routes, the price for small planes set by endemic airlines is evidently lower and the premium effect of private airlines is significant. By contrast, on duopoly and competitive routes, the premium effect for small planes is obvious. The big three airlines present an obvious premium effect during peak times in all markets, endemic airlines have a premium effect on competitive routes, and private airlines have a premium effect on duopoly markets. In the duopoly market, all airlines exhibit a significant J-curve effect. On monopoly routes, endemic airlines also show an obvious J-curve effect. By contrast, for the rest of the cases, the price dynamic path increase smoothly and steadily rather than follow the J-curve effect.

References

- Bergantino, A.S. and Capozza, C. (2011), The impact of market structure and price discrimination strategies in the airline sector, Working paper.
- Borenstein, S. (1989), Hubs and high fares: dominance and market power in the U.S. airline industry, *The Rand Journal of Economics* 20(3): 344-365.
- Borenstein, S. (2005), US domestic airline pricing, 1995-2004, Working paper.
- Brueckner, J.K., Dyer, N.J. and Spiller, P.T. (1992), Fare determination in airline hub-and-spoke networks, *The Rand Journal of Economics* 23(3): 309-333.
- Dender, K.V. (2006), Determinants of fares and operating revenues at US airports, *Journal of Urban Economics* 62(2007): 317-336.
- Dixit, A. and Gundlach, G.T. (2006), Aggressive and predatory pricing: insights and empirical examination in the airline industry, *American Marketing Association* 25(2): 172-187.
- Dresner, M., Lin, J.S.C. and Windle, R. (1996), The impact of low-cost carriers on airport and route competition, *Journal of Transport Economics and Policy* 30(3): 309-328.
- Dresner, M. and Tretheway, M.W. (1992), Modeling and testing the effect of market structure on price: the case of international air transport, *Journal of Transport Economics and Policy*, May 1992: 171-184.
- Evans, W.N., Froeb, L.M. and Werden, G.J. (1993), Endogeneity in the concentration-price relationship causes, consequences, and cures, *The Journal of Industrial Economics* 41(4): 431-438.
- Evans, W.N. and Kessides, I.N. (1993), Localized market power in the US airline industry, *The Review of Economics and Statistics* 75(1): 66-75.
- Evans, W.N. and Kessides, I.N. (1993), Structure, Conduct, and Performance in the deregulated airline industry, *Southern Economic Journal* 59(3): 450-467.
- Gillen, D. and Hazledine, T. (2006), The new price discrimination and pricing in airline: implications for competition and antitrust, Paper for XIV Pan-American Conference of Traffic & Transportation Engineering, September 20-23: 1-25.
- Graham, D.R., Kaplan, D.P. and Sibley, D.S. (1983), Efficiency and competition in the airline industry, *The Bell Journal of Economics* 14(1): 118-138.
- Hurdle, G.J., Johnson, R.L. and Joskow, A.S. (1989), Concentration, potential entry, and performance in the airline industry, *The Journal of Industrial Economics* 38(2): 119-139.
- Morrison, S.A. and Winston, C. (1990), The dynamics of airline pricing and competition, *The American Economic Review* 80(2): 389-393.
- Peteraf, M.A. and Reed, R. (1994), Pricing and Performance in Monopoly Airline Markets, *Journal of Law and Economics* 37(1): 193-213.
- Roos, N.D., Mills, G. and Whelan, S. (2010), Pricing dynamics in the Australian airline market, *Economic Record* 86(275): 545-562.
- Tretheway, M.W. and Kincaid, I.S. (2005), The effect of market structure on airline prices: a review of empirical results, *Journal of Air Law and Commerce* 70: 467-498.
- Zhang, Q., Yang, H. and Wang, Q. (2013), Market conduct of the three busiest airline routes in China, *Journal of Transport Economics and Policy* 47(3): 335-347.

ⁱAccording to the National Bureau of Statistics (http://www.stats.gov.cn/tjfx/jdfx/t20130715_402911032.htm), China is divided into eastern, central, and western regions.

Risk of Abuse of Dominance in Airport Slots for ‘Better’ European Airports?

Steven Truxal

Senior Lecturer, The City Law School, City University London, United Kingdom.

Fellow, Humboldt-Universität zu Berlin, Germany.

Email: Steven.Truxal.1@city.ac.uk.

Abstract

The view in Europe is that excess demand for capacity at congested European airports necessitates regulation of airport slots so as to ensure the fullest and most efficient use of existing capacity at coordinated airports while maximising consumers’ benefits and promoting competition.

This paper explores the development of the European Union (EU) framework on airport *slot allocation* and *slot exchange* over the past two decades. Council Regulation (EC) 95/93 laid down common rules for the allocation of slots at Union airportsⁱ, followed by four amendments (2002ⁱⁱ, 2003ⁱⁱⁱ, 2004^{iv} and 2009^v) that represent a gradual, comprehensive revision process towards developing a more flexible system of airport slot allocation.

The European Commission adopted a comprehensive set of measures vis-à-vis the ‘Better Airports’ Package in 2011. This comprised a policy summary document and three legislative measures on ground handling, noise and airport slots.^{vi} The cornerstone of the policy is the Commission’s Proposed (Recast) Slots Regulation^{vii}. At first glance, the Parliament’s Amendments seems to campaign for further liberalisation of the internal air transport market on the one hand, and re-regulation of it on the other.

First, this paper considers key changes in the Parliament’s Amendments under two headings: ‘streamlining the *slot allocation* regulation’ and ‘legalisation of *slot exchange*’. Next, with reference to relevant case law of the Court of Justice of the European Union (CJEU) and the adopted ‘essential facilities’ doctrine, this paper discusses state-owned airports and possible ‘airport favouritism’, particularly relating to access, charges/fees and allocation of slots. Finally, this paper examines recent outright purchases of slots by incumbent airlines. The author posits that the effects of the ‘legalisation’ but light-touch regulation of slot exchange raises concern over the risk of future abuses of dominance in airport slots, which may thwart the objective of the Commission’s ‘Better Airports’ Package.

Keywords: airports, dominance, slots, slot trading, slot exchange.

JEL: K2, K21, K33, L41, L42, L43, L93, L13.

1. Introduction

As global demand for air travel rises, so too does air traffic.^{viii} Demand for capacity at many already congested airports will also increase, necessitating substantial logistical planning^{ix} and often a commensurate level of regulation.

The ‘airport slot’, a permission given by a coordinator to use the full range of airport infrastructure necessary to operate an air service at a coordinated airport on a specific date and time for the purpose of landing or take-off, is an essential tool in the operation of the global airline industry.^x

The primary objective of the European Union (EU) framework for the regulation of airport slots is to ensure the fullest and most efficient use of existing capacity at congested Union airports while maximising consumers’ benefits and promoting competition. There are two key airport categories that require regulation

of landing and take-off slots where capacity is deemed insufficient in Europe: schedules facilitated airports^{xi} and coordinated airports.^{xii}

The allocation of slots has been regulated for schedules facilitated airports and coordinated airports in the EU since 1993. The first piece of EU legislation in this area, Council Regulation (EC) 95/93 laid down common rules for the allocation of slots at Union airports^{xiii}, or Allocation of Airport Slots Regulation ('Slots Regulation'). The legislation formed part of the third of three packages of liberalisation of the EU single market for air transport.^{xiv}

A block exemption from the EU competition rules for scheduling and slot allocation consultations via the International Air Transport Association (IATA) was in place from 1988—2006.^{xv} A proposal by the European Commission (EC) led to modernisation and simplification of the legal framework for the internal air transport market in 2006. Since then, the EU competition rules apply to all players in the air transport sector, including airlines participating in IATA conferences.^{xvi}

The aim of the Slots Regulation is 'to ensure that where airport capacity is scarce, the available landing and take-off slots are used efficiently and distributed in an equitable, non-discriminatory and transparent way'.^{xvii} It also requires Member States responsible for 'schedules facilitated'^{xviii} or 'coordinated'^{xix} airports to appoint a coordinator or schedules facilitator, and set out the role of the coordinator^{xx} whose role is to distribute airport slots through equitable, non-discriminatory and transparent means.

The slot allocation rules were amended four times: in 2002^{xxi}, 2003^{xxii}, 2004^{xxiii} and 2009.^{xxiv} It can be said that the amendments represent a gradual, comprehensive revision process aimed at developing a more flexible system of airport slot allocation. For instance, in response to the economic crisis and its impact on EU air carriers, the so-called 'use it or lose it' rule^{xxv} was suspended temporarily in 2008 and 2009, allowing air carriers to keep the same slots for the summer season of 2010 as attributed to them for the summer season of 2009.

Art. 8 of the 2004 Slots Regulation^{xxvi} sets out the current process of slot allocation, which includes provisions for 'slot mobility'^{xxvii}, or slot trading. In short, 'slots are allocated from the slot pool to applicant carriers as permissions to use the airport infrastructure for the purpose of landing or take-off for the scheduling period for which they are requested, at the expiry of which they have to be returned to the slot pool'.^{xxviii} Air carriers may continue to use a prior allocated series of slots in a subsequent season so long as the series 'has been operated, as cleared by the coordinator, by that air carrier for at least 80 % of the time during the scheduling period for which it has been allocated'.^{xxix}

Further requirements that air carriers must provide required information to the coordinator^{xxx}, adhere to the rules governing slot mobility^{xxxi}, ensure all new slots are placed in the pool^{xxxii}, and not misuse allocated slots, which would otherwise amount to 'slot abuse'.^{xxxiii}

2. Studies on Slot Allocation

From 2004 – 2011, the EU commissioned the following three studies on European airport slot allocation:

- the 2004 NERA study to assess the effects of different slot allocation schemes^{xxxiv};
- the 2006 Mott MacDonald study on the impact of the introduction of secondary trading at Community airports^{xxxv}; and
- the 2011 Steer Davies Gleave study on the impact assessment of revisions to Regulation 95/93^{xxxvi}.

The general conclusions offered by the comprehensive studies appear to suggest to varying degrees that the system is working although it still 'prevents optimal use of the scarce capacity at busy airports'.^{xxxvii} Points raised by the studies points that are most relevant to this paper are discussed below.

NERA Economic Consulting, in conjunction with the Faculty of Law at the University of Leiden and

Consultair Associates, completed a study in 2004 – ‘Study to Assess the Effects of Different Slot Allocation Schemes’ – which considered the introduction of market mechanisms for airport slots. The study considered how customers might be affected in the short term if air carriers are charged to access airport infrastructure, including landing fees.^{xxxviii} Of particular relevance were those airports where demand exceeded supply (capacity).

The study also found that in the longer term

... there may be further effects stemming from changes in *competitive conditions* in airline markets provoked by the redistribution of slots between different carriers and market segments. In principle, the use of market mechanisms to allocate scarce airport capacity might affect conditions of competition in airline markets in two ways: first, through its effects on the level of concentration in the relevant markets; second, through its effects on market entry conditions in the relevant markets.^{xxxix}

In the main, the NERA report identified ‘the need for regulatory intervention in the markets for slots at congested airports over and above the powers already available under existing EU competition policy legislation’^{xi} and possible means of regulatory intervention that might be applied. The study also queried briefly the application of Art. 102 TFEU to the control of slots by an airport operator and an airline holding a dominant position at a Union airport.^{xli}

A subsequent study entitled ‘Study on the impact of the introduction of secondary trading at Union airports’ by Mott MacDonald and others was published in 2006.^{xlii} In this study, whilst there is no reference made to Art. 102 TFEU^{xliii}, there is good discussion, again, on speculative changes to *market conditions* following introduction of secondary trading at Union airports. In that regard, the study specifically finds a likely effect on market share, specifically around airline alliances.

One of the likely effects is an increase in the market share of existing dominant incumbent airlines, particularly if they have developed a strong interlining hub. Although this can possibly be viewed as a deterioration in competition at any one airport, a broader view can be taken whereby – for example – a strengthened oneworld Alliance (BA and partner airlines) at London-Heathrow will be competing with a strengthened Star Alliance (Lufthansa and partners) at Frankfurt, and a strengthened Skyteam Alliance at Paris-Charles de Gaulle and Amsterdam (Air France, KLM and partners). As a result, decreased levels of competition at each individual airport may be accompanied (even compensated) by increased levels of competition between alliances at different airports.^{xliv}

Indeed, we have seen evidence of the effects on market share at EU airport hubs. Tactical and strategic alliance partners clearly align their schedules with one another to provide more seamless travel to customers wherever possible. The effect of this on hub-and-spoke networks is that, in this author’s view, six key airports in the EU emerge as ‘alliance hubs’: London Heathrow (LHR) and Madrid (MAD) for oneworld Alliance; Paris Charles de Gaulle (CDG) and Amsterdam (AMS) for Skyteam Alliance; and Frankfurt (FRA) and Munich (MUC) for Star Alliance (with a mini-hub at LHR). Owing to the focus on alliance traffic, it is likely that the most profitable routes sought by business and luxury travellers will be best delivered at each separate alliance hub, and therefore attract frequent flyers from the respective programmes. Taking the EU airports above as examples, one must agree that the global alliance frequent flyer networks and schedules has become of paramount importance to gaining market share in the EU.^{xlv}

Steer Davies Gleave concluded an ‘Impact assessment of revisions to Regulation 95/93’ and report in 2011. The study provides an evaluation of the current operation of the Slots Regulation and an analysis of a sample of 15 airports, including all large EU hubs and other most congested airports, as well as a cross-section of other large airports. The report also contains an impact assessment of various options for revision to the Slots Regulation.

Of particular relevance to this paper, the Steer Davies Gleave report provides a review of the Airport Charges Directive.^{xlvi} It finds that the Directive ‘imposes relatively *few obligations*, mostly relating to non-

discrimination between users and requirements for consultation and provision of information. Even if a carrier tried to claim that it was unfairly discriminated against by a slot reservation fee, Article 3 specifically allows modulation of charges for reasons of public and general interest, and therefore there should be no issue'.^{xlvi} Also, in terms of incumbent airlines enjoying 'grandfather rights', the report concluded:

Despite significant new competition in the European air transport market, including the growth of low cost airlines such as easyJet and Ryanair, the system of historical preference means that it is very difficult for new entrants to challenge the dominant position of the traditional incumbent airlines at the most congested airports. At these airports, the mobility (turnover) of slots is very low. Incumbent carriers have little incentive to give up slots, even when other carriers could use them more effectively than they could.^{xlvi}

Interestingly, the report recognises a *Progress Report of the Air Traffic Working Group on Slot Trading* done by the European Competition Authorities in 2005^{xli}, which 'identified a potential problem of "slot hoarding" – airlines holding slots, even though they cannot use them profitably, with the primary objective of preventing other airlines from entering the market or from expanding'.¹ According to the report, '[t]his problem could be exacerbated by secondary trading, as it provides a means for dominant incumbents to acquire more slots. However, secondary trading also increases the opportunity cost of slot hoarding, so it is not clear whether it would make the problem better or worse.'^{li}

Following publication of the three studies^{lii} and holding public consultation on the impact assessment for a possible revision of the Slots Regulation, the EC adopted a comprehensive set of measures vis-à-vis the 'Better Airports' Package in December 2011. The package consists of a policy summary document and three legislative measures on ground handling, noise and airport slots.^{liii} The EC also adopted a Communication on 'Airport policy in the European Union – addressing capacity and quality to promote growth, connectivity and sustainable mobility'.^{liv}

3. Legislative Proposals

According to the Commission,

[it] has been estimated that by revising the current allocation system up to 24 million additional passengers would be accommodated each year at European airports meaning more than €5 billion in economic benefits and up to 62,000 jobs by 2025 thanks to a more resource efficient allocation system.^{lv}

At the centre of the Better Airports Package is the Commission's Proposed Recast Slots Regulation ('EC Proposal')^{lvi}, which European Parliament has amended ('Parliament's Amendments')^{lvii}. At first glance, it would seem that the Parliament's Amendments drive further liberalisation of the internal air transport market on the one hand, and re-regulation of it on the other.

The three key changes in the EC Proposal are:

- 1) integration of slot allocation with the reform of the European air traffic management system (Single European Sky);
- 2) amendment of the 80/20 'use it or lose it' rule and definition of a series of slots and resort to the airport charge system to discourage the late return of slots to the pool; and
- 3) introduction of the possibility for secondary trade in slots and increased competition

This paper considers the first two changes above under the headings 'streamlining the *slot allocation* regulation' and the third change as 'introduction of *slot exchange*'; one must be attentive of the distinction.

3.1 Streamlining the Slot Allocation Regulation

According to the EC's 2011 Airports Package Communication, the objective of the Slots Regulation is 'to ensure that access to congested airports is organised through a system of fair, non-discriminatory and

transparent rules for the allocation of landing and take-off slots so as to ensure optimal utilisation of airport capacity and to allow for fair competition'.^{lviii}

In 1993, when the first Slots Regulation was introduced, national/flag carriers still dominated the EU air transport market; most of these were also state-owned. The succeeding amendments to the Slots Regulation have moved in sync with progress in the sector towards a larger, more diverse and competitive market.

The EC appears to attribute some of the sector's 'success' in this regard in reflecting on whether 'such progress could have been achieved without a system to ensure that slots at busy airports are allocated free of any undue influence from government, national carriers or airports'.^{lix} The EC also questions then whether or not the introduction of market mechanisms for allocation and use, and transparency objectives would be the most helpful proposals.

In the context of growing airport congestion and the limited development of major new airport infrastructure, the slots are a rare resource. Access to such resources is of crucial importance for the provision of air transport services and for the maintenance of effective competition.^{lx}

Additionally, in terms of historical slots, the EC 'recognises the importance for airlines in terms of stability of schedules ... but questions whether market mechanisms could be introduced to withdraw or auction historical slots'.^{lxi}

3.2 'Legalisation' of slot exchange and introduction of MBMs

Secondary trading, which is defined by the Commission as 'the exchange of slots for financial or other compensation'^{lxii}, is presently 'legal' but not regulated.

The EC Proposal:

- adds Art. 106 TFEU^{lxiii};
- removes the power to require transfers of slots by public authorities^{lxiv};
- strengthens the coordinator role and independence, and requires Member States to ensure coordinators have necessary resources;
- increases the series of slots length from 5 to 15 slots;
- adds sanctions for the late handing back of slots; and
- changes the 'use it or lose it rule' to 85/15.^{lxv}

Parliament's Amendments aim 'to allow for the introduction of market-based mechanisms [MBMs]^{lxvi} across the EU provided that safeguards to ensure transparency or undistorted competition are established, including greater independence for slot coordinators'.^{lxvii} The rationale is that this will help to ensure a more optimal allocation of airport slots by ensuring that slots go only to those air carriers able best to utilise them.

Whilst the 1993 Slots Regulation, as amended, is silent on the question of exchanges for *monetary and other consideration*, the EC adopted a Communication in 2008 that explained 'how the rules with respect to the independence of the slot coordinator, new entry, local guidelines and exchange of slots for monetary and other consideration should be interpreted'.^{lxviii} Effectively, this Communication clarified that 'for the first time that secondary trading is an acceptable way of allowing slots to be swapped among airlines'.^{lxix} It is of interest to note that UK High Court ruled in 1999 that a slot exchange between British Airways (BA) and KLM was consistent with national and EU law.

The following are some more recent examples of buying and selling of slots within the UK, by year:

- Flybe sold six pairs of slots to and from London-Heathrow (LHR) for approximately £40 million^{lxx} (2004);
- BA bought 102 Heathrow slots from British Midland (bmi) for approximately £30 million^{lxxi} (2007);
- the Bland Group sold four pairs of slots at LHR after it sold GB Airways to easyJet^{lxxii} (2007);
- it was confirmed that Lufthansa had bought BMI in a £223 million deal including 11 per cent share of

- LHR slot market, giving Lufthansa just over 16 per cent^{lxxiii} (2009);
- BA (now IAG) acquired BMI from Lufthansa, including more than 40 pairs of slots at LHR^{lxxiv}; IAG gave commitments to release 12 pairs of slots at LHR^{lxxv}, which Virgin Atlantic won as ‘remedy slots’, arguing all the slots should be given to one competitor to create more competitive markets^{lxxvi} (2012); and
- Flybe, which is struggling financially, sold all of its slots at LGW to easyJet for approximately £20 million^{lxxvii} (2013).

It is likely that the number of ‘successful’ swaps at London airports following the entry into force of the EU-US Open Skies Agreement^{lxxviii} prompted the 2008 Communication^{lxxix}, which was the first step in creating a market to allocate scarce capacity at EU airports through the introduction of secondary trading in slots and increased competition. The EC Proposal aimed to adopt the current slot allocation system to development of market mechanisms, such as with the London experience.

Revision of the existing legislation, however, is not only required for promoting competition. Discrimination could remain where a Member State favours its national carrier, or an airport favours a particular airline such as the one with the majority of customers. Additionally, the EC states that since secondary trading in airport slots ‘does not benefit from a uniform and consistent legislative framework, including guarantees of transparency and competitive safeguards. It is therefore necessary to regulate secondary trading in slots in the European Union’.^{lxxx}

4. Parliament’s Amendments

In December 2012, the European Parliament voted on the ‘Better Airports’ Package, in particular the EC Proposal for the introduction of secondary trading in slots, ‘which goes to the heart of the slot proposals. It added additional measures to strengthen the EC Proposal on the independence of the slot coordinators across Europe and higher transparency of information regarding slot allocation’.^{lxxxi}

Parliament’s Amendment’s have incorporated the following six key amendments to the text of the EC Proposal:

- 1) Rather than introducing ‘market mechanisms’ for the more efficient allocation and use of slots, the EU will introduce ‘slot exchange mechanisms’.^{lxxxii}
- 2) A ‘series of slots’ will comprise 5 slots, which have been requested for the same time on the same day of the week regularly in the scheduling period, rather than the proposed 15.^{lxxxiii}
- 3) The following proposed paragraph has been deleted: ‘The determination of the coordination parameters shall not affect the neutral and nondiscriminatory character of the slot allocation.’^{lxxxiv}
- 4) The position on local rules has been clarified: ‘Local rules shall concern the allocation and monitoring of slots. Those rules may be applied only where it can be proved that an airport reaches an alarming level of congestion and that performance or throughput improvements can therefore be delivered through locally applied rules. Such local rules shall be transparent and non-discriminatory, and shall be agreed on in the coordination committee referred to in Article 8(3).’^{lxxxv}
- 5) The provision in Art. 11 (EC Proposal) on slot reservation has been deleted.
- 6) The Commission’s proposed amendment of the 80/20 ‘use it or lose it’ rule to 85/15 has been reverted. The Parliament’s Amendments retains the 80/20 rule.^{lxxxvi}

Parliament’s Amendments incorporate the following point *inter alia* as new text:

The relevant theory and case law have not yet advanced sufficiently to produce an exhaustive legal definition of airport slots. As of now it is expedient to be able to work on the assumption that the use of slots in the public interest – hence not in any strict sense a public good - may serve as a guideline for a legal definition thereof. It is therefore appropriate to formulate a definition of slots which establishes that they may become subject to rights and governs the allocation thereof.^{lxxxvii}

Seemingly, this is a call for development of legal and relevant market definitions of slots. If we view airport

slots as property rights – disregarding for a moment the fundamental question of ‘who are the owners?’ – a thought is whether we could use the EU competition rules as ‘can opener’ *ex post* – or whether that is prevented by Art. 345 TFEU, which provides: ‘The Treaties shall in no way prejudice the rules in Member States governing the system of property ownership...’. But is there an interference with property rights? Parliament’s Amendments make the exchange of airport slots valid and promotes the ‘trade-able’ nature of these (property or contractual?) rights under EU law.

In a similar vein, we might consider the Strasbourg court on protection of contractual rights with respect to compensation payments following forced divestiture or transferring of slots, and in the EU following *International Fruit Company III*.^{lxxxviii} By way of comparison, it should be noted that US law does not recognise slots as property rights: ‘Slots do not represent a property right but represent an operating *privilege* subject to absolute FAA control...’.^{lxxxix}

Returning to the question of airport slot ownership, Frankfurt Airport (Fraport) considers, unsurprisingly, that airports are owners of airport slots and that the DFS (German Navigation Services) is the owner of what they call ‘airway’ slots.^{xc} As early as May 2008, the leading international accountancy firm, Deloitte & Touche LLP, forecasted that ‘airlines would start to value landing slots as assets on balance sheets’.^{xc} Clearly everybody wants to claim ownership but there is a discernible lack of clarity on the legal definition and effect.

Parliament’s Amendments contain additional amendments signalling longer-term financing of the development of EU air transport infrastructure via proceeds from slot exchanges collected by each Member State.^{xcii} This might take the form of future taxation on such exchanges.

5. Airport Favouritism?

5.1 Access

On control of slots and access to airport infrastructure, citing the special case of *Holyhead II*^{xciii} following Sabena’s bankruptcy and applying three cases relating to access to seaports^{xciv} *mutatis mutandis* to airports, the NERA report suggested that:

The abuse of a dominant position is liable to arise in cases where the operator of an airport seeks to alter slots to the benefit of its main customer-airline. Hence, the operator would infringe Article 82 EC [Article 102 TFEU]. The fact that the allocation of a slot to the airline would involve the reorganisation of other slots would not constitute a valid justification of such a refusal because the operator of the airport as the operator of an “essential facility” is expected to go to provide market access, that is, airport access, on a fair and non-discriminatory basis. The operator of the essential facility must carry the burden of proof that it provided equal *access* to all users of the facility. The operator of an essential facility is deemed to go far in order to accommodate the requests for access made by its users. The above flows from cases, which have been decided upon in the context of access to ports.

Other relevant cases relating to access to seaports are: *Rødby-Puttgården*^{xcv}, *Elsinore*^{xcvi} and *Roscoff*.^{xcvii}

5.2 Charges/fees and allocation of slots

Under EU law, the ‘essential facilities’ doctrine imposes on owners of ‘essential facilities a so-called “duty to deal” with competitors. Under Art. 102 TFEU, a refusal to deal can constitute an abuse of a dominant position.’^{xcviii}

It is necessary to consider the ‘essential facilities’ doctrine in the light of the *Bronner*^{xcix} case, which concerned the refusal of a media undertaking holding a dominant position in the territory of a Member State to include a rival daily newspaper of another undertaking in the same Member State in its newspaper home-delivery scheme. In that case, the question for the Court was whether a home-delivery scheme constituted a separate market or whether this was interchangeable with sales in shops and kiosks.^c

The Court, in deciding whether an undertaking in a dominant position has a duty to deal with its competitor, appears to impose a stricter test of the essential facilities doctrine *Bronner*. According to Evrard (2004):

It seems that if a facility is *indispensable* for the requesting undertaking, the refusal to grant access to it will inevitably prevent that undertaking from competing on the market and, thus, will eliminate it. Alternatively, if the refusal to use the facility is not likely to eliminate all competition on the part of the requesting undertaking, it inevitably means that the facility is not essential.^{ci}

Thus, the effect on the ‘essential facilities doctrine’ in EU law post-*Bronner*^{cii} is that the fact that facility has dominant position is no longer sufficient; the facility must also be indispensable as well.

A scholarly review of key decisions by Evrard (2004)^{ciii} reveals that the Court of Justice of the European Union (CJEU) has been consistent in its application of the *Bronner* doctrine in subsequent cases. By way of comparison, we consider the post-*Bronner* case of *Aéroport de Paris*.^{civ}

Aéroport de Paris (ADP) involved airline catering services and two competitors at Paris-Orly Airport. The CJEU confirmed Commission’s Decision that the legal monopoly running Paris airports, ADP, had abused its dominant position at Orly Airport by requiring one groundhandler (AFS) to pay a higher fee than another (OAT), which was discriminatory. The Court held that ‘the relevant market is that for the management of airport facilities, which are indispensable for the provision of groundhandling services and to which ADP provides access’.^{cv} With reference to the application by the Commission and Court of First Instance (now General Court) of *British Leyland*^{cvi} to the situation in ADP, the CJEU agreed that the relevant market was both the management of and access to the airport facilities.

In this judgment, the CJEU strengthened that definition of the relevant market (product) in providing that ‘a licence from ADP is also a prerequisite for access to the market for the services offered by ADP and such access is *indispensable* for the supply of groundhandling services to airlines’.^{cvi}

It follows that ADP’s authorisation to access the airport was indispensable to carry out the groundhandling services it requested. The Court confirmed that the owner of an essential facility may not impose discriminatory conditions on requesting undertakings.^{cvi} It is also worth noting that ADP was not present on downstream market, but the Court found this was irrelevant. The *effect* on the downstream market was enough to constitute abuse.^{cix}

Whilst no infringement nor jurisprudence have been located on *abuse* of a dominant position in slots, the *Aéroport de Paris*^{cx} case and a few others such as *airport charges at Finnish airports*^{cxii}, *landing fees at Brussels Airport*^{cxiii}, and *landing charges in use at Portuguese airports*^{cxiii} may be useful for contemplating the application of Art. 102 TFEU to the system of airport charges and landing fees to market regulation of secondary trade in slots.^{cxiv} Airports are indispensable to civil aviation, yes, but are airport slots also indispensable to airlines? If the answer is in the affirmative then by definition the airport slot must be an essential facility, too.

One of the foremost aims of the EC Proposal is transparency; this is also referred to nine times in the draft text. It is likely that greater transparency in the system of slot allocation and trading in the Union will result in less opportunity for airport, or even Member State, favouritism of airlines.

Also, on an airline holding or being led to acquire a dominant position at a Union airport, the NERA report referred *inter alia* to the case on *landing charges in use at Portuguese airports*.^{cxv} In that case, the Commission found an infringement of Art. 101 TFEU in conjunction with Art. 106(2).^{cxvi} This is of particular interest where the airport in question is state-owned.^{cxvii}

6. Abuses of Dominance in Slots?

The application of Art. 101 TFEU to airport slot transactions (i.e. sales, transfers or exchanges) could present difficulties. Individual slot transactions may have only an appreciable effect on competition either on the

upstream or downstream markets, and therefore be deemed *de minimis*.^{cxviii} Certainly, if a series of slot transactions are made together then a greater effect on competition is possible.^{cxix} Furthermore, non-compete clauses would likely lead to market sharing and constitute a violation of Arts 101 and 102 TFEU, and Arts 53 and 54 of the EEA Agreement.^{cxx}

Turning to Art. 102 TFEU, we query if the introduction of MBMs to the slot allocation system vis-à-vis legalisation of ‘slot exchange’, which effectively enables the highest bidder to purchase slots, will generate the first case of abuse of dominance in slots? Or will an undertaking’s dominance in slots at EU airports simply lead to a strengthened competitive advantage for hub carriers? Efficient hub use is not in itself anti-competitive; in theory this would lead to benefits for consumers through increased capacities at better timings. What is unclear is whether the airfares on respective routes will increase as well. Fares will not necessarily increase merely if a hub carrier exercises market power in slots, and therefore at the airport in question, but perhaps an increased opportunity for abuse is present in such an environment.

With respect to access to slots, noting of course that air carriers are subject to the EU competition rules, including the Merger Regulation, it is likely that the acquisition by one carrier of another will continue to lead to Art. 9 commitments^{cxxi} such as divestiture of slots and/or return of some of the acquired slots to the pool.

On the one hand, we question whether these types of commitment decisions are changing the ‘regulatory nature’ of competition law. On the other hand, a novel situation has arisen insofar as air carriers now *buy* slots outright. In other words, in the absence of a requirement to report the resulting concentration in slots to the EC and no investigation^{cxii} as such in cases where there is no merger or acquisition, or other joint venture, this *purchase* of slots seems to lack oversight. The Merger Regulation is useless in this instance as it cannot be used *ex ante*. Is this not then a ‘grey market’, which should be particularly concerning with reference to dominance and the theory of refusal to supply (slot hoarding) when applying the competition rules?

In terms of access to airport infrastructure, which it is now clear is *indispensable* to the operation of an air service; it is ‘very difficult for new entrants to challenge the dominant position of the traditional incumbent airlines at the most congested airports. At these airports, the mobility (turnover) of slots is very low’.^{cxiii} This is, it is submitted, almost entirely down to the current system of historical preference that is grandfather rights under the 80/20 ‘use it or lose it’ rule discussed above.

As the *Impact Assessment* that accompanies the EC Proposal explains:

Dominant carriers are reluctant to give up slots and they are impeding access to the market by hoarding or babysitting slots. The report by the European Competition Authorities on slot trading identified as a potential problem the fact that airlines are holding slots, even though they cannot use them profitably, with the primary objective of preventing other airlines from entering the market or from expanding (slot hoarding). These airlines could alternatively proceed to babysitting, by leasing slots to other airlines, but here also competition concerns could arise: the lessor could restrict the use of the slots by the lessee, it could choose to lease the slots only to airlines that are not considered to be strong competitors, it could ask for excessive prices etc.^{cxiv}

Whilst the issue is recognised, this area appears to lack adequate oversight.

A further hurdle perhaps, applying even a conservative theory of harm, is showing how reservation of slots, or ‘slot hoarding’, constitutes manipulation of the downstream market.^{cxv} Arguing the airport slot as upstream is potentially problematic. What exactly is the downstream market? Whilst an airport may be pricing excessively, a good defence might be built citing issues with market definition and lack of legal certainty.

7. Conclusions

Art. 6 of the Parliament’s Amendments provides:

On an annual basis, the coordinator or schedules facilitator shall submit to the Member States concerned, to the Commission and to all parties involved in their financing at their request, an activity report describing the general slot allocation and/or schedules facilitation situation ... [which] shall also contain aggregate and individual data on financial compensation derived from the sale of slots ...^{cxxvi}

Although the reporting will ensure some transparency of the process of slot allocation and exchange, it is unclear whether it will also lead to price control or price speculation. Exclusionary behaviour, overbidding and predatory pricing could ensue. The parties involved in the financing of the coordinator or scheduling facilitator will tend to include a relatively small group of airlines, which are likely to be the dominant carriers at the airport(s) concerned. It is questionable, therefore, whether limiting open access to the financial compensation data will create true liberalised, 'open market' conditions for the sale and exchange of airport slots. Indeed, the small group of airlines will become privileged to the market price for slots at the airport and may be in a position to influence this price to squeeze out competitors.

Furthermore, in the absence of a formal notification requirement on the sale or exchange of slot with respect to market share and the EU competition rules, there is a significant risk of only piecemeal economic scrutiny of those exchanges.

One way to resolve this might be setting caps on slot holdings. In 2005, the UK Civil Aviation Authority (CAA) and Office of Fair Trading (OFT) considered 'controls aimed at limiting the actions of specific airlines, for example a cap on slot holding'^{cxxvii}, but were unclear on how this should be implemented. CAA/OFT contemplated whether applying a cap on slot holdings only at hub airports could be a way forward. In conclusion, however, CAA/OFT felt that 'imposing caps across the board would seem too blunt an instrument, would risk adverse outcomes, and would be particularly onerous to implement effectively'.^{cxxviii} Therefore, they did not recommend caps in the end.

In any case, it is quite probable that the spirit of liberalisation with a dash of re-regulation will continue to give way to a gradual introduction of market mechanisms in this area, such as the withdrawing and auctioning of historical slots. In the meantime, issues arising shall be taken on a case-by-case basis. So, Parliament's Amendments appear to be just another step in the liberalisation of the internal air transport market with some decentralisation^{cxxix}, but it remains to be seen how the markets for slot exchange will react, and competition authorities will deal, with dominance and abuse in future.

In the meantime, mindful of the semi-recent outright purchases of slots by incumbent airlines examined above, it should come as no surprise that the 'legalisation' but light-touch regulation of slot exchange indeed raises concern over the risk of future abuses of dominance in airport slots, which may thwart the objective of the Commission's 'Better Airports' Package. Whilst the European Commission's intention clearly is to improve the situation at Europe's congested airports, the legislative proposal (Recast) it has made, the Common Position of European Council and Parliament's Amendments do not appear to go far enough to achieve this. Ultimately, the coordinators and schedules facilitators must exercise their duty to approve slot purchases and exchanges that are consistent with the EU and national competition rules – but more precise guidelines on for slot allocation and exchange are needful, particularly as regards new entrants, economic efficiency and consumer welfare. Until then, it appears that the current system of allocative efficiency, insofar as slots purchased will flow to the highest bidder, prevails.

ⁱ An amended version of this paper is published in 36(6) E.C.L.R. 299-309. Council Regulation (EEC) 95/93 of 18 January 1993 on common rules for the allocation of slots at Community airports, [1993] OJ L14/1, 22.01.1993.

ⁱⁱ Regulation (EC) 894/2002, of the European Parliament and of the Council of 27 May 2002 amending Council Regulation (EEC) No 95/93 on common rules for the allocation of slots at Community airports, [2002] OJ L142/3, 31.05.2002.

ⁱⁱⁱ Regulation (EC) No 1554/2003 of the European Parliament and of the Council of 22 July 2003 amending Council Regulation (EEC) No 95/93 on common rules for the allocation of slots at Community airports, [2003] OJ L221/1, 04.09.2003.

^{iv} Regulation (EC) No 793/2004 of the European Parliament and of the Council of 21 April 2004 amending Council Regulation (EEC) No 95/93 on common rules for the allocation of slots at Community airports, [2004] OJ L138/50, 30.04.2004.

^v Regulation (EC) No 545/2009 of the European Parliament and of the Council of 18 June 2009 amending Regulation (EEC) No 95/93 on common rules for the allocation of slots at Community airports, [2009] OJ L167/24, 29.06.2009.

^{vi} It should be noted that before being adopted, the EC Proposals must be approved by the European Parliament and the Member States under the EU's post-Lisbon legislative procedure.

^{vii} 'Airport package Proposal for a Regulation of the European Parliament and of the Council on the common rules for the allocation of slots at European Union airports (Recast)', Brussels, 01.12.2011, COM(2011) 827 final, 2011/0391 (COD). European Parliament adopted a legislative resolution on 12 December 2012 on the proposal for a regulation of the European Parliament and of the Council on common rules for the allocation of slots at EU airports (Recast) (COM(2011)0827 – C7-0458/2011 – 2011/0391(COD)).

^{viii} According to Airports Council International (Europe), EU airports have experienced notable increases to passenger traffic from November 2013 to January 2014, available at www.aci-europe.org/media-room.html, *see also* IATA website, available at www.iata.org/pressroom/pr/Pages/2013-10-31-01.aspx.

^{ix} Air traffic management authorities may approve or reject a submitted flight plan.

^x Whilst the author recognises that *airport* competition deserves further study, this paper deals with *airport slot* competition in the main. For a discussion on overlapping catchment areas, see Starkie, D. 'Airport Regulation and Competition', 8 *Journal of Air Transport Management* 63–72 (2002); on airports as platforms, see Starkie (2002) and Gillen, D. 'The Evolution of the Airport Business: Governance, Regulation and Two-sided Platforms', Martin Kuntz Memorial Lecture, Hamburg Aviation Conference (2009) available at www.hamburg-aviation-conference.de; and more generally, Rochet, J.-C. and Tirole, J. 'Platform Competition in Two-Sided Markets', 1 *Journal of the European Economic Association* 990–1029 (2003); Rochet, J.-C. and Tirole, J. 'Two-Sided Markets: A Progress Report', 37(3) *RAND Journal of Economics* 645–557 (2006); and M. Armstrong, 'Competition in two-sided markets', 37(3) *RAND Journal of Economics* 669–691 (2006). On vertical structure, see Barbot, C. 'Airport and airlines competition: Incentives for vertical collusion', 43 *Transportation Research Part B* 952–965 (2009).

^{xi} This is defined as 'an airport with a potential for congestion at some periods and where a schedules facilitator has been appointed to facilitate the operations of air carriers operating or intending to operate at that airport'. (See Art.2(i), as amended, Regulation (EC) No 793/2004 of the European Parliament and of the Council of 21 April 2004, [2004] OJ L138/52).

^{xii} This is defined as 'an airport with a high level of congestion where demand exceeds capacity during the relevant period and where, in order to land or take off, it is necessary for an air carrier to have a slot allocated by a coordinator'. (See Art.2(g), as amended, Regulation (EC) No 793/2004 of the European Parliament and of the Council of 21 April 2004, [2004] OJ L138/52).

^{xiii} Council Regulation (EEC) 95/93 of 18 January 1993 on common rules for the allocation of slots at Community airports, [1993] OJ L14/1, 22.01.1993.

^{xiv} The Slots Regulation is also relevant for European Economic Area and therefore extends to cover Iceland, Liechtenstein and Norway.

^{xv} See EC Press Release, 'Competition: Commission revises Block Exemption for IATA passenger tariff conferences', IP/06/1294, Brussels, 02.10.2006, available at: http://europa.eu/rapid/press-release_IP-06-1294_en.htm.

^{xvi} IATA slot conferences take place twice annually, in mid-November (summer slots) and mid-June (winter slots). IATA World Slot Guidelines are available at: <https://www.iata.org/policy/slots/Documents/wsg-5.pdf>.

^{xvii} European Legislation Summaries, Summary of Regulation (EC) 95/93, available at: http://europa.eu/legislation_summaries/transport/air_transport/l24085_en.htm.

^{xviii} Formerly 'coordinated'.

^{xix} Formerly 'fully coordinated'.

^{xx} Art.4, Council Regulation (EEC) 95/93 of 18 January 1993 on common rules for the allocation of slots at Community airports, [1993] OJ L14/1, 22.01.1993.

^{xxi} Regulation (EC) 894/2002, of the European Parliament and of the Council of 27 May 2002 amending Council Regulation (EEC) No 95/93 on common rules for the allocation of slots at Community airports, [2002] OJ L142/3, 31.05.2002.

^{xxii} Regulation (EC) No 1554/2003 of the European Parliament and of the Council of 22 July 2003 amending Council Regulation (EEC) No 95/93 on common rules for the allocation of slots at Community airports, [2003] OJ L221/1, 04.09.2003.

^{xxiii} Regulation (EC) No 793/2004 of the European Parliament and of the Council of 21 April 2004 amending Council Regulation (EEC) No 95/93 on common rules for the allocation of slots at Community airports, [2004] OJ L138/50, 30.04.2004.

^{xxiv} Regulation (EC) No 545/2009 of the European Parliament and of the Council of 18 June 2009 amending Regulation (EEC) No 95/93 on common rules for the allocation of slots at Community airports, [2009] OJ L167/24, 29.06.2009.

^{xxv} The historical slots are held as ‘grandfather rights’. This point is discussed in further detail below.

^{xxvi} Regulation (EC) No 793/2004 of the European Parliament and of the Council of 21 April 2004, [2004] OJ L138/55, Art.8.

^{xxvii} Regulation (EC) No 793/2004, introduced slot mobility as a system of slot trading. After one year (two years for new entrant slots), the air carrier has grandfather rights to trade the slot under Art.8a.

^{xxviii} in accordance with the provisions of Art.10

^{xxix} *Ibid*, Art.8(2), para.2.

^{xxx} *Ibid*, Art.7.

^{xxxi} *Ibid*, Art.8a.

^{xxxii} *Ibid*, Art.10(1)

^{xxxiii} *Ibid*, Art.14

^{xxxiv} Available at: http://ec.europa.eu/transport/modes/air/studies/doc/airports/2004_01_slot_allocation_schemes.pdf.

^{xxxv} Available at: http://ec.europa.eu/transport/modes/air/studies/doc/airports/2006_11_airports.zip.

^{xxxvi} Available at: <http://ec.europa.eu/transport/modes/air/studies/doc/airports/2011-03-impact-assessment-revisions-regulation-95-93.pdf>

^{xxxvii} See http://europa.eu/legislation_summaries/transport/air_transport/l24085_en.htm.

^{xxxviii} NERA, ‘Study to Assess the Effects of Different Slot Allocation Schemes’, January 2004, available at: http://ec.europa.eu/transport/modes/air/airports/slots_en.htm, pp.101—102.

^{xxxix} *Ibid* (emphasis added).

^{xl} *Ibid*, p.102; Arts 101 and 102 of the Treaty on the Functioning of the European Union (TFEU), and the EC Merger Regulation (Council Regulation (EC) No 139/2004 of 20 January 2004 on the control of concentrations between undertakings, [2004] OJ L24/1, 29.01.2004).

^{xli} This paper endeavours to continue that discussion below.

^{xlii} Mott MacDonald, ‘Study on the impact of the introduction of secondary trading at Union airports’, November 2006, available at: http://ec.europa.eu/transport/modes/air/airports/slots_en.htm.

^{xliiii} Art.82 of the Treaty Establishing the European Community (TEC).

^{xliv} *Ibid*, p. 9-6.

^{xlvi} It has been argued elsewhere that the situation differs elsewhere, for instance at US hub airports.

^{xlvi} Directive 2009/12/EC of the European Parliament and of the Council of 11 March 2009 on airport charges, [2009] OJ L70/11, 14.03.2009.

^{xlvi} Steer Davies Gleave, ‘Impact assessment of revisions to Regulation 95/93’, March 2011, available at: http://ec.europa.eu/transport/modes/air/airports/slots_en.htm (emphasis added).

^{xlvi} *Ibid*, p.3.

^{lix} ‘Progress Report of the air traffic working group on slot trading’, European Competition Authorities, 17.06.2005; Competition issues associated with the trading of airport slots, A paper prepared for DG/TREN by UK Office for Fair Trading and Civil Aviation Authority, June 2005.

ⁱ Steer Davies Gleave, ‘Impact assessment of revisions to Regulation 95/93’, March 2011, p.91.

^{li} *Ibid*; see also ‘Commission Staff Working Paper, ‘Impact Assessment, Accompanying the document Proposal for a Regulation of the European Parliament and of the Council on common rules for the allocation of slots at European Union airports (Recast)’, Brussels, 1.12.2011, SEC(2011) 1443, final.

^{lii} The Steer Davies Gleave report was published in March 2011, and in December 2011 the Commission adopted its Better Airports Package, including the EC Proposal. It is highly likely that feedback on the Slots Regulation and the Airport Charges Directive provided by Steer Davies Gleave was instrumental in highlighting these points to the Commission and contributory to the drafting of the EC Proposal. It is interesting, however, that ‘slot hoarding’ is not addressed in the text of the EC Proposal.

^{liii} It should be noted that before being adopted, the EC Proposal must be approved by the European Parliament and the Member States under the EU’s legislative procedure.

^{liv} COM (2011) 823, final.

^{lv} Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, ‘Airport policy in the European Union - addressing capacity and quality to promote growth, connectivity and sustainable mobility’, Brussels, 1.12.2011, COM(2011) 823, final, para.19.

^{lvi} ‘Airport package Proposal for a Regulation of the European Parliament and of the Council on the common rules for the allocation of slots at European Union airports (Recast)’, Brussels, 1.12.2011, COM(2011) 827, final, 2011/0391 (COD).

^{lvii} The EC Proposal was voted in first reading by the Plenary of the European Parliament in December 2012 and the Council adopted a General Approach in October 2012. Further discussions between the two legislators are necessary before the final adoption, in second reading, of the Proposal. The timing for the Council’s political agreement / common position depends on the negotiations between the Institutions and on the developments in the Groundhandling Proposal. See Proposal for a Regulation of the European Parliament and of the Council on groundhandling services at Union airports and repealing Council Directive 96/67/EC, COM(2011)0824 – 2011/0377 (COD); Proposal for a regulation of the European Parliament and of the Council on common rules for the allocation of slots at EU airports (Recast), COM(2011)0827 – C7-0458/2011 – 2011/0391 (COD).

^{lviii} Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, ‘Airport policy in the European Union - addressing capacity and quality to promote growth, connectivity and sustainable mobility’, Brussels, 1.12.2011, COM(2011) 823 final, p.2.

^{lix} *Ibid.*, p.3.

^{lx} *Ibid.*, p.12.

^{lxi} *Ibid.*

^{lxii} ‘Airport package Proposal for a Regulation of the European Parliament and of the Council on the common rules for the allocation of slots at European Union airports (Recast)’, Brussels, 1.12.2011, COM(2011) 827 final, 2011/0391 (COD), p.13.

^{lxiii} EC Proposal, Recital 28. ‘The application of the provisions of this Regulation should be without prejudice to the competition rules of the Treaty, in particular Arts 101, 102 and 106’ (emphasis added).

^{lxiv} EC Proposal, Art.14. Art.14: ‘This Regulation shall not affect the powers of public authorities to *approve* [formerly *require*] the transfer of slots between air carriers and to direct how these are allocated pursuant to national competition law or to Arts 101, 102 or 106 of the Treaty or Council Regulation (EC) No 139/2004.’ The following sentence was deleted: ‘These transfers can only take place without monetary compensation.’ Thus, the power to require transfer of slots has been transferred to the Commission.

^{lxv} EC Proposal, Art.14.

^{lxvi} This has been amended in the Parliament’s Amendments (see below) to ‘slot exchange’.

^{lxvii} See http://europa.eu/legislation_summaries/transport/air_transport/124085_en.htm.

^{lxviii} European Commission Press Release, ‘Airport slot allocation: The Commission clarifies the existing rules’, IP/08/672, 30.04.2008; See also COM (2008) 227, 30.04.2008, as amended.

^{lxix} *Ibid.*

^{lxx} O’Connell, D. ‘The sky-high demand for Heathrow slots’, *Sunday Times*, 22.02.2004.

^{lxxi} Parker, A. ‘BA buys extra slots at Heathrow’, *Financial Times*, 01.04.2007.

^{lxxii} Press reports in 2007 estimated that LHR slots could be fetch a price of between £5-12 million depending on the timing. See Done, K. ‘Takeoff jigsaw falling into place at Heathrow’, *Financial Times*, 26.10.2007.

^{lxxiii} Arnott, S. ‘Lufthansa wins BMI sale battle with £115m to spare’, *The Independent*, 23.06.2009; and Wiesmann, G. ‘Germans eye long-haul routes from Heathrow’, *Financial Times*, 30.10.2008.

^{lxxiv} ‘BA-owner IAG completes BMI takeover’, *BBC online*, 20.04.2012, available at: <http://www.bbc.co.uk/news/business-17786998>.

^{lxxv} Commission Press Release, ‘Mergers: Commission approves acquisition of British Midlands (bmi) by IAG subject to conditions’, IP/12/338, 30.03.2012

^{lxxvi} Rivers, M, ‘Virgin Atlantic secures IAG’s 12 Heathrow remedy slots’, *Flight Global*, available at: www.flightglobal.com/news/articles/virgin-atlantic-secures-iags-12-heathrow-remedy-slots-379181/.

^{lxxvii} Strydom, M, ‘Flybe sells Gatwick slots to easyJet for 20m’, *The Telegraph*, 23 May 2013, available at: www.telegraph.co.uk/finance/newsbysector/transport/10075367/Flybe-sells-Gatwick-slots-to-easyJet-for-20m.html.

^{lxxviii} It is possible this conclusion was reached only on the basis that the previous UK—US bilateral (Bermuda II) was extremely prescriptive and restrictive.

^{lxxix} European Commission Press Release, ‘Airport slot allocation: The Commission clarifies the existing rules’, IP/08/672, 30.Apr.2008), See also COM (2008) 227, 30.04.2008, as amended.

^{lxxx} ‘Airport package Proposal for a Regulation of the European Parliament and of the Council on the common rules for the allocation of slots at European Union airports (Recast)’, Brussels, 01.12.2011, COM(2011) 827, final, 2011/0391 (COD), p.13.

^{lxxxi} European Commission Press Release, ‘Aviation: MEPs vote on “better airports” package’, IP/12/1363, 12.12.2012.

^{lxxxii} Parliament’s Amendments, recital 4.

^{lxxxiii} Parliament’s Amendments, Art.2, point 13.

^{lxxxiv} EC Proposal, Art.4, para.3.

^{lxxxv} Parliament’s Amendments, Art.9, para.8.

^{lxxxvi} Parliament’s Amendments, Art.18, para.4(2).

^{lxxxvii} Parliament's Amendments, recital 5a.

^{lxxxviii} Joint cases 21-24/72, [1972] ECR 1219.

^{lxxxix} FAA Federal Aviation Regulations (FAR) Part § 93.223, 14 CFR.

^{xc} Fraport AG Policy Paper, 20.09.2002.

^{xcⁱ} Deloitte & Touche LLP, 'Open Skies, open for business?' (May 2008), available at [www.deloitte.com/assets/Dcom-UnitedKingdom/Local%20Assets/Documents/UK_THL_OpenforSkiesOpenForBusiness_May08\(2\)!!1!!1.pdf](http://www.deloitte.com/assets/Dcom-UnitedKingdom/Local%20Assets/Documents/UK_THL_OpenforSkiesOpenForBusiness_May08(2)!!1!!1.pdf)

^{xcⁱⁱ} Parliament's Amendments, Recital 26a and Art.13, para.3,

^{xcⁱⁱⁱ} [1994] OJ L 55/52; In this case, following Sabena's bankruptcy in 2001, all of its slots were transferred to its subsidiary (100 per cent), DAT. In liquidation it was agreed that DAT could make full use of the slots. Whilst DAT did not sell the slots, the Commission approved the transaction but required DAT progressively to return some of the slots; *See also* Commission's Report on Competition (1992), para.219.

^{xc^{iv}} *Rødby-Puttgården*: OJ 1994, L 55/52; *Elsinore*: Commission Press Release, IP 96/205 of 6 March 1996; *Roscoff*: Commission Press Release, IP 95/492 of 16.05.1995

^{xc^v} Commission Decision 94/119/EC, [1994] OJ L055/52 (concerning a refusal to grant access to the facilities of the Port of Rødby, Denmark).

^{xc^{vi}} Cases COMP/A.36.568 and COMP/A.36.570. 'These two parallel complaints related to alleged abuses within the meaning of Art.82 EC involving excessive port fees charged by the port of Helsingborg for services provided to ferry operators active on the Helsingborg–Elsinore route between Sweden and Denmark. After extensive investigation, the Commission came to the conclusion that the available evidence was insufficient to demonstrate to the requisite legal standard that the prices at issue were excessive. The decisions point to more general difficulties in applying Art.82 TEC to excessive pricing cases, particularly in cases where no useful benchmarks are available. Given that existing case-law on this issue is rather limited, the decisions may provide useful guidance when determining the economic value of a service and whether a price is excessive/unfair and thus constitutes an abuse of a dominant position within the meaning of Art.82 EC [Art.102 TFEU]' (Source: European Commission, Report on Competition Policy, Volume 1, 2004, SEC(2005) 805, final).

^{xc^{vii}} Commission Press Release, 'Irish Ferries Access to the Port of Roscoff in Brittany: Commission Decides Interim Measures Against the Morlaix Chamber of Commerce', IP 95/492 of 16.05.1995.

^{xc^{viii}} It has been argued by Evrard that, following *Commercial Solvents* (Joined Cases 6/73 and 7/73, [1974] ECR 223, [1974] 1 CMLR 309), in which the CJEU first dealt with the 'essential facilities' in all but using that terminology, the Court's decision in *Bronner* (Case C-7/97, [1998] ECR I-7791, [1999] 4 CMLR 112) was a catalyst for limiting the doctrine's application to where the facility is indispensable and for imposing the application of a forward-looking test (Source: Evrard, SJ, 'Essential Facilities in the European Union: *Bronner* and Beyond', 10(3) *Columbia Journal of European Law* (Summer 2004), pp.491—526).

^{xc^{ix}} Case C-7/97, *Oscar Bronner GmbH & Co. KG v Mediaprint Zeitungs- und Zeitschriftenverlag GmbH & Co. KG, Mediaprint Zeitungsvertriebsgesellschaft mbH & Co. KG and Mediaprint Anzeigengesellschaft mbH & Co. KG*, [1998] ECR I-7791, [1999] 4 CMLR 112.

^c Case C-7/97, [1998] ECR I-7791, [1999] 4 CMLR 112, para.34.

^{ci} Evrard, S.J. 'Essential Facilities in the European Union: *Bronner* and Beyond', 10(3) *Columbia Journal of European Law* (Summer 2004), p.508.

^{cⁱⁱ} [1998] ECR I-7791.

^{cⁱⁱⁱ} *Supra* note 101, pp.491—526.

^{c^{iv}} Case C-82/01 P, [2002] ECR I-9297.

^{c^v} *Ibid*, para.92.

^{c^{vi}} Case 226/84, *British Leyland v Commission* [1986] ECR 3263.

^{c^{vii}} *Supra* note 104, para.93 (emphasis added).

^{c^{viii}} *See* Evrard, SJ, 'Essential Facilities in the European Union: *Bronner* and Beyond', 10(3) *Columbia Journal of European Law* (Summer 2004), pp.508—509.

^{c^{ix}} *Supra* note 104, paras 164—165.

^{c^x} *Ibid*.

^{c^{xi}} [1999] OJ L 69/24-30; Commission Decision 1999/198 of 10 February 1999, relating to a procedure pursuant to Art.8[2] of the EC Treaty, regarding airport charges at Finnish airports. 'At Finnish airports, domestic flights benefited from a discount of 60 per cent as compared with intra-Community flights, for no objective reason. The Commission held that Art.8[2] EC applied to airport operations through Regulation 17/62/EEC rather than through Regulation 3975/87 as amended. There is no justification for the imposition of differentiated landing charges because that would result in applying dissimilar conditions for equivalent landing and take-off services. The Finnish system is therefore discriminatory and distorts competition on the relevant markets, contrary to Art.8[2] EC' (Source: NERA, p.251).

^{c^{xii}} [1995] OJ L 216/8-14; Commission Decision 95/364/EC of 28 June 1995 regarding landing fees at Brussels airport. 'This airport applied a system of stepped discounts, which increases with a high volume of traffic. The charging system at Brussels airport favours airlines with high volume of traffic at Brussels Airport, and places small airlines at a

competitive disadvantage. Hence, Brussels Airport abused its dominant position in the relevant market by introducing the above system of stepped discounts' (Source: NERA, p.251).

^{cxiii} [1999] OJ L 69/31-39; Commission Decision 1999/199/EC of 10 February 1999. This case 'also related to a system of discounts on landing charges in use at Portuguese airports, and the differentiation of those charges according to the origin of flights. The Commission argued that the Portuguese charging system is incompatible with Art.[86](2) read in conjunction with Art.8[2] EC' (Source: NERA, pp.251-252). It should also be noted that CJEU dismissed an action brought by Portugal for annulment of this decision (*See Case C-163/99, [2001] ECR I-2613*).

^{cxiv} It should be noted that, in a number of cases, the Commission has required airlines to give up ('divest') slots in the context of alliances (e.g. *Increase of frequencies on the route London (Heathrow) – Brussels*, Commission Decision 92/552 of 21 October 1992, [1992] OJ L 353/32 (1992); *Lufthansa/SAS*, Commission Decision 96/180 of 26 January 1996, [1996] OJ L 54/28-42; and *Austrian Airlines/Lufthansa*, *See* Commission notice concerning the alliance between British Airways and American Airlines, [1998] OJ C239/10, and also in respect of mergers or take-overs as well (e.g. Case IV/M.0019 – *KLM/Alitalia*, Case M.2041 – *United Airlines/US Airways*).

^{cxv} *Supra* note 113.

^{cxvi} It may be significant to note that the CJEU dismissed an action brought by Portugal for annulment of this decision (*See Case C-163/99, Portuguese Republic v Commission of the European Communities*, [2001] ECR I 2613).

^{cxvii} Whilst it is beyond the scope of this paper, it is worth querying here, with reference to the pending appeal to the Court of Justice in *Greek Lignite*, whether the rarely used Art.106 TFEU (read together with Art.102 TFEU) might offer the Commission yet more discretion to intervene in this area.

^{cxviii} Commission Notice on agreements of minor importance, which do not appreciably restrict competition under Art.81(1) TEC (*de minimis*), OJ C36/13, 22.12.2001; *See also supra* note 10 on two-sided markets.

^{cxix} UK Civil Aviation Authority and Office of Fair Trading, 'Competition issues associated with the trading of airport slots', OFT832 (June 2005), pp.15, 49.

^{cxx} Art.101 TFEU applied to the non-compete clauses in *SAS—Maersk Air* [2001] OJ L265/15, [2001] 5 CMLR 1119.

^{cxxi} Council Regulation (EC) No 1/2003 of 16 December 2002 on the implementation of the rules on competition laid down in Arts 81 and 82 of the Treaty, [2003] OJ L1/1, 04.01.2003, Art.9.

^{cxxii} Noting however that the coordinator must comply with EU law. *See* Article 8(5), Regulation (EC) No 793/2004 of the European Parliament and of the Council of 21 April 2004 amending Council Regulation (EEC) No 95/93 on common rules for the allocation of slots at Community airports, [2004] OJ L138/56, 30.04.2004.

^{cxxiii} 'Commission Staff Working Paper, 'Impact Assessment, Accompanying the document Proposal for a Regulation of the European Parliament and of the Council on common rules for the allocation of slots at European Union airports (Recast)', Brussels, 1.12.2011, SEC(2011) 1443 final, para.46.

^{cxxiv} *Ibid*, para.49.

^{cxxv} For an assessment of the various theories of harm in EU competition law, see Zenger, H and Walker, M, 'Theories of harm in European Competition law: A progress report', (2009), available at <http://ssrn.com/abstract=2009296>.

^{cxxvi} Parliament's Amendments, Art.6, para.1.

^{cxxvii} UK Civil Aviation Authority and Office of Fair Trading, 'Competition issues associated with the trading of airport slots', OFT832 (June 2005), p.20.

^{cxxviii} *Ibid*, p.25.

^{cxxix} Subject to the point raised above on EC discretion and possible joint application of Arts 106(1) and 102 TFEU to find infringement.

The Implications of Market-based Measures on the Mitigation of Aircraft Engine Emissions

Cherie Lu^{1*} and Ming-Tao Chou¹

¹ Department of Aviation and Maritime Management, Chang Jung Christian University, Tainan, Taiwan
No.1, Changda Road., Gueiren District, Tainan City 71101, Taiwan,
Tel: +886-6-2785123 ext 2259, Fax: +886-6-2785056, e-mail: cherie@mail.cjcu.edu.tw

**Corresponding Author*

Abstract

This paper reviews the current applications of market-based measures (MBMs) in the air transport industry worldwide and investigates the differences between, and purposes of, various measures. The current MBMs for mitigating aircraft engine emissions include emission charges, carbon offset and carbon trading. This research aims to investigate the implications of potential MBM schemes on airlines by evaluating the relationship and variation between two data series, namely the carbon trading price and the fuel price. The Vector Autoregressive Moving Average (VARMA) model multivariate time series analysis is applied for investigating the correlation between the carbon trading price and the fuel price. Starting from short term leading or lagging, a one directional - or an interactive - causal relationship could indicate whether a long-term equilibrium exists between these two series. This time series modelling has been developed for evaluating the various variables that influence airline choices in responding to the application of carbon trading schemes. The research results and the suggestions will serve as a good reference for government as well as the industry when facing the global environmental challenges of the move towards sustainable development.

Keywords: Market-based measures, aircraft engine emissions, greenhouse gases, carbon trading and offset, econometric model

1. Introduction

Despite the economic downturn and unexpected drawbacks that have followed it, the air transport industry is still forecast to experience a 5-6% annual growth for the next 20 years, with the Asian markets taking the lead. This growth brings more environmental problems, not only climate change, than ever before. The International Civil Aviation Organisation (ICAO), major international aviation organisations and national governments have stated the importance of market-based measures (MBMs) as one of the policy options for achieving the sustainable development of the industry. These MBMs include environmental charges, taxes, trading, offset and voluntary agreements generally applied at international, national or airport levels, mainly for the purposes of mitigating greenhouse gases (GHGs) emitted from aircraft engines. The ICAO council meeting in October 2010 adopted the development of MBMs for the international industry as one of its first priorities. The implementation of a global MBM is scheduled for 2020.

Many measures have been implemented to mitigate aviation emissions, including improved aircraft engine design, aircraft operations, air traffic management and alternative fuels. Market-based measures (MBMs) are also considered to be one of the effective options (ICAO, 2010; FAA, 2004). MBMs are economic techniques for internalising externalities, with an attempt to bring the market into the path of maximising social welfare. In the context of aviation emissions, charges, taxes, carbon trading and offsets as well as voluntary agreements have already been implemented in various parts of the world. This paper focuses on carbon trading and emission charges, which directly target different emissions from aviation fuel usage and have been widely discussed and applied. It is worth noting that some countries (such as Germany) have implemented taxes on air passengers for environmental purposes, whilst domestic fuel taxes, indirectly targeting emissions, are

imposed in some countries (such as the USA). So far international aviation fuel is exempt from tax by international treaty (Button, 2005). More than 30 airlines in the world offer offset programmes, known as passenger volunteer carbon-offset programmes, to their passengers (IATA, 2009; Eijgelaar, 2011).

Aircraft engine emissions have known impacts on human health, vegetation, materials, the ecosystem and the climate (Lu, 2011). The most notable ones can be considered in two domains: local air quality (LAQ) during landing and take-off (LTO) and climate change during the cruise stage. The exhaust pollutants NO_x , HC (unburnt hydrocarbons) and CO are listed in the ICAO engine certification database (ICAO, 2012). Nevertheless, research has shown that other pollutants such as particulate matter (PM) and SO_x , which are also emitted by aircraft engines, also have impacts on human health (Schipper, 2004; Lu, 2009a). While CO_2 is well known to have a climate change impact, the effects of NO_x on the ozone layer, and of contrails (vapour trails) are also important. Therefore, the issue should be considered geographically from the local, regional and global levels, depending on the transport of various emissions.

At a global or international level, emissions trading or voluntary agreements might be a feasible approach in controlling the total amount of pollutants from aviation activities. The European Union (EU) decided to incorporate the aviation industry in the existing European Union Emissions Trading Scheme (EU ETS) from 2012 onwards, all flights arriving at and departing from Community aerodromes are included (EC, 2009). However, this inclusion has been temporarily suspended depending on the outcome of the ICAO council meeting in 2016.

Some airports have restrictions on the use of aircraft engines, ancillary power units or measures on ground vehicles and energy use in terminal buildings (CEIT, 2009). However, so far, engine emission charges have only been put in place at airports in five countries: Switzerland, Sweden, the United Kingdom, Germany and Denmark (Boeing, 2014). Any emissions charge does not stand alone. In fact, it should be established as a system or mechanism which takes into account the actual environmental costs, their subsequent impact on airline operations and passenger behaviour, as well as the use of the collected revenues to achieve the maximum social welfare objectives.

This paper first reviews aircraft engine emissions charges at airports, airline passenger voluntary carbon offset programs and emission trading mechanisms that have been applied worldwide. Section 3 presents the methodology of the model. Section 4 gives the empirical results of the analysis, followed by conclusions.

2. Overview of the Applications of Market-based Measures for Mitigating Aviation Carbon Emissions

2.1. Aircraft engine emission charges at airports

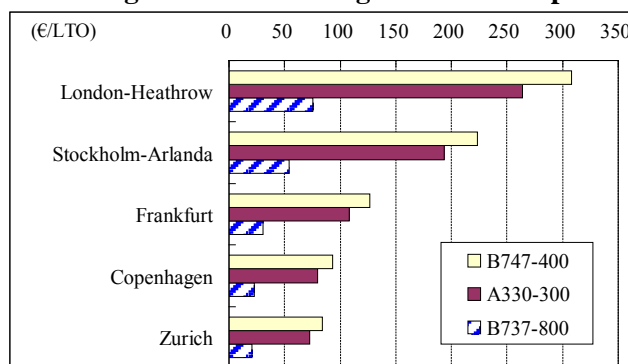
So far there only some airports in Switzerland, Sweden, Germany, the United Kingdom and Copenhagen Airport, that have aircraft engine emission-related surcharges. Swiss and Swedish airports have the longest history of implementing such charges, both since late 1990s. No other airports joined the move until London-Heathrow Airport introduced emission charges in 2004, followed by London-Gatwick in 2005 and Frankfurt in early 2008 (Fleuti, 2007). By mid-July 2011, more German airports and Copenhagen Airport had also introduced aircraft engine emission charges. By March 2014, there are a total of 25 airports in 5 countries with aircraft engine emission charges (Boeing, 2014).

Several different schemes were applied in the earlier stages, but in recent years, all these airports have implemented the same formula for charging aircraft engine emissions, namely the one recommended by European Civil Aviation Conference (ECAC). However, NO_x with an HC emission index as a weighting factor, is the only pollutant that emission charges are based on at all of these airports, with different rates (per kilogram of NO_x during LTO with the ICAO certification LTO modes) applied (ECAC, 2003).

Figure 1 shows the emissions charges on three aircraft types (B747-400, A330-300 and B737-800) at five airports. The unit charge per kilogram of NO_x for these airports vary from €2.00 to €7.31 (£6.09). Amongst the selected airports, London-Heathrow has the highest charges for all aircraft types with around €300 for a

B747-400, €260 for a A330-300 and €75 for a B737-800, followed by Stockholm-Arlanda. Copenhagen and Zurich have the lowest charges at around 25% of Heathrow's. As airports revise their user charges periodically, charge levels and schemes vary according to when research was carried out. For comparison, in 2007 Stockholm-Arlanda had the highest charge level, followed by Zurich, Frankfurt and London-Heathrow (Lu, 2009b). Clearly, London-Heathrow has increased the unit charge per kilogram of NO_x greater than other airports in recent years.

Fig 1. Comparison of aircraft engine emission charges at five European airports (as of April 2011)



The revenues collected from these emission charges are generally earmarked for investment-related emission mitigation purposes. In the case of Zurich Airport, the revenue from the aircraft engine emission charges is around 2.0-3.2 million euros. This used to be around 5.0% of the total landing charges, but has now reduced to around 3.7% (Zurich Airport, 2010). The revenue is solely used for improving air quality, including:

- The air quality monitoring system at and around the airport;
- The analysis of dispersion model and an inventory of GHGs;
- The provision of ground power units for aircraft on aprons;
- The installation of compressed natural gas stations for airside vehicles and equipment;
- Construction of speed taxiways to improve the aircraft taxiing efficiency;
- Research and development in air quality management.

2.2. Airline passenger voluntary carbon offset programs

More than 30 airlines in the world have implemented a passenger voluntary carbon offset program. The amount of carbon emissions per flight varies according to flight distance, aircraft types and payload etc. Passengers can choose to pay an extra charge to compensate for their share of the carbon emitted by their particular flight. Table 1 lists examples of some airlines in the world that run a carbon offset scheme.

Table 1. Examples of Airlines with passenger voluntary carbon offset programs in the world

Region	Airlines
Asia and Oceania	• All Nippon Airways, Cathay Pacific, Japan Airlines, Malaysia, Air New Zealand, Qantas, Dragonair
Europe	• Air France, Austrian, British Airways, Air France, Austrian, Blue1, Brussels Airlines, Iberia, KLM, Lufthansa, Scandinavian Airlines, Spanair, SWISS, TAP Portugal, Virgin Atlantic Airways
North America	• Air Canada, United
Africa	• Kenya Airways

Source: Airline websites

It can be seen that there are more European airlines with carbon offset schemes, followed by Asian airlines. Table 2 lists the carbon counts for economy, business/first class passengers for selected airlines - Cathay Pacific, Japan Airlines and Lufthansa - and the carbon counts estimated by the ICAO carbon emissions calculator. Table 2 shows that there is not much difference between economy and business classes for short and medium hauls, but the CO₂ emitted has increased significantly for long haul flights. In terms of the unit

carbon price, Japan Airlines has the highest level at €50/tonne, compared with the lower level of €7/tonne for the case of Cathay Pacific.

Table 2. Carbon offset comparison of three airlines and ICAO (as of June 2013)

Flight	Organisation	Seating Class	CO ₂ (kg)	Carbon offset (TWD)	CO ₂ unit price (TWD/kg)
One way short-haul Taipei to Hong Kong	ICAO	Economy	98	-	-
		Business	98	-	-
	Cathay Pacific	Economy	70	19	0.27
		Business	110	29	0.26
	Lufthansa	Economy	137	116	0.85
		Business	205	155	0.76
	Japan Airlines	Economy	190	386	2.03
		Business	190	386	2.03
One way medium-haul Taipei to Tokyo Narita	ICAO	Economy	187	-	-
		Business	187	-	-
	Cathay Pacific	Economy	200	52	0.26
		Business	300	77	0.26
	Lufthansa	Economy	240	194	0.81
		Business	361	272	0.75
	Japan Airlines	Economy	289	588	2.03
		Business	289	588	2.03
One way long-haul Taipei to Los Angeles	ICAO	Economy	780	-	-
		Business	1,561	-	-
	Cathay Pacific	Economy	1,080	281	0.26
		Business	1,620	422	0.26
	Lufthansa	Economy	1,120	853	0.76
		Business	1,680	1,319	0.79
	Japan Airlines	Economy	1,223	2,486	2.03
		Business	2,446	4,872	2.03

Source: Compiled from airlines' websites

2.3. Emission trading in different regions of the world

A few countries and regions in the world have implemented various forms of emission trading scheme as a means of mitigating the impacts of carbon emissions. The schemes, such as those in the United Kingdom, Japan, New Zealand and China, generally involve different domestic industries (ICAO, 2010). Australia imposed a carbon tax in July 2012 as a step towards implementing a carbon trading scheme in the near future. The European Union Emission Trading Scheme (EU ETS), which started in 2005, has dominated the attention of the international aviation industry, as the European Commission decided to include international aviation in the existing EU ETS from 2012 (EC, 2009). This involves imposing a cap on CO₂ emissions from all international flights that depart from or arrive at an airport within the European Union, to or from anywhere in the world. However, due to opposition from airlines and some countries in different parts of the world, high expectation has been placed on ICAO to find a unified global MBM. In order not to get involved in these questions, this paper aims to examine the characteristics and impacts of trading schemes, rather than their political aspects.

3. The Vector Autoregressive Moving Average (VARMA)

For econometric analysis tools, the analysis of time series plays a significant role (Hansen and West, 2002; Hamilton, 1994). The Vector Autoregressive Moving Average (VARMA) has been applied in a significant number of studies (Bohara and Sauer, 1990; Kascha and Mertens, 2009; Chou and Huang, 2010; Chou, 2011; Chou et al., 2012). This research will apply the VARMA model to investigate the dynamic relationship between the carbon trading price and the aviation fuel price index in order to understand potential airline

behaviour in response to the application of carbon offset and carbon trading schemes.

We assume the carbon price and the fuel index series as a stationary series. If the VARMA model is VARMA(1,1), then $\phi(B)Z_t = C + \theta(B)a_t$ can be simplified as:

$I - \phi(B)Z_t = (I - \theta(B))a_t$, of which a formula of matrix and vectors is as Eq. 1:

$$\left(\begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix} - \begin{bmatrix} \phi_{11} & \phi_{12} \\ \phi_{21} & \phi_{22} \end{bmatrix} B \right) \begin{bmatrix} \text{Carbon price}_{1t} \\ \text{Fuel index}_{2t} \end{bmatrix} = \left(\begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix} - \begin{bmatrix} \theta_{11} & \theta_{12} \\ \theta_{21} & \theta_{22} \end{bmatrix} B \right) \begin{bmatrix} a_{1t} \\ a_{2t} \end{bmatrix} \quad (1)$$

In this formula, $\phi(B) = 1 - \phi_1 B - \dots - \phi_p B^p$, $\theta(B) = 1 - \theta_1 B - \dots - \theta_q B^q$ are matrix polynomials of B , ϕ and θ are $k \times k$ matrices, C is $k \times 1$ fixed value vector, a_t is random vibration vector of a series of independent normal distribution with zero average value. The covariance matrix is Σ and the constant vector C is regarded as constant C , which can be demonstrated as $C = (I - \phi_1 - \phi_2 - \dots - \phi_p)\mu$, parameters ϕ_{ij} and θ_{ij} can be illustrated as the manner in which series i is affected by series j .

Macroeconomic variables are predominately non-stationary series, and the series which will be analysed in this research is also a macroeconomic variable. Therefore, prior to estimation using the VARMA model, we must first conduct a unit root test for each variable, and confirm that both the carbon price and the fuel index can pass the process of unit root test and are stationary series. Once the series are confirmed to pass the unit root test, we can then examine the causal relationship of the two sets of series; otherwise, we only can test whether a co-integration effect exists between the two variables (Engle and Granger, 1987). The co-integration effect illustrates that the regression relationship between non-stationary variables may also cause a false causal relationship, and therefore conclusions may be incorrectly drawn. If the carbon price and the fuel index series are non-stationary, there would be a need to convert them into a stationary series. If the original series appears stationary after p times of finite difference, we can then call this series a co-integration with p steps, which can be written $I(p)$. Consequently, after p ($p > 0$) steps co-integrating the non-stationary variables, namely the carbon price and the fuel index, we can then refer to the carbon price and the aviation fuel series as p steps p times co-integration, with a symbol $CI(p, p)$.

Once the carbon price and the fuel index series can be proved stationary, we can then conduct analysis on their causal relationship. The order of VARMA model for the carbon price and the fuel index series can be measured as the best candidate model through SCAN (the smallest canonical), which is derived from Partial Autoregression (PAR). The SCAN method provides an easier method of deciding the most suitable candidate model than PAR (Liu et al. 2004, 2005; Chou and Lin, 2010). This research will therefore apply the SCAN method to test the suitable steps of VARMA, and to seek necessary information.

4. Empirical Analysis

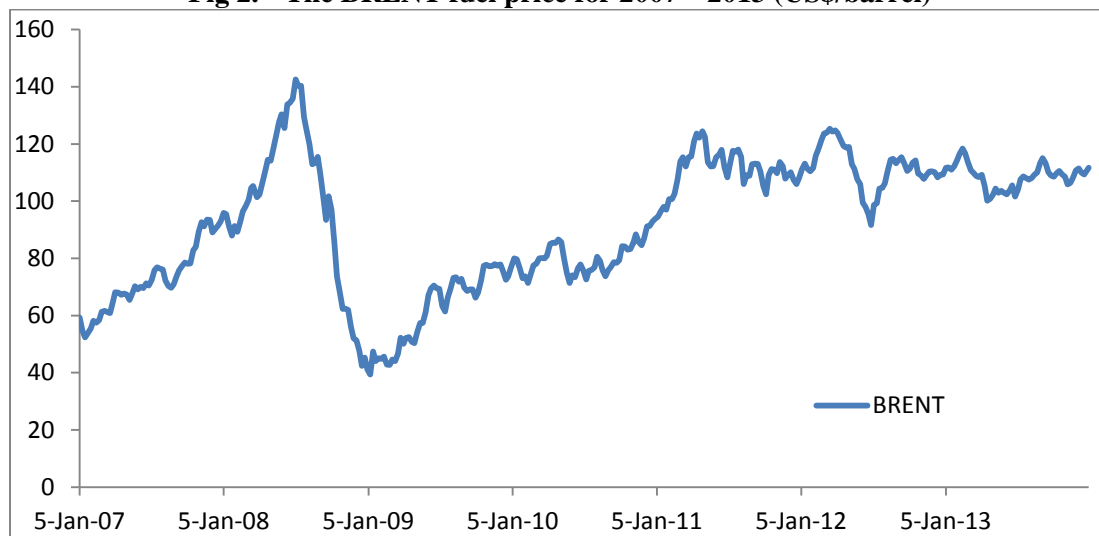
This paper employs the VARMA model to construct a dynamic model between the carbon price and the aviation fuel index to conduct its analysis. Since the main purpose is to understand the relationship between various variables in the system, this model can address the shortcomings of the univariate time series, and can analyze whether a feedback relationship exists between the series (Hamilton, 1994). The VARMA model is able to collect more knowledge on this relationship and collectively develop models which can obtain information from a related series, thereby effectively constructing a dynamic relationship among the variables and improve forecasting accuracy.

There are various carbon trading markets in the world, such as the European Climate Exchange (known as ICE Europe), the Chicago Climate Exchange (CCX), the UK Emissions Trading Group (ETG), the Australian Climate Exchange (ACX) and the China Tianjin Climate Exchange (TCX) etc.

This research uses the historical Brent fuel price (BRENT) (Figure 2) and carbon trading price (EAU) from ICE Europe (Figure 3) as the two major data sources for VARMA analysis. The research collected the

BRENT and EAU weekly data series for the total time period of 6 years from 5th January 2007 to 31st December 2013, with a total of 365 data sets. The BRENT trend shown in Figure 2 has an average of 92.172 with a standard error of 23.938 (min 39.400, max 142.540). Figure 3 shows the trend of EAU and an average of 14.298 with a standard error of 6.420 (min 3.130, max 30.550).

Fig 2. The BRENT fuel price for 2007 – 2013 (US\$/barrel)



Source: ICE, 2014

Fig 3. The EAU trend for 2007 – 2013 (euros/tonne)



Source: ICE, 2014

4.1. BRENT and EAU unit root test

Macroeconomic variables are generally not static series. As both BRENT and EAU are considered as macroeconomic variables, there is a need to conduct a unit root test to understand whether both indices are static series. Before running the VARMA model, the Augmented Dickey-Fuller (ADF) unit root test was conducted. The results, shown in Table 3, suggest that the two data series were discovered to be stationary with a first differential order within the 1% significance level, despite the fact that the original series did not pass the test. However, this concludes that the BRENT and EAU series have a long-term equilibrium relationship (Engle and Granger, 1987).

Table 3. BRENT and EAU unit root test results

ADF test	Original series	First differential order
BRENT	-2.035	-15.237***
EAU	-1.786	-14.017***

Note: The criteria for the ADF unit root test ADF within 1%, 5% and 10% significant levels are -3.448, -2.869 and -2.571 respectively, which are denoted as ***, ** and *.

4.2. VARMA analysis of BRENT and EAU

This paper uses SCAN to analyze the VARMA model. Table 4 shows the SCAN chart with the vertical axis for the differential order of P and the horizontal axis for the differential order of Q. The most appropriate differential order of VARMA is revealed when both orders are vertically intercepted with P and Q at the first differential order. Table 4 illustrates that VARMA (1,1) is the best model for BRENT and EAU.

Table 4. Results of SCAN Analysis

P	Q	0	1	2	3	4	5	6
0		X	O	X	O	O	O	X
1		X	O	O	O	O	O	O
2		X	O	O	O	O	O	O
3		X	O	O	O	O	O	O
4		O	O	O	O	O	O	O
5		X	O	O	O	O	O	O
6		X	O	O	O	O	O	O

The method of maximum likelihood estimation (MLE) is used for the evaluation of VARMA, with the insignificant parameters set to be zero. Under the matrix model Eq. 2, the BRENT and EAU are inter-related. The modelling results show that a relationship exists between BRENT and EAU in both directions. BRENT is influenced by its previous price level and the EAU price. However, if the significance level is increased to 1%, shown as the matrix model Eq. 3, only the previous series might have influence on later ones for BRENT, but there is no clear relationship between BRENT and EAU. This is due to the fact that the EAU level has been decreasing over the past few years with huge variance for the time period of 2007 – 2013, whilst the BRENT index is still quite high.

$$\begin{bmatrix} BRENT_t \\ EAU_t \end{bmatrix} = \begin{bmatrix} 0.000 \\ (0.000) \\ -0.001 \\ (0.002) \end{bmatrix} + \begin{bmatrix} 0.892 & 0.010 \\ (0.067) & (0.011) \\ -0.341 & 0.011 \\ (0.739) & (0.067) \end{bmatrix} \begin{bmatrix} BRENT_{t-1} \\ EAU_{t-1} \end{bmatrix} + \begin{bmatrix} a_{BRENT_t} \\ a_{EAU_t} \end{bmatrix} - \begin{bmatrix} 0.810 & -0.004 \\ (0.089) & (0.004) \\ -1.311 & 0.863 \\ (1.005) & (0.040) \end{bmatrix} \begin{bmatrix} a_{BRENT_{t-1}} \\ a_{EAU_{t-1}} \end{bmatrix} \quad (2)$$

$$\begin{bmatrix} BRENT_t \\ EAU_t \end{bmatrix} = \begin{bmatrix} 0.000 \\ (0.000) \\ -0.001 \\ (0.001) \end{bmatrix} + \begin{bmatrix} 0.853 & 0 \\ (0.093) & 0 \\ 0 & 0 \end{bmatrix} \begin{bmatrix} BRENT_{t-1} \\ EAU_{t-1} \end{bmatrix} + \begin{bmatrix} a_{BRENT_t} \\ a_{EAU_t} \end{bmatrix} - \begin{bmatrix} 0.746 & 0 \\ (0.119) & 0.841 \\ 0 & (0.027) \end{bmatrix} \begin{bmatrix} a_{BRENT_{t-1}} \\ a_{EAU_{t-1}} \end{bmatrix} \quad (3)$$

On the other hand, the authors have used the data from January 2006 to January 2013 for the same analysis. The modelling results show that a relationship exists between BRENT and EAU in both directions. BRENT is influenced by its previous price level and the EAU price, as well as the previous level of EAU corrected factors. EAU is influenced by its previous level and the BRENT level as well as the previous level of BRENT corrected factors. Both BRENT and EAU exert directional influence of each other. On first examination this result appears to be contrary to what was expected: an increase in fuel price should encourage economizing measures from oil consumers, thereby reducing consumption and creating a glut of carbon permits, thus reducing the price of these. On the other hand, such economic measures will also have a downward effect on the oil price itself for the same reason.

5. Conclusions

A review has been undertaken of aircraft engine emission charges, airline carbon offset and emission trading measures employed in the aviation industry. There is a factor of 7 difference between the highest and lowest charge per kg of carbon in the offset schemes studied.

Through application of the VARMA model, there is no clear relationship found between the Brent oil price index and the EU climate exchange carbon trading price for six years of data from 2007-2013. The reason is mainly due to the economic downturn from 2008 onwards, resulting in less fuel consumption and higher carbon quota than the industry needs (Haita, 2013).

Acknowledgements

The authors would like to thank Taiwan Ministry of Science and Technology for its research grant which has allowed this paper to be produced.

References

- Boeing's website: <http://www.boeing.com/commercial/noise/list.html> (Accessed on March 2014).
- Bohara, A.K. and Sauer, C. (1990), A VARMA analysis of German money and income data: Fixed versus flexible exchange rates, *Review of World Economics* 126(3): 456-473.
- Button, K. (2005), The taxation of air transportation, Working paper, George Mason University.
- CE Delft (2008), Lower NOx at higher altitudes: policies to reduce the climate impact of aviation NOx emission, Delft, the Netherlands.
- CEIT (2009), AIRCLIP: airports and climate preservation, A research study within TAKE OFF, funded by Federal Ministry for Transport, Innovation and Technology, established by Central European Institute of Technology, Austria.
- Chou, M.T. and Huang, B.C. (2010), An analysis of the relationship between forward freight agreements and steel price index - An application of the vector ARMA model, *African Journal of Business Management* 4: 1149-1154.
- Chou, M.T. and Lin, S.C. (2010), An analysis of the relationships between baltic dry index and steel price index- An application of the vector AR model, *Journal of the Chinese Institute of Transportation* 22: 211-232.
- Chou, M.T., Yang, Y.L. and Chang, S.C. (2012), A Study of the Dynamic Relationship between Crude Oil Price and the Steel Price Index, *Review of Economics and Finance* 5: 30-42.
- Chou, M.T. (2011), Research on the relationship between forward freight agreements and the fuel oil index, *African Journal of Business Management* 5: 8033-8040.
- ECAC (2003), NOx emission classification scheme, Recommendation ECAC/27-4, European Civil Aviation Conference, Brussels.
- European Commission (2009), Directive 2008/101/EC of the European Parliament and of the Council of 19 November 2008 amending Directive 2003/87/EC so as to include aviation activities in the scheme for greenhouse gas emission allowance trading within the Community, *Official Journal of the European Union*, L31.2009.
- Eijgelaar, E. (2011), Voluntary carbon offsets a solution for reducing tourism emissions? Assessment of communication aspects and mitigation potential, *European Journal of Transport and Infrastructure Research* 11: 281-296.
- Engle, R.F. and Granger, C.W.J. (1987), Cointegration and error correction Representation, estimation and testing, *Econometrica* 55: 251-276.
- FAA (2004), Aviation and the environment: a national vision framework for goals and recommended actions, Report to the United States Congress, Federal Aviation Administration, December, the United States.
- FAA (2012), Aviation environmental and energy policy statement, Federal Aviation Administration, the United States.
- Fleuti, E. (2007), Local emission charges in Europe, Presented at ICAO colloquium on aviation emissions with exhibition, May, Montreal.

- Kascha, C. and Mertens, K. (2009), Business cycle analysis and VARMA model, *Journal of Economic Dynamics and Control* 33(2): 267-282.
- Hansen, B. E. and West, K. D. (2002), Generalized method of moments and macroeconomics, *Journal of Business and Economic Statistics* 20: 460-469.
- Haita, C. (2013), The state of the EU carbon market, *International for Climate Governance*.
- Hamilton, J. D. (1994), *Time Series Analysis*, Princeton University Press: 291-350.
- IATA (2009), A global approach to reducing aviation emissions: first stop: carbon-neutral growth from 2020, International Air Transport Association.
- ICAO (2012), ICAO aircraft engine emissions databank, International Civil Aviation Organisation. <http://easa.europa.eu/environment/edb/aircraft-engine-emissions.php> (Accessed on September 2012).
- ICAO (2010), ICAO environmental report 2010 – Aviation and climate change, International Civil Aviation Organisation, Montreal.
- Liu, L. M., Hudak, G. B., Box, G. E. P., Muller, M. E. and Tiao, G. C. (2004), Forecasting and time series analysis using the SCA statistical system, *Scientific Computing Associates Corporation* 1: 44-46.
- Liu, L. M., Box, G. E. P. and Tiao, G. C. (2005), Forecasting and time series analysis using the SCA statistical system. *Scientific Computing Associates Corporation* 2: 4-11.
- Lu, C. (2011), The economic benefits and environmental costs of airport operations: The example of Taiwan Taoyuan International Airport, *Journal of Air Transport Management* 17: 360-363.
- Lu, C. (2009a), The implications of environmental costs on air passenger demand for different airline business models, *Journal of Air Transport Management* 15: 158-165.
- Lu, C. (2009b), Climate change and aviation – 9: Aviation and economic development: The implications of environmental costs on different airline business models and flight networks, edited by Stefan Gossling and Paul Upham, 193-220, ISBN-10: 1844076202, Earthscan.
- Schipper, Y. (2004), Environmental costs in European aviation, *Transport Policy* 11: 141-154.
- Zurich Airport (2010), Aircraft emission charges Zurich Airport, July, Switzerland.

Investigating International Forwarders' Preferences toward Air Cargo Services and Their Purchasing Behavior

Jin-Ru Yen*, Tsung-Sheng Liang, Chia-Ping Tsou and Chia-Yu Li

Department of Shipping and Transport Management, National Taiwan Ocean University, Keelung, Taiwan.

Email: jinruyen@gmail.com

**Corresponding Author*

Abstract

According to ACI's survey, the growth of global air cargo from years 2010 to 2012 is only one million tons. The growth rate is just 0.2% in 2011, lower than the growth rate in the past. The air cargo market faces a short saturation. When airlines do not expect an optimistic air cargo market in the near future, they tend to allocate more resources to maintain existing customers rather than to develop new markets. Therefore, it is essential for airlines to understand their customers' preferences toward air cargo services. This study will survey air cargo forwarders who are operating in five major regions (China, Northeast Asia, Southeast Asia, North America and Europe) to elicit their preferences toward air cargo services provided by one major airline based in East Asia. Five items (fare, space, flight stability, services and network) are used to represent forwarders' preferences. Respondents are clustered by their regions to investigate any differences and similarity among different clusters. Additionally, the reason that forwarders would like to continue cooperating with the airline is cross-tabbed with their preferences to get insight into how preferences affect forwarders' purchasing behavior.

Keywords: air cargo service; cluster; global air cargo carrier.

1. Introduction

According to ACI's survey, the growth of global air cargo from years 2010 to 2012 is only one million tons (ACI, 2012). The growth rate is just 0.2% in 2011, lower than the growth rate in the past. The air cargo market faces a short saturation. When airlines do not expect an optimistic air cargo market in the near future, they tend to allocate more resources to maintain existing customers rather than to develop new markets. As air cargo market faces a short saturation, airlines need to find a way out to increase their competitiveness. It is essential for airlines to understand their customers' preferences toward air cargo services.

Various factors that have a bearing on air freight services have been identified in the literature. For example, Farshid et al. (2012) demonstrate that dynamic routing with real-time information can improve delivery reliability and reduce expected costs. Additionally, the relationship between airline services and customer satisfaction has also been addressed. Hsu (2006) shows that airline cargo service quality has a positive influence on customer (forwarder) satisfaction and customer satisfaction had a positive influence on his/her loyalty. Therefore, how to make customers (forwarder) feel satisfied is an important issue for airlines to increase competitiveness. Maarten and Verbeeten (2014) indicate that customer satisfaction is a value driver; however, customer satisfaction is not cost-free and managers have to consider the costs, as well as the benefits, of increasing customer satisfaction.

To increase customer satisfaction, it is very important for airlines to understand the preferences of their customers. Meng et al. (2010) indicate that airlines have five key service criteria of importance: delivery value, knowledge innovation value, service value-added, information value, and performance satisfaction value. They also mention four key customer satisfaction factors: reliability, agility, customization, and flexibility. Liu (2008) indicates that the 'quality and efficiency of export cargo' is the most important factor to be considered by managers of both terminal operators and freight forwarders. Chen (2007) reveals that the following five

items of service quality need to be urgently improved: complete information system, service personnel's specialized ability, variety of services, capability of tracing goods, accurate flight schedules.

This study will survey air cargo forwarders who are operating in five major global regions (China, Northeast Asia, Southeast Asia, North America and Europe) to elicit their preferences toward air cargo services provided by one major airline based in East Asia. The target airline uses five items to represent forwarders' preferences, namely fare, space, flight stability, services and network. According to the experiences of the target airline, these five categories seem to work well in defining forwarders' preferences.

Fare is one of the major factors that influence the forwarder's costs; therefore the flexibility/discount of fare affects a forwarder's choice about carriers. For example, if airlines offer forwarders with long-term relationships a good price, they would be more willing to maintain the cooperation with airlines. Space means how much capacity airlines can offer when forwarders are looking for a space for their shippers. There are two ways to offer enough capacity: size of fleet and optimum deployment. Flight stability is a measure to show that flights offered by airlines can be implemented as scheduled. An airline with good flight stability can make sure that cargo can be delivered to destinations on time. Service includes reservation services and transport services. Reservation services indicate that airlines' staff take responsibility for customer order and arrange capacity for forwarders. Transport services are the process of delivery cargo to the destination, including loading, unloading, transshipment, and so on. Network is an airline's ability to deliver cargo to specific destinations requested by shippers. Different airlines offer services to different destinations. The more destinations an airline can serve, the more forwarders she can attract.

Respondents are clustered by their regions to investigate any differences and similarity of their preferences among different clusters. Additionally, the reason that forwarders would like to continue cooperating with the airline is cross-tabled with their preferences to get insight into how preferences affect forwarders' purchasing behavior. The results of this study can provide global air cargo carriers useful information to improve their services in various regions.

An explanation of how the sample is obtained is presented in the next section. The third section analyzes those obtained data with descriptive statistics and discusses their empirical implications. The final section concludes this research.

2. Sampling and Questionnaire Design

The survey was conducted through on-line questioners in June and December 2013. An email was sent to each sampled forwarder of the target airline to ask the forwarder to fill our questionnaire on a specific website. More than two thousand emails were sent out and about one thousand effective questionnaires were received, giving an overall response rate of about 50.0%. The exact number of sampled respondents is not provided in this paper in order to avoid the identification of the target airline. The sampling was clustered on the basis of five service areas provided by the airline: China (CH), Northeast Asia (NE), Southeast Asia (SE), North America (NA) and Europe (EU).

Two sets of questions were included in the questionnaires. The first one asked the forwarder to choose the most satisfied and unsatisfied factors provided by the airline of interest. The second one asked forwarders whether or not they would like to cooperate with the airline in the future. The respondents were also asked to choose a factor from the previously mentioned five ones, i.e. fare, space, flight stability, service and network, for their decisions.

3. Analysis

This section conducts three types of analysis. The first one investigates the most satisfied factor chosen by forwarders, based on their business with the airline of interest. The second one analyzes the reason why forwarders are willing to maintain cooperation with the airline. At the end, the reason that forwarders would like to continue cooperating with the airline is cross-tabled with their preferences to get insight into how preferences affect forwarders' purchasing behavior.

3.1 *The most satisfied factor*

This section shows the result of forwarders' most satisfied factor. As indicated in table 1 and figure 1, the percentage of sampled forwarders that chooses service as the most satisfied factor is the highest one in each geographical area. This implies that service, relatively speaking, is the most important competitiveness of the target airline in all regions. Differences, however, exist in the second factor among different regions. In China, forwarders label space as the second satisfied factor. Recently, China becomes more open in her air cargo market and there are many destinations that are accessible by air services. The airline of interest now provides a lot of space for forwarders to book. In Northeast Asia, the second satisfied factor is network. Traditionally, NE is the gateway between Asia and other regions such as NA, India, and Middle East. Airlines that serve NE usually provide more destinations for forwarders to choose. Therefore, the factor of connectivity becomes the second satisfied factor in NE. For the target airline fare is the least satisfied factor in both CH and NE. This is not the case in other regions. Fare has been chosen as the second satisfied factor in SE, NA and EU. Interestingly, fare has been the most important competitive issue in these regions due to various reasons. In SE this is because of severe competition. In the markets of NA and EU, fare competition results from Trade imbalance. As indicated in table 1, the target airline's competitiveness in fare in these three regions is better than in CH and NE, relatively speaking.

Table 1. Forwarders' most satisfied factor with the airline

Area	Fare (%)	Space (%)	Stability (%)	Service (%)	Network (%)	Others (%)	Total (%)
CH	7.7	15.0	13.1	56.6	5.8	1.8	100.0
NE	9.1	12.5	9.1	51.1	17.0	1.1	100.0
SE	21.8	7.9	9.4	55.9	4.8	0.3	100.0
NA	13.5	3.5	6.5	74.7	1.2	0.6	100.0
EU	11.6	5.7	11.5	63.2	6.9	1.1	100.0
Total	12.7	8.9	9.9	60.3	7.1	0.9	100.0

3.2 *The reason why forwarders are willing to maintain cooperation with the airline*

This section investigates the reason why forwarders are willing to maintain cooperation with the airline of interest. As indicated in the last row of Table 1, the major reason for the forwarder's decision of continue cooperating with the airline is service (40.7%), which is followed by fare (23.3%), space (13.5%), stability (11.8%), and network (8.8%), from high to low respectively. The diversity of answers is evident with the fact that no single factor represents the choice of more than 50% of the total sample. Among all factors, service is the one that more forwarders consider as the reason for maintaining cooperation with the airline. One reason for this result might relate to its wider range of coverage which includes the delivery service and staff service. Another reason might be that forwarders are extremely sensitive to the condition of their cargo and the staff they encounter while using air cargo services. The attitude and proficiency of airline staff will directly affect the feeling of forwarders. Additionally, by examining whether or not a shipment arrives on time with required conditions forwarders can judge the quality of services provided by airlines. As a result, these reasons can explain why service is considered by more forwarders when they make a decision to continue doing business with the airline of interest.

Except for service, fare is another factor that is chosen by about a quarter of the sample. Forwarders collect a large amount of cargo and book the space in lower prices and charge customers at a higher rate to make a profit. Therefore, the fare level will affect the profits of forwarders and is considered as a non-ignorable factor. In the current air cargo market, each airline still charges differently for the same origin-destination service even though IATA (2014) has announced the TACT Rule as a reference. The fare involved trade secrets so that no one published the rate to public. For this reason, forwarders must care fare charged by the airline and query each airline under consideration.

It is possible that forwarders in different regions have different reasons for continue cooperating with the target airline. This issue is also illustrated in Table 2. In each region, service is the major factor that

forwarders are willing to maintain cooperation with airlines. However forwarders in different regions have different opinions on the secondary factor. In SE, NA and EU, the secondary factor is fare. On the other hand, in CH and NE the factors are space and network, respectively.

More forwarders in SE, NA, and EU consider fare as the reason for decision to continue doing business with the airline than forwarders in other regions. As mentioned in section 3.1, this implies that relatively the target airline's competitiveness in fare in these three regions is better than in CH and NE. Huge demand in important/export market in SE causes strong competition. Airlines must provide lower prices for forwarders to obtain better market share. As indicated in section 3.1, fare competition in NA and EU results from Trade imbalance. More air cargo is shipping from East Asia to NA and EU than the other way.

Forwarders in China choose space as the secondary factor. Due to the continuous growth in economy and her open policies in air transportation, China's market of air cargo continues to grow and there are many destinations accessible by air services. The airline of interest now provides a lot of space for forwarders and maintains her competitiveness in space.

The main reason that the target airline maintains her competitiveness in network in NE is that the long-haul services from NE to NA and EU are not adequate. For example, Japan only operates short-haul freighter routes in NE. Only Northeast China, South Korea and Taiwan provide long-haul routes to NA and EU. Northeast China re-exports air cargo to EU via Russia, South Korea has some destinations in South America and Taiwan has more destinations in NA.

Table 2. Forwarders' preferences of maintaining cooperation with the airline

Area	Fare (%)	Space (%)	Stability (%)	Service (%)	Network (%)	Others (%)	Total (%)
CH	14.0	14.4	11.4	52.2	5.0	3.0	100.0
NE	13.1	19.0	14.3	31.0	21.4	1.2	100.0
SE	29.3	11.3	6.6	46.3	6.0	0.6	100.0
NA	30.2	10.2	16.1	36.1	5.9	1.5	100.0
EU	30.1	12.6	10.7	37.9	5.8	2.9	100.0
Total	23.3	13.5	11.8	40.7	8.8	1.8	100.0

3.3 Cross tabulation analysis

The section of 3.1 investigates forwarders' most satisfied factors with the target airline and section 3.2 analyzes reasons that forwarders are willing to maintain cooperation with the airline. As indicated in Table 1 and 2, results from both sections are very similar. This leads us a reasonable hypothesis that a forwarder's satisfaction with a specific factor might affect her reason for maintaining cooperation with the airline of interest. This section conducts a cross tabulation analysis (CTA) to validate the hypothesis. To take the diversity of geographical locations into account, the CTA is conducted for each region. Since the sample size is only about 1000, which is not enough when divided into five regions, two actions have been taken to avoid violating the assumption of normal distribution as made by the standard chi-square test. First, reasons why forwarders are willing to maintain cooperation with the airline are divided into two categories, "service" and "others," as shown in the first column of tables 3.1 to 3.5. "Service" consists of respondents who choose service as their reason, and "others" contains respondents who choose all other reasons. Secondly, the Fisher's Exact Test is used, which is based on the assumption of Binomial distribution. Results of the CTA of each region are shown from tables 3.1 to 3.5, which are then summarized in table 3.6.

As shown in Tables 3.1 to 3.6, the null hypothesis that forwarders' reason for continuing cooperating with the target airline is independent from their most satisfied factor is rejected in the regions of CH, NE, SE, and NA, when the level of significance being set at 0.2 (Tables 3.1, 3.2, 3.3, and 3.4). It indicates that forwarders' most satisfied factor will affect their reason for continuing cooperating with the target airline. For example, Table 3.1 reveals the result of CTA in China. Among respondents who choose the reason to continue as "service,"

about 62.2% indicate that service is the most satisfactory factor, which is greater than the number (50.4%) among respondents who choose the reason to continue as "others."

Conversely, the satisfied factor of forwarders in EU does not affect their reasons for the continued cooperation with the target airline. In Table 3.5, for example, the difference between the percentage of forwarders who choose "service" as their reason for keep cooperation and are most satisfied with service (59.4%), and the percentage of forwarders who choose "others" as their reason and are most satisfied with service (65.5%) is not statistically significant.

For the target airline, this information will help her to increase the effectiveness of investment and reduce the chances of a wrong investment. Therefore, it is more likely for the airline to make an efficient investment with limited resources. In this study, investigation results reveal that forwarders' most satisfied factors and their reasons for continuing cooperating with the airline are relevant in China, Northeast Asia, Southeast Asia and North America. Thus, if the target airline can keep the most satisfied factor (service in this study), she will maintain the cooperation with forwarders in these four regions. In Europe, the most satisfied factors of the forwarders do not interact with the reasons for continued cooperation with the airline. A further study is necessary to get insight into the relationship between forwarders' preferences and their behavior after purchasing and using air cargo services.

The relationship between forwarders' preferences and their willingness to continue cooperating with the target airline is further validated by the analysis shown in Table 4. In Table 4, forwarders who refuse to continue cooperating with the airline of interest are cross-tabulated with respect to their most satisfied factor. The null hypothesis is rejected at the level of significance being set as 0.1. This again implies that forwarders' reason for not willing to maintain cooperation with the airline interact with their most satisfied factor. Results of analysis indicate that the distribution of choosing "service" and "others" as their refusing reason appears different. The percentage of forwarders who choose "service" for refusing reason and feel service as the most satisfied factor (50.0%) is lower than the percentage of forwarders who choose "other" for refusing and feel service as the most satisfied factor 69.2%). It shows that forwarders who refuse to maintain cooperation because of "service" feel less satisfied in service at the same time.

Table 3.1 Cross tabulation analysis of CH

		Most Satisfied Factors (%)						Total
		Fare	Space	Stability	Service	Network	Others	
Reason to continue (%)	Service (52.2)	5.6	14.7	13.3	62.2	2.8	1.4	100.0
	Others (47.8)	9.9	15.3	13.0	50.4	9.2	2.3	100.0
Total		7.7	15.0	13.1	56.6	5.8	1.8	100.0

Fisher's Exact Test: Value is 8.427. Exact Significance (2-sided) is 0.128.*

Table 3.2 Cross tabulation analysis of NE

		Most Satisfied Factors (%)						Total
		Fare	Space	Stability	Service	Network	Others	
Reason to continue (%)	Service (30.7)	11.1	3.7	11.1	66.7	7.4	0.0	100.0
	Others (69.3)	8.2	16.4	8.2	44.3	21.3	1.6	100.0
Total		9.1	12.5	9.1	51.1	17.0	1.1	100.0

Fisher's Exact Test: Value is 7.144. Exact Significance (2-sided) is 0.181.*

Table 3.3 Cross tabulation analysis of SE

		Most Satisfied Factors (%)						Total
		Fare	Space	Stability	Service	Network	Others	
Reason to continue (%)	Service (53.5)	17.5	4.5	9.6	64.4	3.4	0.6	100.0
	Others (46.5)	26.6	11.7	9.1	46.1	6.5	0.0	100.0
Total		21.8	7.9	9.4	55.9	4.8	0.3	100.0

Fisher's Exact Test: Value is 15.8666. Exact Significance (2-sided) is 0.004.*

Table 3.4 Cross tabulation analysis of NA

		Most Satisfied Factors (%)						Total
		Fare	Space	Stability	Service	Network	Others	
Reason to continue (%)	Service (41.2)	11.4	0.0	10.0	77.1	1.4	1.4	100.0
	Others (58.8)	15.0	6.0	4.0	73.0	1.0	1.0	100.0
Total		13.5	3.5	6.5	74.7	1.2	1.2	100.0

Fisher's Exact Test: Value is 7.844. Exact Significance (2-sided) is 0.128.*

Table 3.5 Cross tabulation analysis of EU

		Most Satisfied Factors (%)						Total
		Fare	Space	Stability	Service	Network	Others	
Reason to continue (%)	Service (36.8)	9.4	6.3	18.8	59.4	6.3	0.0	100.0
	Others (63.2)	12.7	5.5	7.3	65.5	7.3	1.8	100.0
Total		11.5	5.7	11.5	63.2	6.9	1.1	100.0

Fisher's Exact Test: Value is 3.333. Exact Significance (2-sided) is 0.694.

Table 3.6 Summary of cross tabulation analysis in all regions

Area \ Value	Fisher's Exact Value	Exact Sig. (2-sided)
CH	8.427	0.128*
NE	7.144	0.181*
SE	15.866	0.004*
NA	7.844	0.114*
EU	3.333	0.694

Table 4. Cross tabulation analysis of forwarders refusing to maintain cooperation with the airline

		Most Satisfied Factors (%)						Total
		Fare	Space	Stability	Service	Network	Other	
Reason for not continuing (%)	Service (17.0)	12.5	12.5	0.0	50.0	0.0	25.0	100.0
	Others (83.0)	10.3	5.1	12.8	69.2	2.6	0.0	100.0
Total		10.6	2.1	4.3	66.0	6.4	10.6	100.0

Fisher's Exact Test: Value is 9.006. Exact Significance (2-sided) is 0.058.*

4. Conclusion

The purpose of this research is to investigate forwarders' preferences toward air cargo services provided by a specific airline based in East Asia and their purchasing behavior after using the service. Research results offer the airline a reference of investing or improving their services in the present air cargo market. Results also indicate that the best way to elevate the airline's competitiveness is to realize what forwarders want.

To explore forwarders' preferences, a set of data from a customer satisfied survey conducted by the airline of interest is investigated. The research reveals reasons why forwarders are willing to continue the cooperation with the airline. In addition, these reasons are cross-tabulated with respect to forwarders' most satisfied factors to investigate the relationship between these two variables.

Research results indicate that more forwarders in every region choose service as the reason why they maintain the cooperation with the airline and they feel that service is the most satisfactory factor. On the other hand, the second factor that forwarders choose exists variation in different regions. In China, forwarders choose space. In Northeast Asia, forwarders choose network. In Southeast Asia, North America, and Europe, forwarders choose fare. Furthermore, the result of cross-tabulation analysis shows two opposite facts. In CH, NE, SE, and NA, reasons why forwarders maintain cooperating with the airline are affected by their most satisfied factors. Conversely, in EU, the relationship is not statistically significant.

In brief, service is the worthiest item for target airline to invest, and the target airline should focus on service, which is the most satisfied factor in each region. Additionally, forwarders in CH, NE, SE, and NA tend to be influenced by the most satisfied items while choosing airlines. Therefore, the target airline can sustain the competitiveness and maintain the cooperation with forwarders by focusing only on the most satisfied items. In the EU, however, the forwarders' most satisfied factor has little relationship with their preferences. As a result, the target airline must spend more resources on searching for forwarders' preferences.

This research provides the target airline a reference for investing or enhancing their air cargo service in the future. They can be more effective for allocating resources to important factors.

Reference

- Aaron, B.S. and Johannes, V.C. (2001), Assessing the importance of hub airports for cargo carriers and its implications for a sustainable airport management, *Airport Management* 62–70.
- ACI (2012), *ACI Annual World Airport Traffic Report (WATR)*.
- Chen, Y.C. (2007), *A Study of Applying Quality Function Deployment to Improve Customer Service Satisfaction: The Case of Airlines' Cargo Business*, ROC, Taiwan Ocean University, Department of shipping and transportation management.
- Farshid, A., Alper, E.M. and Ratna, B.C. (2012), Dynamic routing of time-sensitive air cargo using real-time information, *Transportation Research Part E*, 48: 355–372.
- Hiroshi, O., Tae-Seung, K., Tae Hoon, O. and Chunyan, Y. (2005), Choice of air cargo transshipment airport: an application to air cargo traffic to/from Northeast Asia, *Journal of Air Transport Management* 11:149–159.
- Hsu, S.C. (2006), *The study on the Relationships among Service Quality, Customer Satisfaction and Customer Loyalty for Airline Cargo Services – A perspective of Air Cargo Forwarder*, ROC, Kaohsiung First University, Department of logistic Management.
- IATA (2014), *The Air Cargo Tariff and Rules (TACT)*, Feb 2014.
- Liu, C.L. (2008), *Factors Influencing the Selection of Air-cargo Terminals – The Case of Export Business in Taoyuan Airport*, ROC, Kainan University, Department of logistic and Shipping Management.
- Maarten, T. and Verbeeten, F.H.M. (2014), Customer satisfaction: Cost driver or value driver? Empirical evidence from the financial services industry, *European Management Journal* 32(3): 499–508.
- Meng, S.M., Liang, G.S., Lin, K. and Chen, S.Y. (2010), Criteria for services of air cargo logistics providers: How do they relate to client satisfaction?, *Journal of Air Transport Management* 16: 284–286.
- Tsai, M.C., Tsai, Y.T. and Lien, C.W. (2011), Generalized linear interactive model for market segmentation: The air freight market, *Industrial Marketing Management* 40(3): 439–446.
- Zhang, A. and Zhang, Y. (2002), Issues on liberalization of air cargo services in international aviation, *Journal of Air Transport Management* 8: 275–287.

Online Container Transport Planning with Decision Trees based on Offline Obtained Optimal Solutions

Bart van Riessen^{1,2}, Rudy R. Negenborn² and Rommert Dekker¹

¹ Econometric Institute, Erasmus University Rotterdam, Rotterdam, The Netherlands.

Email: vanriessen@ese.eur.nl, rdekker@ese.eur.nl.

² Department of Maritime and Transport Technology, Delft University of Technology, Delft, The Netherlands.

Email: r.r.negenborn@tudelft.nl.

Abstract

Hinterland networks for container transportation require planning methods in order to increase efficiency and reliability of the inland road, rail and waterway connections. Earlier proposed centralised methods can in theory find the optimal solution for the multimodal inland transportation problem in retrospect, but are not suitable when information becomes gradually available. Besides real-time up-to-date information on inland services necessary for applying these methods in practice is typically not available. In this paper we aim to derive online decision rules for suitable allocations of containers to inland services by analysing the solution structure of a centralised optimisation method used offline. The online decision support system (DSS) must be able to instantaneously allocate incoming orders to suitable services, without the need for continuous planning updates. Such a DSS is beneficial, as it is easier to implement in the current practice of container transportation than a fully automated planning system, while providing a better performance. A case study is used to show the method's purpose and to compare the quality of the resulting plan with alternatives.

Keywords: Intermodal planning; Synchromodal planning; Container transportation; Decision support, Decision trees.

1. Introduction

Continuous growth of global container volumes puts increasing pressure on the inland road, water and rail connections, especially in developed countries with limited public support for infrastructural expansion. Simultaneously, shippers require more reliable inland connections because their supply chain demands for just-in-time delivery, and the environmental impact of the inland transportation is increasingly bound by restrictions from governments and from shippers themselves. The port of Rotterdam is one of the few major ports in the world with three inland modes of transportation. Although the inland network has sufficient capacity in general, temporary congestion occurs frequently on all inland modes: road, water, and rail connections. Most inland transportation of containers is carried out by operators that are dedicated to the specific modes. In 2010 the Port of Rotterdam Authority announced specific modal split restrictions to become effective in 2030 (Port of Rotterdam, 2010). In the light of these developments, an integral approach for the routing and planning of all inland container transportation is vital. In recent years, several studies have proposed centralised optimisation methods for determining the optimal allocation of containers to inland transportation services of all available modes, considering available capacity, costs, lead times and emissions. The proposed methods are suitable for solving the *offline* planning problem, in which an optimal plan is created for a batch of transportation orders collectively. Such a centralised offline approach is difficult to implement in practice for various reasons:

- The nature of the inland transport logistics requires an online approach, in which a customer can get immediate feedback on the selected mode, route, and most importantly, the estimated time of arrival. Consequently, updates in the planning of inland transportation have large influences on the subsequent production processes, possibly with large additional costs.

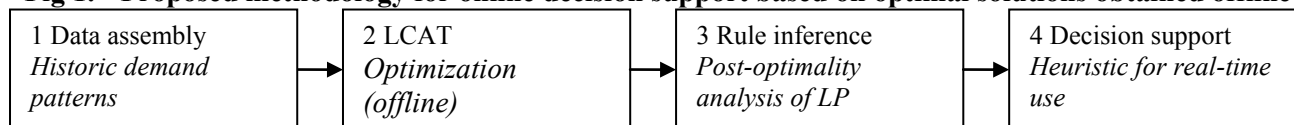
- Proposed centralised optimisation methods depend strongly on automation, both for terminals, as for other parts of the supply chain. The models lack the flexibility to deal with special occasions: e.g. last-minute changes to transportation orders. For allowing these special cases, direct communication between manual operators is essential (Douma, 2008). For this reason an approach is required that presents the manual operators with a comprehensible solution that can be adapted if necessary.
- Finally, the supply chain of container logistics lacks information integration (van der Horst and de Langen, 2008). This is also the case in the setting of our problem: the manual planning operators often do not have real-time capacity information about the inland services. So, for allocating a container to a service, available capacity must be checked manually with the service operator.

In this study we propose an online DSS that addresses these issues, while providing improved planning support. Firstly, the proposed method allows allocating incoming transport orders directly to available inland services, resulting in a stable solution and instant feedback to the customer without the necessity of continuous planning updates. Secondly, the model can be used as a centralised method, but does not require extensive automation. The model is based on an analysis of the solution space of an offline optimization model, and translates the offline model's optimal solutions to a white box of online decision rules. A white box method based on decision rules is more comprehensible for manual planners and allows manual changes if necessary. It will therefore more easily be accepted for use in daily practice. Finally, the model allows for a centralised planning approach without fully centralised information. As a transport order arrives, the DSS will allow human planners responsible for a central network planning to check available capacity on a specific service manually.

Existing methods for online decision making for planning of inland container transportation focus on finding cheapest or shortest paths per transport order (Ziliaskopoulos and Wardell, 2000; Ayed et al., 2011). Nabais (2013) proposed a more advance method for solving the online problem. This method uses model predictive control to achieve a required modal split, but the approach requires real-time automated data processing and is less insightful to human planning operators.

In this paper, our goal is to create an online DSS, without the need for extensive automation and information centralisation. For this we use optimal solutions of representative historic transport problems of a corridor as a baseline for suitable transport allocations. This approach is pictured schematically in Figure 1. First, the data of historic demands are assembled. Secondly, the recently proposed *linear container allocation problem with time restrictions* (LCAT) is applied (van Riessen et al., 2013). The resulting optimal solutions for historical demand periods provide the baseline for online decision support and are used in the third step to find properties of an effective planning of a container considering the uncertainty in the demand. The relations between container properties and the planned mode and route for that container in the optimal solution are determined. For this, we use a method of supervised learning, where the outcomes of the training sets, i.e., the optimal plans, are known in advance. The supervised learning algorithm creates rules for the allocation of a container to a suitable service based on the container and order properties, such as the time of availability, the transportation lead time, and container mass. Subsequently, the set of rules can be used in an online setting as a real-time DSS: for each incoming order the DSS will provide a human planner with a set of suitable services in an understandable way.

Fig 1. Proposed methodology for online decision support based on optimal solutions obtained offline



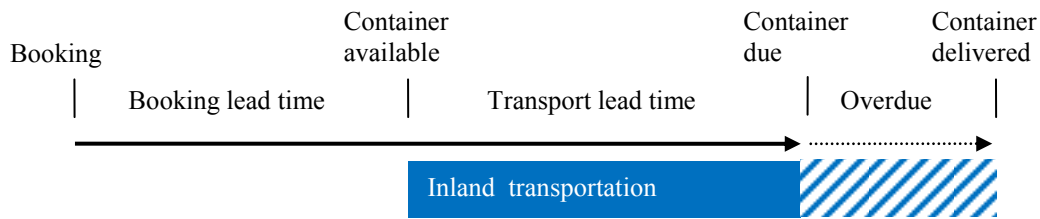
The remainder of this paper is organised as follows. Section 2 gives a formal description of the optimization problem under consideration. Section 3 introduces the proposed methodology for real-time decision support based on offline optimality. In Section 4, the method is applied in a case study of a hinterland transportation corridor. This case study is motivated by a practical case in the port of Rotterdam. Section 5 summarizes the findings of the study and provides an outlook on future research.

2. The Multimodal Planning Problem

2.1 Problem definition

For a certain transport corridor, orders arrive sequentially. The attributes of an order are the number of containers for the order, the booking lead time, the transport lead time and the size and weight of each container in the order. The number of containers is measured in standard container sizes of Twenty feet Equivalent Units (TEU). The booking lead time is the time between the arrival of the order and the availability of the container; the transport lead time is the time between the availability of the containers and the due time at the destination (see Figure 2). The customer's goal is to transport the container for the lowest possible price, ideally before the due time of the containers, but possibly a little later as indicated by the overdue time. In practice, overdue delivery can sometimes be negotiated with customers, in our modelling overdue delivery is allowed at a penalty cost for the network operator. Historical data provides the distribution of attribute values.

Fig 2. Timeline of orders and inland transportation



For a particular corridor, a set of inland services is available, characterized by the mode of transport (barge, rail or truck), cost per container, departure time, arrival time, and vehicle capacity (volume and weight). Naturally, the time between departure and arrival of a service depends on the mode's travel speed. Typically, speed and cost are high for trucking and low for barge transport. Volume capacity is high for barge transportation and low for a truck. The weight capacity for both barge and truck is mostly not restrictive. The mode train has intermediate levels for speed, cost and capacity, but typically has a restrictive weight capacity, especially in mountainous regions.

Nowadays, for planning the container transportation often a greedy approach or first come, first serve (FCFS) approach is used. In case of a greedy approach, a booking is assigned to the cheapest feasible service at the time of order arrival, i.e. the cheapest service with free capacity that travels within the containers time restrictions. In a FCFS approach, a booking is assigned to the first feasible service at the time of order arrival. In both methods, an order is assigned *instantaneously* at the time of order arrival.

For the problem addressed in this study we also need to allocate an incoming order immediately to the most suitable inland service, but now also taking into account the optimization of the entire corridor. We propose a method for allocating orders to services based on optimal historical plans. The workloads in container terminals have a stochastic nature with all actions like arrivals, departures and handlings distributed unevenly in time (Murthy, 2005). The method must operate well under various circumstances and therefore multiple historic order arrival patterns are used. The proposed method is capable of automatically identifying the preferred allocation per incoming order.

It is expected that the performance of the method is comparable to a low-level assignment strategy such as FCFS for cases with orders that are entirely randomly distributed across the selected input features. If, however, historic information contains specific demand patterns, identifiable from the selected features, our method will capture that pattern without further detailed analysis. In Section 3 we will describe how our method uses historic information and offline results from an optimal model in a DSS. First, the model for the offline optimization is introduced.

2.1 Offline optimization problem

The model we use to determine the optimal solution for the transportation planning is based on the earlier proposed LCAT model. That model delivers optimal solutions for the planning of an entire network. Here we focus on a single corridor only as that is common practice in container logistics. For that reason, we simplify the LCAT model by omitting the constraints for paths with intermediate transfers. The set of all cargo types that must be planned is denoted by demand set C and the set containing all services by S . Let x_s^c denote the number of TEU of cargo type $c \in C$ that is assigned to service $s \in S$. The number of days that these containers are late is denoted by τ_s^c . The number of TEU of cargo class c assigned to a direct truck is denoted by v^c . The objective of the *Corridor LCAT* (CLCAT) is to minimize total transportation costs consisting of three terms representing the transit costs, the overdue penalty and the cost for direct trucking, respectively:

$$\min J_{\text{CLCAT}} = \sum_{s \in S} \sum_{c \in C} (c_s x_s^c + c_\tau \tau_s^c + c_t^c v^c), \quad (1)$$

$$\text{subject to:} \quad v^c + \sum_s x_s^c = d^c \quad \forall c \in C \quad (2)$$

$$\sum_c x_s^c \leq u_s \quad \forall s \in S \quad (3)$$

$$\sum_c W_c x_s^c \leq m_s \quad \forall s \in S \quad (4)$$

$$x_s^c T_D^s \geq x_s^c t_{\text{available}}^c \quad \forall c \in C, \forall s \in S \quad (5)$$

$$\sum_q x_s^c (T_A^s - t_{\text{due}}^c) \leq \tau_s^c \quad \forall c \in C, \forall s \in S \quad (6)$$

$$x_s^c, \tau_s^c, v^c \geq 0 \quad \forall c \in C, \forall s \in S, \quad (7)$$

where the transit costs for service s are denoted as c_s , the overdue costs are c_τ per day and the cost for direct trucking a container of cargo class c is denoted as c_t^c . The total demand of cargo class c is denoted by d^c . This demand must be transported on one of the intermodal services or by direct truck. The maximum capacity of service s is denoted by u_s (TEU capacity) and m_s (mass capacity). Constraint (2) ensures that all demand is met. By constraint (3) and (4), the total number of TEU on each service is restricted to the available capacity. Constraints (5) and (6) are the time constraints, where constraint (6) is a constraint for on-time delivery: τ_p^c measures the total number of days that containers of cargo class c on service s are late. Finally, constraint (7) is the nonnegativity constraint for the three sets of variables.

For most demand patterns, multiple optimal solutions of (1) – (7) exist. In order to get decision rules that resemble the optimal solutions as closely as possible in the next step of the approach proposed in this paper, we need to determine a set of optimal solutions for demand set C . Finding all optimal solutions is a very difficult task (Valiant, 1979), so we use an alternative approach. In order to generate a set of optimal solutions for the demand, we solve the following problem P times:

$$\min \sum \mathbf{r} \mathbf{x} \quad (8)$$

$$\text{subject to:} \quad (2) - (7) \quad (9)$$

$$\sum_{s \in S} \sum_{c \in C} c_s x_s^c + c_\tau \tau_s^c + c_t^c v^c = J_{\text{CLCAT}} \quad (10)$$

where $\mathbf{x} = [x_s^c, \tau_s^c, v^c]^T$, a vector of all decision variables, and \mathbf{r} is a vector of the same length of random numbers from the standard uniform distribution (ranging from 0 to 1). By (10), all feasible solutions of

(8) – (10) are optimal solutions of (1) – (7). The random vector \mathbf{r} is introduced to get random subset of solutions out of the set of all optimal solutions, i.e., solving Problem (8) – (10) corresponds to generating random optimal solutions from the set of optimal solutions to (1) – (7). By definition, all these solutions have equal objective value J_{CLCAT} . Below, we describe how these optimal solutions are used in a learning algorithm to obtain a real-time DSS.

3. Method for Obtaining the Real-time DSS

3.1 Supervised Learning

This study focuses on developing an online method that is suitable for operational usage in a real-time setting. The quality of the online method is compared to the quality of a theoretically optimal solution, obtained offline. In the method we propose in this study, we do not aim to formulate the online decision problem explicitly. Instead we aim to translate the results of an optimal model into rules for online application. An expert system that can provide decision support for container transportation planning may require a large amount of rules, depending on the complexity of the task at hand. Rule inference by interviewing operational planning experts has two disadvantages. This approach typically results in a few rules per man day (Quinlan, 1986). As a result, the rule inference for an entire network may be time-consuming. Secondly, the quality of the transportation by the operational planning experts is unsure. For these reasons, we use a machine learning technique to infer the decision rules based on optimal planning solutions of the offline problem.

Carbonell *et al.* (1983) classify machine learning algorithms along three dimensions: the learning strategy, the application domain, and the representation of the knowledge. Here, we consider the task to train a DSS for real-time use, based on available optimal solutions, obtained offline. The required learning strategy is a *non-incremental learning from example*-strategy (Carbonell *et al.*, 1983), i.e., all examples of transportation allocations in the optimal solutions are provided at once to the machine learning process.

Secondly, the machine learning process proposed in this work is used to develop a DSS for the planning process of inland container transportation. In the classification of Carbonell *et al.* (1983) this method belongs to the category of *planning and problem solving*.

The third dimension that Carbonell *et al.* (1983) distinguishes is the representation of the knowledge, or the learning technique. The selection of a suitable supervised machine learning technique for the container planning problem is made based on four criteria. Firstly, the resulting classifier must be able to show which rules and criteria lead to a decision. This is important for practical acceptance by the manual planning operators and is defined as a *white box* property. Secondly, the machine learning method must be able to use offline data. Subsequently, we require a classification method that can distinguish between multiple classes, i.e., different inland services. Finally, the learning method must be suitable for using input parameters with categorical data, for instance, the customer type. In Table 1 we provide an overview of available techniques and the compliance with the four criteria; below we explain the techniques briefly. Decision trees are a way to represent rules underlying data with hierarchical, sequential structures that recursively partition the data (Murthy, 2005). Decision trees can be formulated as a special case of a rule-based algorithm, for which each rule assigns a disjoint subset of attributes to a class. A rule-based classifier is best suitable for binary classification problems (Kotsiantis, 2007). A perceptron algorithm uses linear weight function of the input features to distinguish between two classes in a binary set. It is mostly used in an online setting with an update algorithm for the weight function. Radial Basis Function Networks are three layer neural networks where each node is represented by a symmetrical radial basis function. A Bayesian network can be depicted as a directed acyclic graph, where each node represents a feature. The arcs represent causal influences between the features. It is possible to use a priori information about the relation between features. Instance-based learning algorithms use the proximity of a new instance to earlier instances to make a decision. Although it is possible to show on what *nearest neighbours* a decision is based, it is difficult to show the features that have caused a decision. Finally, Support Vector Machines use a formulation to transform the feature space in such a way that two classes are separable. This approach is restricted to binary classification problems. Based on Table 1, decision trees and rule-based classifiers are the only method suitable for separating multiple classes based on offline data with the white box property. We select decision trees as the classification approach for our study,

as this method is easier to use for classification problems with multiple classes (Kotsiantis, 2007). Also, decision trees show the decision process in a more comprehensible way.

Now, the challenge is to create an accurate classifier. This can only be determined after the learning process, using one of at least three techniques (Kotsiantis, 2007): splitting the data in a training and test set, cross-validation or leave-one-out cross-validation. In our method we use a test set and a training set to validate the performance of the classifier.

Decision tree classifiers (DTC) are used as a method to structure complex decision-making. The decision is split up in multiple stages of simpler sub decisions. A decision tree (DT) can be represented by an acyclic directed graph, where a decision rule is associated with each node (Safavian et al, 1991). To make a decision using a decision tree, the sub decisions per node are applied recursively to the parameters of the case. The decision rule at each node level defines what the next node of the decision process will be. This is called the *child*-node. Nodes without children are called *leaf* nodes and are associated with the final decision outcomes of the tree.

Table 1. Types of supervised machine learning methods

	White box	Offline/online	Multiple classes	Categorical
Decision trees	Y	Offline	Yes	Yes
Rule-based classifiers	Y	Offline	Yes	Yes
Perceptrons	Y	Online	No	No
Radial basis function networks	N	Offline	Yes	No
Naive Bayes classifiers	N	Offline	Yes	Yes
Bayesian networks	N	Offline	Yes	Yes
Instance-based learning	N	Online	Yes	No
Support Vector machines	N	Offline	No	No

Based on Kotsiantis (2007); Rish et al. (2001); Steiwart and Christman (2008)

3.2 Decision Tree Inducer

The generalization error of a tree is defined as the misclassification rate over the input distribution (Rokach *et al.*, 2005). Typically, the goal of a DT inducer is to find an optimal tree that minimizes the generalization error. In our case, the generalization error is the number of containers that is classified to another service than in the optimal allocation as determined by the offline problem solution. Finding an optimal tree is an NP hard task, which is only feasible for small problem sizes (Rokach *et al.*, 2005). The topology of a decision tree and the decision rule at each node can be estimated empirically, using real-world data for which the intended outcome is known, i.e., supervised learning (Arentze and Timmermans, 2004).

Estimating a decision tree involves three aspects: design of the tree structure, the inference method decision rule at each node, and the selection of the feature set containing the input parameters (Safavian et al, 1991). The tree structure and decision rules are determined using a learning heuristic, or *inference method*. Rokach *et al.* (2005) provide an overview of inference methods: Most often a top-down heuristic is used as inference method, although bottom-up inference methods also exist. The inference of the tree usually involves a growth phase followed by a pruning phase. In the growth phase, branches are added starting from the root of the tree while considering a splitting criterion. In the pruning phase, branch nodes are turned into leave nodes and the leaf nodes of that node are removed (Rokach *et al.*, 2005). According to Arentze and Timmermans (2004), the following are the most widely used learning heuristics: C4.5 (Quinlan, 1993), CART (Breiman, 1993) and CHAID (Kass, 1980). All methods consider a condition based on a single input variable as splitting criterion and use a top down induction method. Chandra and Varghese (2009) mention two popular splitting criteria: the Gain ratio (Quinlan, 1993) and the Gini index (Breiman, 1993). Lastly, the set of input parameters must be determined. Often, this is carried out in a greedy way, by adding the input parameter that adds the most value to the classification accuracy iteratively, until no more improvement is made (Rokach *et al.*, 2005).

The induction of a decision tree via a learning heuristic requires a training set for the learning process and a test set to evaluate the quality of the induced tree in a cross-validation. If some observations are more important than others, it is possible to add observation weights to each observation.

In our method, the DT is induced in a series of steps:

1. For obtaining the DT, we assemble N demand sets for training
2. Subsequently, we determine P optimal solutions per demand set using the CLCAT model.
3. In the next step of the approach, the resulting solutions are used for the growth of a single DT.
4. Then finally, the obtained DT is used in a per-order planning heuristic.

In order to obtain a DTC that performs well under various circumstances and that is not overfitted for a single demand set we use N demand sets for training. The sets can be demand sets from the last N weeks for instance. Per set, P optimal solutions are determined using (8) – (10). By using multiple optimal solutions the obtained DTC is induced on a set of possible plans for a more robust classification compared to using a single optimum. The input features and classes of all allocations in the $N \times P$ optimal plans are assembled. Each observation in this set of solution denotes the assignment of x_s^c containers of cargo class c to service s . The number of containers x_s^c is used as the observation weight. From the transportation booking we obtain the input features for the DTC: we use the container's time of availability ($t_{\text{available}}^c$), the transport lead time ($t_L = t_{\text{due}}^c - t_{\text{available}}^c$) and the container weight W_c . The allocated service denotes the class of the container that the DTC must try to predict.

The inference of the decision tree is carried out using the C4.5 method (Quinlan, 1993, 1996), with Gini's split criterion. The C4.5 method uses recursive partitioning and selects in each node the input feature that gives the least impurity of the child nodes, according to the Gini's index. The Gini index is denoted by (Rokach, 2005):

$$G(y, Z) = 1 - \sum_{c_j \in \text{dom}(y)} \frac{|\sigma_{y=c_j} Z|^2}{|Z|^2},$$

where y represents the target attribute, $|Z|$ represents the number of observations in the set and $|\sigma_{y=c_j} Z|$ the number of observations in the set with target value $y = c_j$. Hence, a pure node with just one class has only observations with $y = c_1$ and Gini index 0; otherwise the Gini index is positive. So the Gini index is a measure of node impurity. The recursive partitioning of nodes continues until in each node the stopping criterion has been reached; in the proposed method, we choose to stop splitting a node that corresponds to less than 20% of the average allocation to a service. With each leaf node, a table is associated containing the class distribution in that leaf node for all observations in the training sets. If a leaf node is pure and the Gini-index equals zero, the classification table for that node has only one entry: all observations in the training set associated with that node were assigned to a single inland service. For leaf nodes with some impurity, the largest class indicates the label of that leaf node.

The obtained DTC classifies incoming transport orders based on the input features by recursively making sub decisions until a leaf node is reached. The label of that leaf node indicates the most common inland service for transports reaching that leaf node, but for our purpose we use the classification table in that leaf node. A human planning operator can use this list for determining the actual allocation, while he considers the remaining capacity and other practical considerations. In the approach we describe in this paper, we use a heuristic for the actual allocation, called the DT heuristic in the remainder of the paper.

3.3 DT Heuristic

The DT heuristic used in this paper uses the inferred DTC to automatically assign incoming orders to inland services. In practice, this process can be carried out by a human operator using the DTC. In order to demonstrate our approach in a systematic way we use an automated heuristic to generate the transportation plan. An incoming transportation order is considered instantaneously as it arrives. The DTC associates this

order with one of the leave nodes. The classification table of that node contains the distribution of services associated with that leaf node in decreasing order. The DT heuristic is then given by the following 2 steps:

1. The container is assigned to the first service in the classification table that has capacity left.
2. If none of the indicated services has capacity available, the container is assigned according to a greedy strategy, i.e., the feasible service with minimum cost is selected.

Note that this greedy strategy will select a direct truck if none of the available inland services has capacity left. The allocation process is repeated at the arrival of every transportation order.

The proposed method solves all three problems of centralised offline approaches that were mentioned in the introduction:

- The proposed method is suitable for application in an online setting: it can be used to directly allocate an incoming transportation order to an inland service.
- The method does not depend on automation of the transportation process. Both creating and using the DTC can be carried out using regular Personal Computers. It allows for manual adaptation of the plan.
- The required data about historic transports and inland services can be obtained in retrospect and requires little automation and integration across various stakeholders in the supply chain.

4. Case Study

4.1 Scenarios

We demonstrate the use of our method in a case study. We compare two scenarios with identical service schedules, but in Scenario 1 the demand is distributed randomly across the input features and in Scenario 2 a specific demand pattern is considered. First we consider Scenario 1. Figure 3 shows a service schedule for a week with the Estimated Time of Departure (ETD) and Estimated Time of Arrival (ETA) of three services from A towards B. Trucks can always be used, and are therefore not shown. Also, five transport demand flows are indicated. These flows have some variability; assume the demand of these flows in TEU is normally distributed with a mean of 50 TEU and a standard deviation of 12.5 TEU. We assume that the weight per TEU is 10 tonnes. The $t_{\text{available}}^c$ and t_{due}^c of these flows are indicated by the shaded bands in Figure 3. E.g., flow 1 is available at A at some point during Monday and is expected two days later at B. The only service suitable for this flow is Train 1, as it departs after the containers are available and arrives at B before the due time of flow 1. Alternatively, trucks could be selected, but at much larger costs. Table 2 provides details on the services.

For this scenario, the optimal solution can be easily found by reasoning: Flow 1 and 2 must be fully assigned to Train 1 and Barge 1, respectively. Flow 3 is fully transported by trucks, as no suitable service is available. Then finally, flow 4 and 5 share service Train 2 up to its full capacity, however, the expected number of containers in flow 4 and 5 is 100 TEU, which is larger than the TEU-capacity for Train 2 (90 TEU), so some trucks must be used. The same solution is found by applying the learning method proposed in the previous section. The resulting DTC is shown in Figure 4: the optimal solution is mapped entirely by the DTC.

Table 2. Inland services for the case study

	Train 1 and 2	Barge 1	Trucking
Capacity[TEU]	90	200	-
[tonnes]	1000	100,000	-
Costs [per TEU]	100	50	285

Fig 3. Transport orders and service schedule for the case study

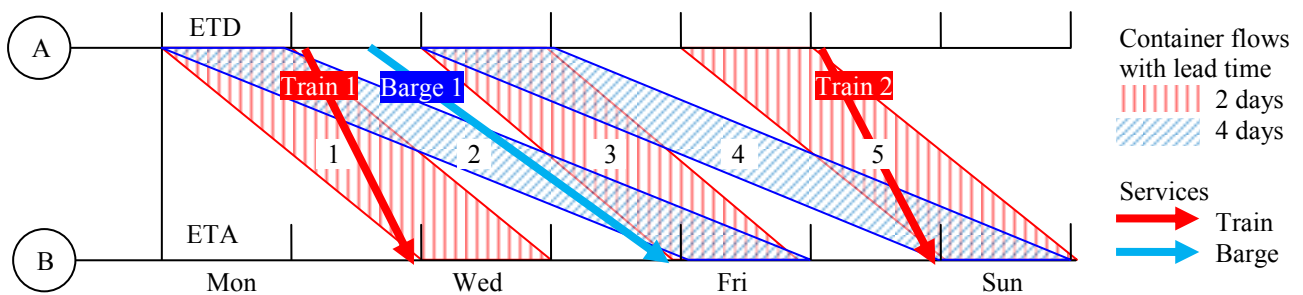


Fig 4. Tree obtained from the learning method (for Scenario 1)

Splitting rules per node

Node 1: $t_{\text{available}}^c < \text{Tue 12PM}$

Go to node 2, else node 3

Node 2: Lead time < 3 days

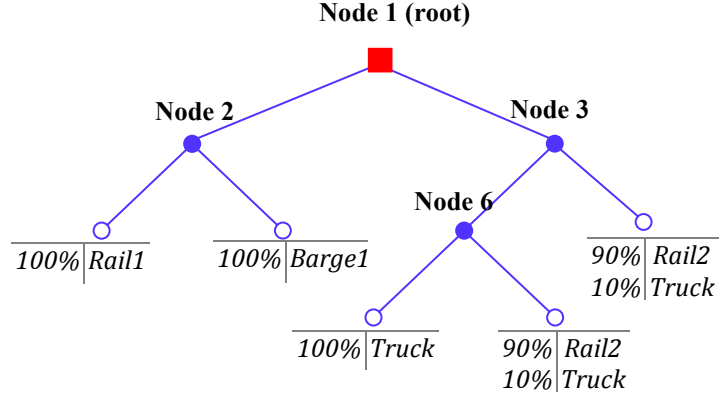
Select Barge 1, else Rail 1

Node 3: $t_{\text{available}}^c < \text{Thu}$

Go to node 6, else select Rail 2

Node 6: Lead time < 3 days

Select trucking, else Rail 2



Scenario 2 is identical to Scenario 1, except for one property: we now assume that all containers of flow 4 have a weight of 25 tonnes. If the solution of scenario 1 would be applied to this scenario, Train 2 will most likely not be used to its full TEU capacity as the weight limit is reached well before that. So, for this scenario the optimal solution is slightly different: all containers of flow 5 must be planned on Train 2, while the containers of flow 4 are planned on Train 2 if possible. The remaining containers of flow 4 must be transported by trucks. With this solution, Train 2 can be used to its full TEU capacity. The corresponding tree for Scenario 2 was generated in a similar way as in Scenario 1.

The scenarios were implemented using the C4.5 implementation of the Statistics toolbox of MATLAB R2012a and the experiments were carried out using an AMD Athlon II X2 3.0 Ghz processor.

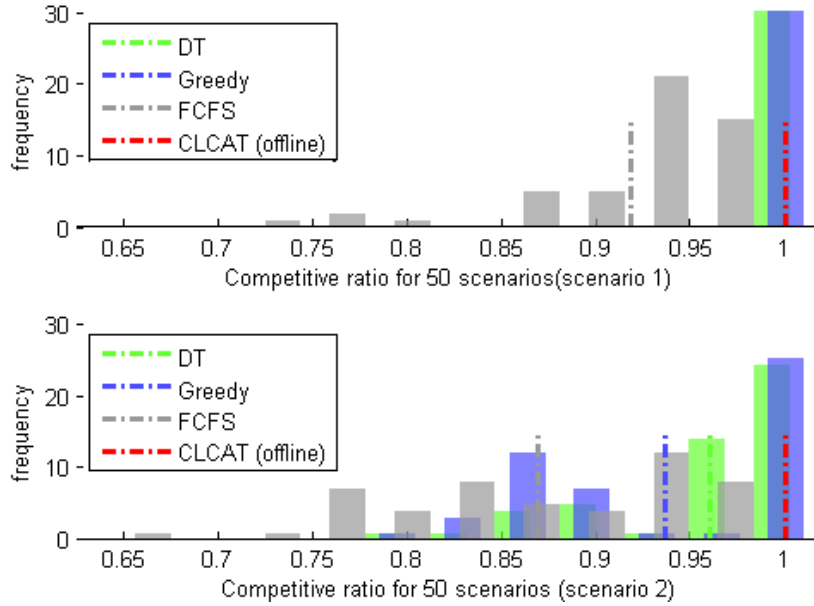
4.2 Experiments

In order to test our method, we apply our DT heuristic to both scenarios described, as well as a greedy and a FCFS heuristic. We compare the objective costs of the heuristics to the optimal objective value by the competitive ratio. The competitive ratio is determined as the ratio of the optimal objective value and the objective value of the heuristic's results (Borodin and El-Yaniv, 1998). The optimal objective value can be obtained offline using the CLCAT model. By this definition, the competitive ratio of the CLCAT solution is always equal to 1, and for the heuristics always ≤ 1 . A high competitive ratio indicates a good plan. Hence, we compare three online heuristics and the optimal offline plan in a series of simulations.

We generate $N = 20$ demand sets of a week for both scenarios. The sets for both scenarios are equal, except for the weight of flow 4: 25 tonnes per TEU instead of 10 tonnes. For each of these sets $P = 50$ optimal solutions are computed and the results are used by the learning algorithm to generate the DTC. Subsequently, we similarly generated 50 test sets for both scenarios and applied the four methods. The results are shown in Figure 5. In scenario 1, both the DT heuristic and the greedy heuristic found the optimum in all 50 test sets. The FCFS heuristic performed much worse with a competitive ratio of 0.92. In Figure 3 can be seen that a FCFS heuristic will allocate orders of flow 2 to Train 1, and requires the use of trucks for flow 1 when Train 1 is full. In Scenario 2, none of the heuristics found the optimum in all 50 cases. However, on average the DT heuristic outperformed the other heuristics with a competitive ratio of 0.96 compared to 0.94 (greedy) and 0.87 (FCFS). The results are in accordance with our expectations: with randomly distributed demand, the DT heuristic performs comparable with the low-level greedy heuristic as in Scenario 1. If the demand follows specific patterns, as in Scenario 2, the DT heuristic outperforms the greedy heuristic.

The scenarios presented here allowed us to demonstrate the ideas behind the proposed method. A more elaborate example in which the method is applied to a more practical case is presented in van Riessen *et al.* (2014). That case study showed similar results: the DT heuristic provides much better results compared to other heuristics used in practice if the historic demand contains specific patterns.

Fig 5. Histogram of competitive ratios and averages of 50 test sets



5. Conclusions & Future Research

In this paper we have proposed a new approach to use information of offline optimal solutions of container transportation problems in an online setting. Three problems concerning existing optimization methods were addressed with this new method:

- The method provides instant decisions for an incoming order, for direct feedback to the customer. The method does not use additional planning updates after the first allocation, allowing the customer to align the container transportation with the subsequent steps in his supply chain.
- The method provides a white box representation of the DSS, useful and acceptable for human operators in logistics.
- The method does not need the level of automation and standardized communication protocols for information exchange that centralised planning optimizations methods need

We proposed to use a supervised learning method to translate the results of offline optimization into real-time decision support rules. We selected decision tree classifiers (DTCs) as the supervised learning method, as this method can use offline input, it is suitable for classifying into multiple classes and it allows for categorical attributes. Most importantly, the result is a insightful decision tree classifier (DTC), a white box for manual operators. The proposed method uses an offline optimal planning method (CLCAT) to get optimal results of historic transportation problems. The results are translated into a DTC with the C4.5 inference method.

With the method it is possible to learn specific demand patterns in historic data. If the historic demand is entirely randomly distributed, the method will not result in an improvement over alternative low-level heuristics, such as first come, first serve (FCFS) or a greedy heuristic. But if the historic demand contains specific categories of containers that should be allocated to specific services, the method will find these categories automatically and give significantly better results than alternative heuristics.

The approach was shown in a case study in which a scenario with random demand was compared to a scenario with a specific category that required alternative routing. The case study showed that the DT heuristic significantly performed better than a FCFS or a greedy heuristic. In this paper we used the DT heuristic to model the human operator using the DTC. In practice this method will support the human operator by indicated suitable services for an order, while the operator is still able to incorporate his specific knowledge into his decisions. In that case, the performance of the method may be further improved.

Acknowledgements

This research is partially supported by the NWO/STW VENI project ‘Intelligent multi-agent control for flexible coordination of transport hubs’ (project 11210) of the Dutch Technology Foundation STW, and Erasmus Smart Port.

References

- Arentze, T. A. and Timmermans, H. J. (2004), A learning-based transportation oriented simulation system, *Transportation Research Part B: Methodological* 38(7): 613-633.
- Borodin, A. and El-Yaniv, R. (1998), *Online computation and competitive analysis* (Vol. 53), Cambridge: Cambridge University Press.
- Breiman, L. (1993), *Classification and regression trees*, CRC press.
- Carbonell, J. G., Michalski, R. S. and Mitchell, T. M. (1983), An overview of machine learning, In *Machine learning*, Springer Berlin Heidelberg 3-23.
- Chandra, B. and Paul Varghese, P. (2009), Moving towards efficient decision tree construction, *Information Sciences* 179(8): 1059-1069.
- Douma, A. M. (2008), *Aligning the operations of barges and terminals through distributed planning*. University of Twente.
- van der Horst, M. R. and de Langen, P. W. (2008), Coordination in hinterland transport chains: a major challenge for the seaport community, *Maritime Economics & Logistics* 10(1): 108-129.
- Kass, G. V. (1980), An exploratory technique for investigating large quantities of categorical data, *Applied Statistics* 119-127.
- Kotsiantis, S. B. (2007), Supervised machine learning: A review of classification techniques, *Informatica* 31: 249-268.
- Murthy, S. K. (1998), Automatic construction of decision trees from data: A multi-disciplinary survey. *Data mining and knowledge discovery* 2(4): 345-389.
- Murty, K. G., Liu, J., Wan, Y. W. and Linn, R. (2005), A decision support system for operations in a container terminal, *Decision Support Systems* 39(3): 309-332.
- Nabais, J. L., Negenborn, R.R., Carmona Benitez, R.B. and Botto, M.A. (2013), A constrained MPC heuristic to achieve a desired transport modal split at intermodal hubs, In *Proceedings of the 16th International IEEE Conference on Intelligent Transportation Systems (IEEE ITSC 2013)*, The Hague, The Netherlands, 714-719.
- Port of Rotterdam (2010), *Port Vision 2030*, www.portofrotterdam.com/en/Port/port-in-general/port-vision-2030/Documents/Port-vision-2030/index.html.
- Quinlan, J. R. (1986), Induction of decision trees, *Machine learning* 1(1): 81-106.
- Quinlan, J. R. (1993), *C4.5: programs for machine learning*, Morgan Kaufmann.
- Quinlan, J. R. (1996), Improved Use of Continuous Attributes in C4.5, *Journal of Artificial Intelligence Research* 4: 77-90.
- van Riessen, B., Negenborn, R. R., Dekker, R. and Lodewijks, G. (2013), Service network design for an intermodal container network with flexible due dates/times and the possibility of using subcontracted transport, In *Proceedings of the International Forum on Shipping, Ports and Airports (IFSPA) 2013: Trade, Supply Chain Activities and Transport: Contemporary Logistics and Maritime Issues*.
- van Riessen, B., Negenborn, R. R. and Dekker, R. (2014), Real-time container network planning based on post-optimization analysis using decision trees, *Manuscript under review*.
- Rish, I. (2001), An empirical study of the naive Bayes classifier, In *Proceedings of IJCAI 2001 workshop on Empirical Methods in Artificial Intelligence*, Sicily, Italy, 41-46.
- Rokach, L. and Maimon, O. (2005), Top-down induction of decision trees classifiers - A survey, *IEEE Transactions on Systems, Man, and Cybernetics, Part C: Applications and Reviews* 35(4): 476-487.
- Safavian, S. R. and Landgrebe, D. (1991), A survey of decision tree classifier methodology, *IEEE Transactions on Systems, Man and Cybernetics* 21(3): 660-674.
- Steinwart, I. and Christmann, A. (2008), *Support vector machines*. Springer, USA.
- Valiant, L. G. (1979), The complexity of computing the permanent, *Theoretical computer science* 8(2): 189-201.
- Ziliaskopoulos, A. and Wardell, W. (2000), An intermodal optimum path algorithm for multimodal networks with dynamic arc travel times and switching delays, *European Journal of Operational Research* 125(3): 486-502.

The Supply Chain Perspective on Slow Steaming

Sara Elzarka and Maha Morsi

College of International Transport & Logistics, Arab Academy for Science, Technology & Maritime Transport, Alexandria, Egypt.

Abstract

Slow steaming in container liner shipping has emerged since 2008 as a mean to reduce the operating costs and the CO₂ emissions of shipping companies. Slow steaming raised the interest of researchers who actively studied the concept in terms of speed reduction, fuel savings and CO₂ emissions, particularly from the shipping lines' side. However, there was a clear gap in research that investigated the impact of slow steaming on the shippers' supply chain performance. Therefore, the purpose of this paper is to investigate the impact of slow steaming on the supply chain performance metrics to determine whether its advantages are extended to benefit the supply chain or not. This study is exploratory using semi-structured interviews on a sample of 12 companies from 3 main sectors: manufacturing, imports/exports, and freight forwarders. Purposive sampling is applied as the companies chosen would be involved in imports/exports activities to/from Asia in which slow steam shipping is most likely to occur. The purpose of the semi-structured interviews would be to identify the impact of slow steaming on the supply chain performance metrics of the chosen companies and examine the extent to which the advantages of slow steaming are extended to their supply chains. The findings revealed that slow steaming did not have a radical impact either positive or negative on the supply chain performance metrics of the selected sample, with the exception of 'order lead time', 'total cycle time' and 'total cash flow'. The study recommends that shipping lines should take a more active role towards promoting sustainability that would support the positive engagement between them and their clients, thus creating a global sustainable culture.

Keywords: Slow steaming; Sustainability; Egypt; Supply chain, Shippers.

1. Introduction

Supply chain management has traditionally been viewed as a process in which raw materials are converted into final products, and then delivered to the end-consumers (Beamon, 1999). The waste and emissions caused by the supply chain have become one of the main sources of serious environmental problems including global warming and acid rain (Kumar et al., 2012). The impact of business operations on the natural environment is one of the main areas in which societies and governments have become more sensitive. This consequently enforced companies to react to the challenges of green issues by implementing sustainable (or green) logistics and supply chain practices (Evangelista et al., 2010).

In the global supply chain, transportation is one of the most important logistics activities as well as one of the primary performance drivers of the supply chain (Chopra, 2007). Nevertheless, transportation is also one of the major sources of pollution in the form of greenhouse gases (GHG) emissions, which is a main contributor to global warming. Accordingly, the maritime transport sector which carries nearly 95% of global trade was forced to adopt new practices that would lower the negative impact of transport on the environment. One of these practices is slow steaming which emerged since 2008 in container liner shipping as a mean to reduce the operating costs and Carbon Dioxide (CO₂) emissions of shipping companies. But despite the financial and environmental benefits that slow steaming brings to the shipping market, supply chains have been impacted by such practice as lead time was lengthened, inventory increased, and production planning became more challenging.

Therefore, the purpose of this paper is to investigate the impact of slow steaming on the supply chain performance metrics to determine whether its advantages are truly extended to benefit the supply chain

partners. With a primary focus on shippers, this investigation would assist in determining the processes that are impacted by slow steaming and in proposing practices to maintain the required supply chain performance measures.

2. Literature Review

2.1 Sustainable supply chains and slow steaming

Environmental sustainability has been receiving growing interest over the years and many organizations have adopted the term in their vision and core values. According to Carter and Rogers (2008), the term sustainability refers to an integration of social, environmental and economic responsibilities. More precisely, green supply chain management (GSCM) is referred to as ‘the achievement of economic, environmental, and social goals in the systemic coordination of key inter-organizational business processes to improve performance in the long-term for the organization and its partners in the supply chain’ (Ageron, et al., 2012). Green supply chain (GSC) considers the environmental effect of the entire process of the supply chain (SC) from the extraction of raw material to the final disposal of goods (Emmett and Sood, 2010; Kumar and Chandrakar, 2012). Activities such as reducing packaging, using biodegradable materials and using more fuel efficient transportation are just very few examples of the different green activities being executed in a GSC (Emmett and Sood, 2010). From a GSC macro level, Evangelista et al. (2010), stated that logistics activities, especially transportation related activities, are the most important contributors to GHG emissions. The maritime transportation system was thus on the top list of the targeted sectors to be greened.

Maritime transport plays a key role in connecting markets by moving more than 90% of cargo to all parts around the world at a relatively low cost when compared with the value of goods being shipped (IMO, 2013; Yang et al., 2013). Therefore, the maritime transport became ‘the most preferred mode of transport among importers and exporters for doing business especially for international trade’ (Abdulrahman, 2012). Additionally, as global supply chain activities continue to expand around the globe with more activities being outsourced offshore, maritime transport not only secured the relatively low cost of transport but also reliability and competitive supply chain performance. As a result, containerized ocean freight became the lifeline of nearly any global supply chain (Fransoo and Lee, 2011; Harrison and Fichtinger, 2013).

In terms of green performance, the container shipping sector is facing the challenge of balancing between cost competitiveness and sustainability, as it is more pressured to respond to the increasing level of pollution caused by vessels (Yang et al., 2013). As a result, many shipping companies proactively developed environmental management systems, to reduce the environmental impact, reduce cost and improve corporate social reputation (Carter and Rogers, 2008; Woo and Moon, 2013). ‘Slow steaming’ emerged as the ultimate solution for shipping companies that would achieve the reduction of GHG emissions as well as the reduction of fuel costs (Kontovas and Psaraftis, 2011; Lindstad et al., 2011).

Slow steaming according to Woo and Moon (2012) is reducing the vessel’s speed than the deliberately designed voyage speed, which necessitates more vessels to transport the same volume of cargo while maintaining the announced weekly service schedule. Slow steaming simply refers to the reduction of the vessels’ speed from 27 knots to 18 knots, whereby the vessel’s engine power is reduced to 42%, resulting in fuel savings up to 75% (Wiesmann, 2010). It is worth noting that the factors that encouraged the adoption of slow steaming was not only limited to responding to the sustainability requirements of the global supply chains, but was also to respond to the following: (1) the global financing crisis that caused a downturn in global economy, (2) the high fuel costs, (3) the increasing operating costs, and (4) the falling freight rates (Wiesmann, 2010; Armstrong 2013; Yin et al., 2013). The reduction of speed and the lower consumption of fuel, resulted in the reduction of greenhouse gases emissions (Cameron et al., 2010; Faber et al., 2010). According to Wiesmann (2010), ‘for every ton of fuel saved, the industry reduces its CO₂ emissions by three tons, and the cylinder lubricating oil consumption of the main engine is reduced at almost the same percentages as the fuel, which also reduces solid particle emissions’.

The introduction of slow steaming raised the interest of researchers who examined the topics from different perspectives. Some researchers focused on studying the relationship between speed reduction and fuel

savings, for instance, Alvarez et al. (2010) attempted to optimize fuel and ship costs with regard to vessel speed and berth availability. Wang and Meng (2012) used historical operating data of a global shipping line to study the relationship between bunker consumption and sailing speed. They formulated a mixed integer nonlinear programming model to investigate the optimal speed and provided an efficient approximation method to obtain a nearly optimal solution.

Other researchers focused on examining the relation between speed reduction, fuel savings and CO₂ emissions. Cariou (2011) measured the rate of reduction of CO₂ for different container trades and estimated the bunker break-even price to attain the long term sustainability of this strategy. He found that reductions can only be sustained under the condition that the bunker price is at least \$350–\$400 for the main container trades. Ronen (2011) developed a cost model to study the optimal speed and the number of vessels needed to maintain a service frequency while minimizing the total cost, including bunker cost, vessel fixed cost and other operating cost. Psaraftis and Kontovas (2012) provided a taxonomy and survey of speed models, recognizing that vessel's speed is a key determinant to both shipping economics and environmental sustainability. Tai and Lin (2013) examined the GHG emissions of international container shipping carriers on the Far East-Europe routes using the slow steaming strategy and the daily frequency strategies. They concluded that both strategies are effective in reducing emissions. Woo and Moon (2013) also analyzed the relationship between voyage speed, the amount of CO₂ emissions, and the operating costs and focused on finding the optimal voyage speed as a solution to reduce emissions at the lowest operating cost possible to satisfy the reduction target of the International Maritime Organization (IMO).

2.2 *The Impact of Slow Steaming on the Shippers and Consignees' Supply Chain*

Shipping lines, freight forwarders or logistics service providers, have to satisfy shippers at one end and the consignees on the other through the provision of efficient and effective services (Lai et al., 2002). Added to these two requirements is sustainability and green performance that would meet the shippers/consignees green standards. However, the shippers/consignees' demand of 'clean' services and a lower carbon footprint would come at a price. Slow steaming would increase the transit times as well as the pipeline inventory costs (Bonney and Leach, 2010; Page, 2011). This longer transit time would require shippers/consignees to extend their forecast range which would affect its accuracy and would require a higher level of safety stock (Bonney and Leach, 2010; Dupin, 2011). Hailey (2013) quoted that "If the time costs for shippers and consignees are compared to the benefits of carriers due to slow steaming, one can see that slow steaming is most of the times not viable on a supply chain level...the costs for shippers and consignees are most of the times higher than the possible benefits for carriers." It is also worth noting that despite the savings made in the shipping lines' fuel costs, nothing of these savings have been passed to the shippers, as shipping lines did not lower their freight rates (Gallagher, 2010). This in return made shippers feel that the benefits of slow steaming are one-sided (Gallagher, 2010).

The review of literature on slow steaming confirmed Maloni et al.'s (2013) claim that academic literature addressed the advantages of slow steaming and focused on the carriers or the shipping lines. The review of literature showed that the three main variables that were investigated by the majority of slow steaming research were speed reduction, fuel savings and CO₂ emissions. Therefore, the gap in literature was apparent in the following aspects: (1) investigating the shippers or cargo owners' perspective on slow steaming as they are the key customers of shipping lines (2) examining the impact of slow steaming on the shippers' supply chain performance which include important metrics other than the (speed reduction, fuel savings and CO₂ emissions) which are the primary concern of shipping lines (3) The majority of research that addressed slow steaming were conducted in Asia, and none addressed the topic within the African or Middle Eastern settings.

3. **Research Methodology**

As previously stated, academic research on slow steaming addressed the advantages of slow steaming and focused on the carriers or the shipping lines, particularly focusing on the relation between speed reduction, fuel savings and CO₂ emissions. However, there was an apparent lack of research that investigated the impact of slow steaming on shippers/consignees who play a very important role in the shipping lines' supply chain, which is the 'customer'. Shippers are the shipping lines' customers at one end, and the consignees are also the

shipping lines' customers at the other. Therefore it was necessary to examine the impact of slow steaming on the shippers/consignees' supply chain using the supply chain performance metrics as a tool in order to determine whether the advantages of slow steaming is extended to benefit the supply chain or not.

This study is exploratory using semi-structured interviews on a sample of 12 companies from three main sectors: manufacturing, exports/imports firms, and freight forwarders. Purposive sampling is applied as the companies chosen would be involved in imports/exports activities to/from Asia in which slow steam shipping is most likely to occur. The purpose of the semi-structured interviews would be to identify the impact of slow steaming on the supply chain performance metrics of the chosen companies. The interviews were conducted by phone with logistics managers and/or operations managers. Each interview lasted approximately 30 minutes, where the interviewees had to answer thirteen questions about the impact of slow steaming on their companies' performance. In these interviews the researchers used Gunasekaran et al.'s (2004) supply chain performance measures framework which outlines thirty two measures divided into three main categories i.e. strategic, operational and tactical, in order to ask the interviewees about the impact of slow steaming on each of these measures. The interviewees in return had to indicate whether there was a positive change, a negative change or no change on these measures.

4. Research Findings

4.1 Basic information on the companies

Table 1. Description of Participating Companies

Company	Main Business	Activities used in container shipping	Shipping Lines
BMW	Car assembly	Importing	Maersk, Hapag-Lloyd, CMA-CGM
Mars	Confectionaries producer	Importing and exporting	Maersk, CMA-CGM, Seago line
Toshiba El Araby	Producer of home appliances and electronics	Importing and exporting	Maersk, CMA-CGM, APL
Samsung	Producer of televisions: LCDs, Plasma screens	Importing	CMA-CGM, Cosco
Alexandria Fiber Company	Producer of acrylic fibers	Importing and exporting	MSC, Yang-Ming
Sakr Globe	Importer and exporter of supplies	Importing and exporting	Maersk, Hapag-Lloyd
Egytronic	Importer of electronics	Importing	MSC, CMA-CGM
Egytrans	Freight forwarder and logistics services	Importing and exporting	MSC, CMA-CGM, Maersk
Tabadol Logistics	Freight forwarder	Importing and exporting	CMA-CGM, MSC, Maersk, Hamburg Sud
Transmisr	Freight forwarder and logistics services	Importing and exporting	MSC, Evergreen, Maersk, Arkas
Gulf Agency	Freight forwarder	Importing and exporting	MSC, Maersk, Seago
Integrated Solutions	Freight forwarder	Importing and exporting	CMA-CGM, Cosco, Seago

The first part the of the interview focused on understanding the companies' main business, the activities in which the companies' are most likely to use container shipping (imports or exports) and the shipping lines that the companies' mainly deal with. The interviews were conducted with 5 manufacturing companies, 2 exports/imports companies and 5 freight forwarders. These companies use container shipping for both importing and exporting activities, where the manufacturing firms are most likely to import raw materials and export finished products, and where freight forwarders and the other exports/imports companies are most

likely to use container shipping for importing supplies, spare parts or finished products. Table 1 shows the description of the participating companies in this research. It is worth noting that according to the confidentiality agreement with the interviewees, the answers or opinions which will be discussed in the following sections will not be specifically associated with the mentioned interviewees.

It was necessary to also ask the interviewees about whether their companies adopt a green or sustainable strategy before discussing the slow steaming issue. For the manufacturing companies, four out of the five companies have a sustainable strategy and are ISO 14001 certified. Most of them started the green strategy nearly 8 or 10 years ago due to their belief of the benefits that green practices would bring to their business and to their corporate image. One of the manufacturers even stated that his company is very strict on green practices especially with suppliers to whom the company plans weekly visits to inspect their operations and ensure that they are implementing the green regulations on which they have agreed. As for the exports/imports firms, they both do not have a green strategy but one of them indicated that it is a vision for the company to achieve within the coming years. All the freight forwarders stated that they have a green strategy which is mainly centralized on recycling activities and outsourcing gas operated trucks.

4.2 *Slow Steaming in Action*

In this part of the interviews, the questions focused on examining in more details how the shipping lines communicated the slow steaming initiative with the interviewed companies. More precisely, the questions focused on the following points: whether or not the shipping lines have notified them about slow steaming and how they described it, identifying any benefits of slow steaming on their supply chains, whether the shipping lines are providing them with information concerning emissions' savings, and their view on whether slow steaming would be sustainable over the long run or not.

All the interviewees stated that none of the shipping lines have notified them about slow steaming and none have explained or described the concept to them. One of the interviewees even stated that they just noticed that the regular duration of the shipping journey increased approximately 5 additional days without any justification from the shipping line. Another interviewee stated that he learned about slow steaming from reading an international shipping magazine and was surprised that none of the shipping lines they work with have taken the effort to explain to them as clients the concept of slow steaming.

The interviewees were then asked on whether their companies benefited from the fuel cost savings that slow steaming makes possible for the shipping lines by obtaining for example lower freight rates. All the interviewees stated that the freight rates did not change despite the implementation of slow steaming by the shipping lines. One of the interviewees explained that the shipping lines might have not been capable of passing these savings to them as clients because the shipping lines must operate more vessels on the same routes to compensate for the lower speed. Another interviewee claimed that some shipping lines like Maersk have made very high investments in the Triple E class of fuel efficient container ships which could be another reason for not passing the fuel cost savings to clients.

It was then important at this point to ask the interviewees on whether the shipping lines provide them with information on emissions savings that can allow them as clients to calculate their carbon footprint, since sustainability is one of the core reasons for the practice of slow steaming. Again, all the interviewees stated that the shipping lines do not provide the percentage of emissions saved although, according to one of the interviewees, it would be a great tool for all the parties involved to track their emissions' performance. One of the interviewees stated that due to the interest of his company in tracking its carbon footprint, he would check the shipping line's website for any published information on emissions savings. And according to his claim, the information provided is not always up to date, or specific to certain routes.

At the end of this part, the interviewees were asked about their opinion on the sustainability of slow steaming over the long run and three opinions prevailed. The first opinion was cynical, claiming that slow steaming will not be sustainable over the long run because the shipping lines are the only beneficiaries and none of the slow steaming benefits is truly extended to any of the other parties. This opinion was further supported by the claim that shippers are more concerned about lead time than about the savings made in the transport journey,

whether in costs or emissions. Thus, shippers would reach for regular or even faster mode of transport in order to decrease their lead time, consequently supporting their competitiveness. The second opinion was neutral, stating that the market is quickly changing and today's trend might not be suitable for tomorrow's market conditions. And the third opinion was positive, stating that with the rising concern of international organizations and governments around the world in setting international regulations for protecting the environment, would of course promote the sustainability of slow steaming in maritime transport.

4.3 The Impact of Slow Steaming on Supply Chain Performance

In order to get more precise details about the impact of slow steaming on the interviewees' supply chains, the researchers used the supply chain performance metrics framework by Gunasekaran et al. (2004) to indicate the change on performance whether positive, negative or no change. The performance metrics are divided into three main categories: strategic, tactical and operational. Table 2 shows the impact of slow steaming on the supply chain performance metrics of the selected sample of companies.

Table 2. The Supply Chain Performance Metrics Framework

Level	Performance Metric	Impact		
		Positive	Negative	No Change
Strategic	Level of customer perceived value of product			12
	Variances against budget			12
	Order lead time		9	3
	Information processing cost		1	11
	Net profit Vs productivity ratio			12
	Total cycle time		6	6
	Total cash flow time		6	6
	Product development cycle time		3	9
	Range of products and services		3	9
	Flexibility of service system to meet customer needs		3	9
	Effectiveness of enterprise distribution planning		1	11
Tactical	Customer query time			12
	Accuracy of forecasting techniques		2	10
	Planning process cycle time		2	10
	Order entry methods			12
	Human resource productivity		1	11
	Supplier delivery performance		1	11
	Supplier lead time against industry norm		2	10
	Supplier pricing against market			12
	Efficiency of purchase order cycle time		1	11
	Efficiency of cash flow method		1	11
	Percentage of defects		1	11
	Cost per operation hour		1	11
	Capacity utilization		1	11
	Utilization of economic order quantity		1	11
	Effectiveness of delivery invoice methods			12
	Percentage of finished goods in transit		5	7
Operational	Quality of delivered goods			12
	On time delivery of goods	1	5	6
	Percentage of urgent deliveries		1	11
	Information richness in carrying out delivery		1	11
	Delivery reliability performance	1	1	10

Source: Adapted from Gunasekaran et al. (2004)

The previous table clearly shows that the impact of slow steaming on the sample of the companies chosen is either negative or no change. The majority of the supply chain performance measures in the strategic level were almost not impacted by slow steaming with the exception of 'order lead time', 'total cycle time' and 'total cash flow time' which were negatively impacted. This negative impact is caused by the slower speed that resulted in the longer duration of the shipping journey that increased the lead time, consequently impacting the total cycle time and the total cash flow time. On the tactical level, the majority of the supply chain performance measures were also not significantly impacted by slow steaming.

Slow steaming had a positive impact on only two supply chain measurement indicators in the operational level for only one company: 'on time delivery of goods' and 'delivery reliability performance'. The interviewee stated that the service schedule of some shipping lines actually became more reliable after implementing slow steaming, and this is the reason for the positive impact it had on these two measures.

Therefore, it can be concluded that slow steaming does not have a radical impact whether positive or negative on the supply chain performance measures of shippers/consignees.

5. Conclusions and Recommendations for Further Studies

This research examined the much discussed topic of slow steaming from the shipping lines' customers' perspectives. Academic literature was found to have a notable gap in research that addressed slow steaming from the shippers' perspective – particularly within the African and Middle Eastern regions - and its impact on their supply chain performance and this research was an attempt to fill this gap. Through the semi-structured interviews, it was found that shipping lines did not engage their clients in the process of implementing slow steaming. This negligence of engagement could only be justified by their fears of facing resistance from clients especially that the regular shipping journey increased from 5 to 10 additional days which of course directly impact the clients' lead time as it was shown in the result of the study. However, since the main trigger for slow steaming is environmental sustainability, shipping lines must think of methods and strategies to convince their clients and partners about the importance of slow steaming and the benefits that everyone would gain, in order not appear that slow steaming's benefits are one-sided which could result in customers' dissatisfaction. In terms of supply chain performance, the study showed that it cannot be claimed that slow steaming negatively impacted the shippers' supply chain performance as many metrics were not affected either positively or negatively. A larger sample and quantitative measures of supply chain performance would give more insights into the impact of slow steaming on the shippers' supply chain performance.

Further research would be recommended to further investigate the impact of slow steaming on the quantifiable measures of green supply chain performance and its different processes. More research is also encouraged within the African and Middle Eastern regions as it involves a significant amount of imports/exports activities to/from Asia in which slow steam shipping is most likely to occur.

References

- Abdulrahman, N. S.F. (2012), A decision making support of the most efficient steaming speed for the liner business industry, *European Journal of Business and Management* 14(2): 37-39.
- Ageron, B., Gunasekaran, A. and Spalanzani, A., (2012), Sustainable supply management: an empirical study, *International Journal of Production Economics* 140(1): 168–182.
- Alvarez, F., Longva, T., and Engebretsen, E. (2010), A methodology to assess vessel berthing and speed optimization policies, *Maritime Economics & Logistics journal* 12(4): 327-346.
- Attali, J., (2010), Transport and Innovation, The International Transport Forum, Leipzig, Germany.
- Beamon, B. (1999), Designing the green supply chain, *Logistics Information Management* 12(4): 332-342.
- Bonney, J. and Leach, P.T. (2010), Slow boat from China, *The Journal of Commerce Online*: <http://www.joc.com/maritime/slow-boat-china>, last accessed in March 2014.
- Cariou, P. (2010), Is slow steaming a sustainable means of reducing CO₂ emissions from container shipping?, Working paper.
- Carter, C. and Rogers D.S. (2008), A framework of sustainable supply chain management: moving toward new theory, *International Journal of Physical Distribution and Logistics Management* 38(5): 360-387.

- Chopra, S., and Meindle, P. (2007), *Supply chain management, strategy, planning and operation*, Pearson Education, New Jersey.
- Darbra, R.M., Ronza, A., Casal, J., Stojanovic, T., Wooldridge, C. (2004), A new methodology to assess environmental management in sea ports, *Marine Pollution Bulletin* 48 (5–6): 420–428.
- Dupin, C. (2011), FMC plans look at slow steaming, *American Shipper*: http://www.americanshipper.com/NewWeb/news_page_SNW2.asp?news=179286, last accessed in March 2014.
- Emmett, S., and Sood, V. (2010), *Green Supply Chains: an action manifesto*, John Wiley & Sons.
- Evangelista, P., Sweeney, E., Ferruzzi, G. and Carrasco, J. (2010), Green supply chains initiatives in transport and logistics service industry: an exploratory case study analysis. In *Towards the Sustainable Supply Chain: Balancing the Needs of Business, Economy and the Environment*, Proceedings of the 14th Annual Conference of the Logistics Research Network, Leeds: 195–203.
- Faber, J., M. Freund, M. K., and Nelissen, D. (2010), Going slow to reduce emissions, can the current surplus of maritime transport capacity be turned into an opportunity to reduce GHG emissions? brussels: seas at risk publishing: http://www.seas-at-risk.org/pdfs/speed%20study_Final%20version_SS.pdf, last accessed in March 2014.
- Fransoo, J. C. and Lee, C. Y. (2011), Ocean container transport: an underestimated and critical link in global supply chain performance, *Production and Operations Management* [online]. http://cms.ieis.tue.nl/Beta/Files/WorkingPapers/Beta_wp303.pdf (Accessed on 15th January 2014).
- Gunasekaran, A., Patel, C., and McGaughey, Ronald E. (2004), A framework for supply chain performance measurement, *International Journal of Production Economics* 87: 333–347.
- Hailey, R. and Wackett, M., (2013), Shipper's lose out in slow steaming, *Lloyd's List*, Available from Lloyds list's website: <http://www.lloydsloadinglist.com/freight-directory/news/slow-steaming-everyones-a-winner-now/20018015270.htm>, last accessed in August 2013.
- Harrison, A. and Fichtinger, J. (2013), Managing variability in ocean shipping, *International Journal of Logistics Management* 24(1): 7 – 21.
- Kontovas, C.A., Psaraftis, H.N. (2011), Reduction of emissions along the maritime intermodal container chain, *Maritime Policy & Management* 38(4): 455–473.
- Krishna, P.B., Krishna, K.V., Kuladeep, M., Kumar, G.K. (2012), The importance of transport and logistics services in green supply chain management, *International Journal of Innovative Technology and Exploring Engineering (IJITEE)* ISSN: 2278-3075 1(6):125.
- Kumar, R. and Chandrakar, R. (2012). Overview of green supply chain management: operation and environmental impact different stages of the supply chain, *International Journal of Engineering and Advanced Technology (IJEAT)* ISSN: 2249 – 8958 1(3).
- Lai, K-H., Ngai, E.W.T. and Cheng, T.C.E. (2002), Measures for evaluating supply chain performance in transport logistics, *Transportation Research Part E* 38: 439–456.
- Lindstad, H., Asbjørnslett, B.E. and Strømman, A.H., (2011), Reductions in greenhouse gas emissions and cost by shipping at lower speeds, *Energy Policy* 39 (6): 3456–3464.
- Maggs, J., (2012), Slow steaming saves money and the climate, *Acid news Journal* 3, Available from acid news' website: <http://www.airclim.org/acidnews/slow-steaming-saves-money-and-climate>, last accessed in August 2013.
- Maloni, M., Paul, J. and Gligor, D. (2013), Slow steaming impacts on ocean carriers and shippers, *Maritime Economics & Logistics* 15 (2): 152–156.
- Notteboom, T. E. (2006), The time factor in liner shipping services, *Maritime Economics & Logistics Journal* 8:19–39.
- Page, P. (2011), Time, money, *The Journal of Commerce's* website: <http://www.joc.com/commentary/time-money> last accessed in March 2014.
- Ronen, D. (2011), The effect of oil price on containership speed and fleet size, *Journal of the Operational Research Society* 62: 211–216.
- Srivastava, S.K. (2007), Green supply-chain management: a state-of-the-art literature review, *International Journal of Management Reviews* 9(1): 53–80.
- Tai, H-H. and Lin, D-Y. (2013), Comparing the unit emissions of daily frequency and slow steaming strategies on trunk route deployment in international container shipping, *Transportation Research Part D* 21: 26–31.
- Victor, N. A. (2013), Vessel optimization for low carbon shipping *Ocean Engineering* 73: 195–207.

- Wang, S. and Meng ,Q. (2012), Sailing speed optimization for container ships in a liner shipping network, *Transportation Research Journal Part E* 48:701–714.
- Wiesmann,A. (2010), Slow steaming-a viable long term option, *WÄRTSILÄ TECHNICAL JOURNAL*:49-50.
- Woo, J- K., and Moon, SH. (2012),The effects of slow steaming on the liners, operating strategy in liner shipping, *International Association of Maritime Economists (IAME) proceeding Conference*, Taipei.
- Woo, J-K. and Moon, D. S-H. (2013), The effects of slow steaming on the environmental performance in liner shipping, *Maritime Policy & Management*: 1-16
- World Maritime Day, A concept of Sustainable Maritime Transportation System, IMO's contribution. Available from IMO's website: www.imo.org/About/Events/WorldMaritimeDay/WMD2013/Documents/CONCEPT%20OF%20%20SUSTAINABLE%20MARITIME%20TRANSPORT%20SYSTEM.pdf, last accessed in December 2013.
- Yang, C-S., Lu, C-S, Haide, J.J. and Marlow, P.B. (2013), The effect of green supply chain management on green performance and firm competitiveness in the context of container shipping in Taiwan, *Transportation Research Part E: Logistics and Transportation Review*: 55-73.

Becoming a Major Hub in the Distribution of Wine: Hong Kong as a Gate to Asian Markets

Yui-yip Lau¹, Adolf K.Y. Ng² and David Guerrero³

¹Division of Business, Hong Kong Community College, The Hong Kong Polytechnic University, Hong Kong.

²Department of Supply Chain Management, I.H. Asper School of Business, University of Manitoba, Winnipeg, Manitoba, Canada.

³Université Paris-Est, IFSTTAR, AME-SPLOTT, France.

Abstract

This paper examines the conditions of emergence of a hub in the distribution of wine. We illustrate this through dissecting wine distribution in East Asia and the case of Hong Kong as an emerging regional wine hub. Indeed, the Hong Kong Special Administrative Region (HKSAR) Government has imposed zero import tax on wine since June 2008. Since then, the city has attracted a large volume of wine from foreign countries and established a wine bond warehouse in the Asia-Pacific region, and the city currently captures important value from wine trade. However, its position may be under threat from competitors it cannot adapt to the needs of the rapidly changing wine market. This paper uses the concept of agility, explaining how market knowledge, flexibility and responsiveness are key elements for regional competitiveness.

Keywords: Wine logistics, Supply chain, Distribution, East Asia.

1. Introduction Characteristics, Regions of Production, Main Markets

1.1 *Wine: A Very Specific Commodity*

Wine is one of the most civilized and natural commodities which leads people to perceive it as a great perfection and enjoyment in life (Hall and Mitchell, 2008, Simpson 2011a). It is purchased at both private and social occasions, and sometimes “on premises” at pubs, restaurants and other recreational arenas (Spawton, 1991). In general, the dynamic nature of wine is unique, complex and almost enigmatic product because it is (1) a provider of sustenance and a luxury item; (2) associated with healthy living, while in excess it can create healthy problems, or even death; (3) a symbol of status and a ‘peasant’ drink; (4) of immense religious and cultural significance and can be associated with hedonistic and debauched behavior; and (5) a fashion item, experience and commodity all in one (Hall and Mitchell, 2008). In this regard, wine becomes one of the most valuable commodities in international business.

1.2 *Shifts in the International Trade of Wine: The Emergence of New Regions of Production and Consumption*

Wine, a traditional industry, was traded between regional wine producing and consuming countries for centuries (Anderson, 2001). Traditionally, the wine production and consumption was relatively localized (Hussain et al., 2007). Until the turn of the century, there was only about 10% of global sales crossing national borders, and the majority was with proximate neighbors (Anderson, 2001). Wine producers in distant countries were isolated from each other, and most of the world’s drinkers consumed either local wines or imports from neighboring producers (Hall and Mitchell, 2008; Mancino and Presti, 2012; Dalmoro, 2013). Indeed, the minimal cross-border interaction stimulated the significant growth of wine market in within Europe (Hussain et al., 2007). More than 75% of the volume of world’s wine production, consumption and trade took place within Europe (Anderson, 2001). The four largest European wine producers, France, Italy, Spain and Germany belong to the so-called the “Old World”, defined as those within Europe, have a long, uninterrupted history of wine production and consumption (Hussain et al., 2007; Flint and Golcic, 2009). As

such, the Old World producers relied on their centuries of tradition and thus wine has been very much a ‘European product’ for a long time (Anderson, 2001; Flint and Golicic, 2009).

1.3 The Drivers of Growth in Wine Trade

Thanks to globalization, the wider and stronger levels of competition in the wine industry are driven by three forces: (1) a worldwide over-supply of grapes and the incumbent pricing pressures. Production surpluses have ranged between 15 and 20 percent over the 1990s (Anderson et al, 2001; Spawton, 2001; Hussain et al., 2007; Flint and Golicic, 2009); (2) increased consolidation in all tiers of the supply chain comprising the producer, distributors and retailing sectors making it difficult for the tens of thousands of wineries to get their product onto the shelves; (3) changing consumer behavior pattern of this product due to consumers are becoming more knowledgeable about products and brands and discerning in their choice of products. For instance, the beverage wine consumers of the 1970s are now becoming the fine wine buyers of the 1990s (Spawton, 2001; Islam and Quaddus, 2005; Hussain et al., 2007; Flint and Golicic, 2009). Like other industries, the wine industry is confronted with both old and new challenges. Among the five major emerging producers, known as the “New World” (i.e., US, Argentina, Australia, South Africa and Chile), they are located outside Europe - have prepared for the rapid invasion of the global wine markets (Hussain et al., 2007). Besides, in 2001, a report commissioned by the French Ministry of Agriculture points out that:

“Until recent years, wine was with us. We were the center, the unavoidable reference point. Today, the barbarians are at our gates: Australia, New Zealand, the USA, Chile, Argentina, South Africa” (Anderson, 2003, pp. 47)”

As depicted in table 1, the global wine production of the Old World has decreased by 1.2%, from 13.8 billion liters in 2002 to 13.7 billion liters in 2010. It is revealed that the top four Old World producers encounter the stiff competition from their New World competitors. Accordingly, they gradually, and continuously, lost market shares within the wine industry (Hussain et al., 2007).

Table 1. Evolution of Wine Production by Country from 2002 to 2010

	2002 Production		2010 Production	
	<i>billion liters</i>	<i>% of world production</i>	<i>billion liters</i>	<i>% of world production</i>
Old World Countries				
France	5.0	19%	4.6	16%
Italy	4.5	17%	4.6	18%
Spain	3.3	13%	3.6	14%
Germany	1.0	4%	0.9	3.8%
Total	13.8	53%	13.7	51.8%
New World Countries				
United States	2.5	10%	2.7	11%
Argentina	1.3	5%	1.6	4.6%
Australia	1.2	5%	1.0	4.4%
South Africa	0.7	3%	0.9	3.8%
Chile	0.6	2%	0.9	3.8%
Total	6.3	25%	7.1	27.6%
World total	26	100%	26.4	100%

Source: Wine Institute (2010)

1.4 The Development of a New Huge Market for Wine in China

The increased global trade provides opportunities to wine business in the contemporary business environment for wine. On average, a quarter of the wine produced the world is traded internationally in the past two decades (Hall and Mitchell, 2008). Decreasing tariffs, reducing logistics cost and the removing certain trade barriers foster wine producers the opportunity to sell their products outside of their own regions and shifts in wine consumption patterns. In 2001, five ‘New World’ countries, namely Australia, Canada, Chile, New Zealand and the US, joined forces to “diminish barriers by reducing regulatory burdens faced by winemakers”

by signing the Mutual Acceptance Agreement on Oenological Practices. In order to enlarge their market share and encounter keen competition from the New World, the Old World countries expanded their new target markets to Asian countries, like China and India (Hussain et al., 2007). It followed that there had been a growing trend that the demand in Europe was declining and grew much more slowly in the US. The wine consumption pattern is expected to shift in one distinct growth area – East Asia (Hong Kong Trade Development Council, 2010), with China being a significant emerging wine market. According to *The International Wine and Spirit Research*, Chinese alone had consumed about 2.1 billion liters of wine. The total value of wine has accumulated to RMB 46.3 billion dollars (Xinhua net, 2013). It is especially true in the first-tier cities, of which Guangzhou, Shenzhen, Beijing and Shanghai have gradually established regular wine consumption patterns in the past decade. Additionally, some festivals including Lunar New Year, Labor Day, National Day and Christmas have reached peak demands. By 2020, wine consumption in China is expected to increase by 40% and ranked the first in the world (China Daily.com, 2013), with wine-tasting increasingly becomes popular, especially among the middle class. In terms of value, wine can be classified into commercial/everyday wine (i.e., around RMB 100); the mid-range (i.e., ranged from RMB 200 to RMB 500) and fine wine (i.e., ranged from RMB 600 to over RMB 1,000). In this regards, the majority of Chinese are expected to purchase fine wine due to a high level of quality assurance (Hong Kong Sea Transport and Logistics Association, BUD Project 2013). Furthermore, East Asian importers encounter considerable logistics challenges in wine trade, especially between Europe and Asian countries. Such complexity could be an opportunity for differentiation for Hong Kong. Higher levels of complexity are mainly determined by (1) Asian importers need to deal with different small operators (i.e., small producers in France); (2) Ex-works practice due to producers in France are not involved in transportation, and thus they must organize the transport and supply chains themselves; (3) Asian importers use freight forwarders and 3PL providers to provide specialized wine logistics service, and hence, wine logistics, including its process and logistics, is often difficult to control effectively; and (4) Most of the wine shipments between France and East Asia are conveyed in dry (rather than reefer) containers. By using dry container to deliver the wine, importers confront with the challenges in humidity and temperature variation, which in turn affect the product quality and value.

1.5 How the International Trade of Wine is Analyzed and How It Could Be From The Point of View of Strategic Management

Despite the significance and importance of wine in international trade, a review of the scholarly work on wine indicates that the existing literature is either limited to quantitative modeling, operational research (for instance, Giuliani, 2007; Ferrer et al., 2008; Bohle et al., 2010) or predominantly descriptive (for instance, Spawton, 1991; Hussain et al., 2007; Flint and Golicic, 2009). Very few studies looked at it from the strategic management perspective, thus leaving a significant research gap yet to be filled.

Understanding such, this paper investigates how the Hong Kong wine industry utilizes their inherent resources and enhances their capabilities to compete with neighboring competitors in the dynamic and challengeable environment. The resources are defined as heterogeneity, rare, imperfectly mobile, imitable and non-substitutable (Peteraf, 1993). The critical resources can either tangible like infrastructure, facilities and configuration, or intangible like individual expertise and skills, know-how, reputation and custom particle that the Hong Kong wine industry owns, controls and access to on a semi-permanent basis (Valentin, 2001; Helfat and Peteraf, 2003; Lai, 2004). On the other hand, capacity is related to the competences and capabilities of the Hong Kong wine industry to perform a coordinated set of tasks to build, integrate and reconfigure the internal and external resources and capabilities so as to appropriately match the opportunities in the environment (Teece et al., 1997; Helfat and Peteraf, 2003). Based on that, this study can help the Hong Kong wine industry to differentiate from their competitors on providing a wide variety of wine service and promote Hong Kong as Asia's wine trading and distribution centre.

The rest of the paper is structured as follows. Section 2 will examine the external environment of the Hong Kong wine industry. Section 3 will investigate wine logistics firms into their wine logistics operations. Section 4 will discuss the possible directions for the Hong Kong wine industry so as to sustain the city's competitive advantage and enhance regional competitiveness in Asia region. Section 5 will discuss how the Hong Kong experience can provide valuable lessons to other countries and regions in developing themselves as the global/regional hub for wine trade and distribution. Finally, the conclusion can be found in section 6.

2. Contemporary Issues: How did Hong Kong Improve its Position in the Trade Network of Wine?

2.1 *The Development of A Wine Market in Hong Kong*

Traditionally, Chinese tea and soft drinks were the most popular beverages consumed by Hong Kong residents (Hall and Mitchell, 2008). Indeed, as a British colony (until 1997), the colonial government indicated slackness and a complacent attitude towards Hong Kong wine industry by imposing a very high wine tax (60-80%). Hence, there was no surprise that wine traditionally played a backseat role in Hong Kong's international trade (Dewald, 2003). Conversely, Hussain et al. (2007) noted that Hong Kong residents became more aware of the health benefits of wine produces, thus triggering an emerging pattern in Hong Kong from consuming Chinese tea and soft drinks to wine. Indeed, between 2000 and 2006, Hong Kong's domestic wine consumption had grown steadily at 10% and 13% in value and volume, respectively. In the same way, its import value has experienced a compound average growth rate (CAGR) of 22% between 2003 and 2006 (Hong Kong Trade Development Council, 2010). Accordingly, the rising popularity of wine consumption in Hong Kong and the soaring Asian demand stimulated public interest about the role of Hong Kong in the international wine market. Towards the end of the last century, the development of Hong Kong as East Asia's wine trading and distribution centre became more explicit (Dewald, 2003). The HKSAR Government recognized that wine investment was a high value-added business which could contribute considerable benefits to the city's economy, forecasting from more than HK\$1 billion in 2012 to almost HK\$3 billion in 2017, while simultaneously creating thousands of new job opportunities. Indeed, the development of wine-related business was considered to be a prerequisite for brining tremendous economic and intangible benefits in the contemporary business environment (Hong Kong Trade Development Council, 2010).

2.2 *How Can Hong Kong Could Improve its Position As A Major Player In Global Wine Trade?*

Globalization and driving forces will continue to create the pressure and strong competition within the wine industry. The Hong Kong wine industry encounters pressure from operators based in nearby neighbors, such as Singapore, Taiwan, and Mainland China. Other regions could play a similar role. For instance, Singapore has developed its homegrown strategy "Wine for Asia" targeting international traders and wealthy Asian buyers. Also, Mainland China also reduced their wine import tariff to 14% in 2004 (Trade Development Council press release, 2010). Therefore, the notion of regional competitiveness encourages the Hong Kong wine industry to encounter a competitive market in Asia region. In this paper, the authors follow the definition of the European Commission (1999) on 'regional competitiveness', which is:

"The ability to produce goods and services which meet the test of international markets, whilst at the same time maintaining high and sustainable levels of income, or more generally, the ability of regions to generate, while being exposed to external competitions, relatively high incomes and employment levels" (European Commission, 1999, pp. 10).

The regional competitiveness creates the Hong Kong wine industry to attain a sustained competitive advantage. Indeed, Porter and Kramer (2006, p.78) proposed that sustained competitive advantage is "an inescapable priority for business leaders in every country". The sustainable competitive advantage is related to the Hong Kong wine industry implements value creating strategy which is not able to duplicate and difficult to implement or imitate by the neighboring rivals in a longer period (Dierickx and Cool, 1989; Barney, 1991; Oliver, 1997). The nature of wine industry is fundamentally heterogenetic that they have differential advantages in the dynamic environmental circumstances (Barney, 1991; Peteraf, 1993; Flint et al., 2009), for instance, the wine logistics service provides is able to link European and Asian operators; possibility of concentrate greater volumes; managing transport (sea/air) solutions more efficiently; developing efficient customs systems; better matching between transport modes; and making wine more attractive to Asian retailers by implementing marketing campaigns. In this regards, Ghemawat (1986) points out that there are three effective strategies that can create the sustainable competitive advantage as required by the Hong Kong wine industry, namely (1) the size in the targeted market; (2) superior access to resources/customers and (3) restrictions on competitors' options. They will exploit their inherent strength and weakness as well as responding to opportunities and threaten others (Barney, 1991; Valentin, 2001).

3. The Concept of Agility: An Analytical Framework to Understand the Strategies of Firms Involved In Wine Trade

In this century, agility plays a significant role in fundamental and irreversible changes of the so-called “First World” economics (Sharp et al., 1999; Gavetti and Levinthal, 2000). In this regard, agility can foster the wine market growth through responding quickly of customer-based valuing of products or services in the unpredictable changing market (Yusuf et al., 1999). The concept of agility has discussed about firms possessing the ability to react quickly and be proactive to tackle customer demand’s fluctuations and the unpredictable and turbulent changes, as well as uncertain market environment (Christopher, 2000; Hult et al., 2002; Lee, 2004; Lin et al., 2006; Ketchen and Hult, 2007). In their study on agility, Lin et al. (2006) argued that agility required firms to enlarge their capabilities so as to keep pace with the ever-changing, and uncertain, environment. They identified four key elements pertaining to (1) responsiveness to identify changes and reactively to respond quickly from the dynamic business market; (2) competency to achieve business objectives efficiently and effectively; (3) flexibility to reach different objectives and goals with the same facilities in the networks and (4) quickness execute tasks and operations as short as possible. To increase agility, there are four critical variables, notably, technology, innovation, organization, and people are interactive and operate interdependently to respond changes proactively (Zhang and Sharifi, 2000).

New and emerging technology can facilitate the innovative and a quality of service to provide reliability and capacity availability in the wine industry. Thanks to technological innovation, it can increase the accessibility to create new markets, new customers, and new opportunities (Hult et al., 2002; Hult et al., 2003). The extensive use of IT, notably, electronic commerce and mobile technology fosters to trace and track in real time (Booth, 1996; Gunasekaran, 1999; Cagliano et al., 2004; Zhou et al., 2006). Here e-commerce plays significant roles in coordinating with different parties in the same platform. It is the main enabler for firms to maintain a competitive edge through reducing operating costs, enhancing strong partnership and improving customer services (Chan et al., 2012). Once the customer places an order, the firm can replenish and deliver wines to customer within 48 hours. Through e-commerce, it attracts virtual and physical wine inventories to Hong Kong and allows access to support services. Hence, it encourages industry cooperation to provide shared services for ordering, tracking and payment processing through electronic means (Hong Kong Trade Development Council, 2010). Furthermore, the wine industry has organized a variety of research and innovative activities to sustain their competitive position during crisis, and turn threats into new business opportunities (Lee, 2004). To support the growth of wine culture in Hong Kong, many hotels and restaurants promote wine appreciation; hosting well-attended wine tasting dinners and deluxe hotel wine cellars bulge with vintage collections; offering wine tasting events (Dewald, 2003; Hong Kong Trade Development Council, 2010).

In the contemporary world, most wine trading firms require a high tolerance, indeed resilience, of risk, and be proactive to environmental changes so that they can reconfigure themselves rapidly and adhocracy make changes to explore the new market opportunities (Hult et al., 2002; Zhou et al., 2006). From the strategic management perspective, effective management plays a significant role in the appropriate business strategies to align and adjust key systems, processes, decisions within the firm, information systems, organizational structure, and performance measurements with organizational goals and objectives (Das and Joshi, 2007). Indeed, the wine market and industry is a highly risky business (Hussain et al., 2007; Flint and Golicic, 2009). Hence, developing the performance measurements promote the firms in response to make changes and meet changing goals flexibility in a high volatile markets (Gunasekaran, 1999). The provision of crystal clear instructions to all levels of employees on its operating system and developing conflict resolution management, i.e., employees who make decisions and resolve conflicts based on the firm interest (Hult et al., 2003; Robbins and Coulter, 2005).

Similarity, the wine trading firms can catch up the new market opportunities through acquiring professional and multi-skilled people to manage, innovate, and initiate environmental change (Naman and Slevin, 1993). The continuous improvement can be achieved through the development of professional training and development systems, as well as, evolving appropriate human resource management programs (Slater and Narver, 1995; Gunasekaran, 1999; Sharp et al., 1999; Yusuf et al., 1999; Zhou et al., 2006). Underinvestment in continuous training and education, the actors’ skills and core competence should be reverted, and upgraded,

so as to respond to customer requirements quickly and effectively (Yusuf et al., 1999). In this regard, Hong Kong has a high level of wine knowledge and appreciation to gain immediate response and survival from the unprecedented threats in the dynamic business environment. For instance, Hong Kong wine logistics industry has set up advanced technological tools including cold chain management, EPC barcode or Radio-frequency identification (RFID) (i.e., used for real time inventory management and security in wine warehouse); anti-counterfeiting technology (such as smart phones application security labels with bar code or QR code use) so as to facilitate lower total cost and provide better customer service in efficient regional distribution (Booth, 1996; Zhang and Sharifi, 2000; Hoek et al., 2001; Chan et al., 2012). To promote Hong Kong wine industry's image, the industry has organized a wide variety of marketing activities and events, such as, HOFEX and Vinexpo. Additionally, Hong Kong wine industry could try to extend sales channel through different B2B market including four stars hotel, senior restaurant, and private clubs. These clients purchased a large quantity of wine, fixed replenishment cycle, and high customer loyalty rate in B2B market.

4. Wine Logistics Service Providers

Logistics is an important component in modern supply chains (Tang and Lau, 2013; Green et al., 2008). The Council of Supply Chain Management Professionals (2007) define logistics management as follows:

"That part of supply chain management that plans, implements, and controls the efficient, effective forward and reverse flow and storage of goods, services and related information between the point of origin and the point of consumption in order to meet customers' requirements." (The Council of Supply Chain Management Professionals, 2007)

Logistics is the concept of the right material, at the right place, at the right time, and in the right condition. It includes a wide range of activities pertaining to inventory management, warehousing, materials handling, secondary assembly, information-related service (notably, cargo track and trace) and distribution (Aguirre et al., 2010), and a part of corporate strategy to manage the organization and facilitate the flow of relevant information between inter-organization and intra-organization (Chan et al., 2012). The objectives are to serve the needs of firm to attain cost and service advantages (Lai et al., 2004). In the wine industry, wine logistics starts from growing, harvesting, processing, manufacturing to consumption. The objectives are to handle, process and deliver right wine to the right customer with the right quantity, in the right conditions at the right time (Shamsuzzoha and Helo, 2010). Also, it aims to cost reduction and flexibility for available wine. The whole process of continuous improvement is to eliminate non-value added activities or waste (Perez et al., 2010). The right wine indicates their salability, grade, freshness, texture, origin, appearance, size, weight, flavor, color, vintage, temperature or any other requirements specified by customers.

In the logistics industry, users (i.e., retailers and producers) and service providers (i.e., third party logistics, or 3PL) are two main categories. Thanks to the globalization and the increase in competitive pressures, many firms develop logistics as a key strategy to attain cost minimization and service maximization (Lun et al., 2006). Hence, there are more and more users which tend to outsource their logistics activities to 3PL providers. Recently, wine has played a significant role in Hong Kong's trading volume leads to a sustainable development in related and supporting industries, notably, logistics industry. A wine logistics service provider demonstrates four major dimensions for wine logistics service management including logistics facilities, a global network of partners, information technology and quality assurance. To explore wine logistics management, wine logistics service providers are examined in the study.

How the French wine is shipped from France to East Asia, and how do merchants buy wine in France? The role of Hong Kong wine logistics service providers has become significantly important. They provide specialized and professional wine logistics management pertaining to managing relationships and operations with actors in process, as well as efficient and effective flows of wine products and relevant information to fulfill customer requirements at a low cost. Also, wine logistics service providers facilitate close collaboration among different actors in managing different wine logistics activities. Wine logistics has evolved substantial changes from self-managed to contracted-out activities in the past decade. Wine logistics service providers could ease wine traders pressure from meeting demand fluctuations, reducing operating costs and capital investments (Lun et al., 2006).

4.1. Information System Management

Under the inevitable trend of globalization, firms encounter multiple pressures including market expansion, keen competition, and increasing customer expectations in a dynamic business environment. This motivates firms to minimize total cost and maximize customer service level through upgrading their capabilities. Thus, firms develop strategies on IT to overcome the complexity existed in global business (Chan et al., 2012). Wine logistics service providers illustrate IT or information systems to integrate wine logistics activities, such as, collecting, processing, retrieving, reporting and storing of data to achieve a competitive edge (Lun et al., 2006). In order to enhance its capacity in intercepting suspected counterfeit wine and verify wine authenticity, Hong Kong wine logistics industry has established a wide variety of advanced technological tools including cold chain management, EPC barcode or Radio-frequency identification (RFID) (i.e., used for real time inventory management and security in wine warehouse); anti-counterfeiting technology (such as smart phones application security labels with bar code or QR code use).

4.2. Transportation Management

In transportation management, one needs to balance the key elements (i.e., transport time, wine safety and quality) so as to facilitate the effective transportation of wine. Most of wine logistics service providers prefer to deliver the wine through sea transport and road transport due to low transport cost and a large number of bond warehouses have set up around ports. In designing wine delivery routing in China, wine logistics service providers consider to use Hong Kong as a transshipment port. Mainland Chinese customs trust goods from Hong Kong and hence, it could enhance customs facilitation measures. Also, Hong Kong wine industry has entered into a Closer Economic Partnership Agreement (CEPA) with Mainland Chinese government in 1 January 2006. Under CEPA, Hong Kong enjoys tariff-free treatment and establishes a cost-effective and convenient distribution hub to store their investment-grade wines for delivery to their markets on-demand. Non-Hong Kong made wine is subject to tariff rates of up to 20% when entering the mainland (HKTDC, 2013). The suggested wine logistics route planning in China has been illustrated in Table 2. During transportation, wine logistics service providers consider either wrapping air cushion inside wine bottle or equipping wine bottle inside wooden board for protection. Wine logistics service providers also require adding insulation layer into wine bottle in order to keep tight temperature control.

Table 2. Suggested Wine Logistics Route Planning in China

Mode of Transport	Route
Sea	Hong Kong → Nansha/Lianhuashan/Huangpu → other cities in Guangdong province
	Hong Kong → Yantian/Shekou/Chiwan → other cities in southern part of China
	Hong Kong → Humen → other cities in Pearl River Delta
	Overseas winery → Hong Kong → Pudong → other cities in northern part of China
	Overseas winery → Hong Kong → Tianjin → other cities in northern part of China
Road	Hong Kong → Man Kam To/Huanggang → Guangdong province
Rail	Hong Kong → Beijing
Air	Hong Kong → Guangzhou → other cities in Pearl River Delta
	Hong Kong → Shanghai → other cities in Yangtze River
	Hong Kong → Beijing → other cities in northern part of China

Source: Hong Kong Sea Transport and Logistics Association, BUD Project (2013)

4.3. Inventory Management

Inventory management includes coordinating, planning and controlling of wine along the logistics process. The level of stock and the speed of materials flow are the major constraints on wine logistics process, and are determined by the nature of demand and supply. On the one hand, the supply of wine comes from different geographical regions, wine logistics service company require to manage inventory with the objective of making available at the right time, the right products, in the right quantity at a cost-competitive manner. On the other hand, a wine logistics firm is indebted to the many customers they work with. The customer are from

different channels across the cities - hotels and restaurants, retail shops, supermarkets, wholesalers and individual consumers who are wine lovers etc. Hence, a wine logistics service firm could establish order management system to plan the order and control the delivery process on time. Common technologies such as Electronic Data Interchange (EDI), Materials Requirement Planning (MRPII), E-Commerce, Customer Relationship Management (CRM), and Enterprise Resource Planning (ERP) can be used to manage wine inventories and integrate various links along the wine logistics operations.

4.4. Warehousing

Wine is a valuable commodity which needs special care in warehouse operations. Suitable temperature and the thermostat are vital to the preservation of wine quality. Wine logistics service providers require storing the wine in appropriate storage facilities during the wait for inspection or customs clearance. Nowadays, Hong Kong Quality Assurance Agency (HKQAA) requires wine logistics service provider to install Wine Storage Management Storage (WSMS). Wine logistics service providers need to fulfill HKQAA code practices and system requirements including Temperature, Humidity, LED Lights, Vibrations, Maintenance, Security, Inventory Management, Fire Systems, Hygiene and Insurance. Basically, fine wine and commercial wine have distinct storage requirement (Table 3). However, it should be noted that the main variations of temperature take place during the travel.

Table 3. Fine Wine and Commercial Wine Storage

Items	Fine Wine	Commercial Wine
Temperature range	11-17°C	17-22°C
Maximum temperature variation per day	3°C	5°C
Maximum temperature variation per year	5°C	10°C
Humidity	55%-80%	>50%

Source: HKQAA (2013)

Hong Kong wine logistics service provider is one of key stakeholders in Hong Kong wine industry. In order to strengthen the competitiveness of Hong Kong wine logistics service provider, the Customs and Excise Department (C&ED) of Hong Kong and the General Administration of Customs of the Chinese mainland signed the “Cooperation Arrangement on Customs Facilitation Measures for Wine Entering the Mainland through Hong Kong” on 9 February 2010. The agreement has been implemented in Shenzhen. The measures include pre-valuation of wine duty and compression of clearance time at mainland ports. C&ED also implemented comprehensive measures to tackle counterfeit wine, for example, by establishing a dedicated investigation team; forming an alliance with the industry to strengthen cooperation in intelligence collection; setting up a specialist team under the alliance; and establishing a liaison network with overseas and Chinese mainland enforcement agencies to deal with suspected counterfeit wine and verify wine authenticity (HKTDC, 2013).

In the future, Hong Kong wine logistics service providers could help Hong Kong vintners to participate in the design and operations of the Mainland wine warehouse and thus, wine warehouse performance could achieve relevant customer metrics. Since the mainland logistics service providers are familiar with customs clearance and inspection, extensive transportation networks, strong logistics facilities support and past experience, it would be a good strategy for the Hong Kong wine logistics service providers to form a strategic partnership with the mainland logistics service providers. The mainland logistics service providers could provide the “last mile” delivery service so as to facilitate wine domestic sales for the success of Hong Kong’s wine logistics industry strategy. Furthermore, Hong Kong wine logistics service providers has a high level of service (i.e., using reefer to deliver the wine from time to time) and emphasized on quality and integrity. These advantages could collaborate with Hong Kong vintners to jointly develop wine market in the second-tier mainland cities (i.e., Dalian, Chengdu).

5. Regional Competitiveness and Policy Recommendations

Competitiveness is a universal term mostly applicable to the business and economic environment. It is a

method of benchmarking used for the firm to assess themselves and compare the internal performance with their competitors. Therefore, the firm gets superior performance by ongoing improvement (Francis et al., 2002; Budd and Hirmis, 2004). According to the UK's Department of Trade and Industry, "the competitiveness is the ability to produce the right goods and services of the right quality, at the right price and at the right time" (Department for Transport, United Kingdom, 2014).

Competitiveness is also understood as the firms has the ability to compete in the international market through the policy inputs like business environment, physical infrastructure and knowledge infrastructure as well as the essential conditions like business performance, productivity, price and cost and labor supply so as to increase efficiency and effectiveness (National Competitiveness Council, The Irish Government, 2006). In addition, the Organization for Economic Cooperation and Development (OECD) (1996) identify the national competitiveness is "the degree to which it can, under free and fair market conditions, produce goods and services which meet the test of international markets, while simultaneously maintaining and expanding the real incomes of its people over the long term."

The regional competitiveness is related to how the industry competes with neighboring rivals by attracting investment from foreign, private and public capital, creating innovation environments by skilled employees, entrepreneurs and creative workers and facilitating the technological development (Porter, 2003). After the removal of alcoholic duties in June 2008, wine imports surged around 80% in the first year. Compared with 2007, the wine-related business has increased by over 30% and the number of employees engaged in wine-related business increased by more than 5,000. In 2012, the imports of wine have reached HKD 8.1 billion, a four-fold increase compared to 2007 (HKTDC, 2013). It followed that the HKSAR government organized various activities and implemented policies to develop Hong Kong into a wine trade and distribution centre

- I. *Developing the first free wine port among major economies.* The Hong Kong SAR Government has announced that duties on wine, beer and alcoholic beverages (except spirits) were exempted in June 2008. Abolition of wine duty will facilitate Hong Kong position as the premier wine destination in the world and encourage high-value wines to be traded and purchased in Hong Kong. To facilitate the city as the first 'free wine port' of the Asia-Pacific region, the HKSAR government has signed cooperation agreements with 13 major wine-producing countries, such as, France (including Bordeaux and Burgundy regions), Spain, Australia, Italy, Hungary, New Zealand, the USA (i.e., Washington and Oregon States), Portugal, Chile and Germany in 2013. Through agreements, Hong Kong could undertake a leading role in organizing wine business activities in Asia Pacific region pertaining to wine-related trade, investment and tourism and providing good business matching opportunities.
- II. *Establishing marketing efforts.* In order to promote Hong Kong as Asia's wine trading and distribution centre, The Hong Kong Trade Development Council (TDC) has organized the first Hong Kong International Wine Expo in August 2008. This provides an opportunity to create a one-stop platform for exhibitors and buyers to meet and explore business opportunities in the emerging markets of Asia and the Chinese mainland. Hence, it could create and retain Hong Kong as a cosmopolitan flair in the world. To enhance reputation and enlarge networks with different Chinese provinces, Hong Kong wine logistics providers have participated and collaborated with Chinese wine exhibitors in different types of wine trade fair and exhibition per year. For instance, the China Food & Drinks Fair (CFDF); China International Wine and Spirits Exhibition; China (Guangzhou) International Wine Fair; Shanghai Wine Festival; International Exhibition of Food & Drink, Hotel, Restaurant & Food Service Equipment, Supplies & Services (HOFEX), to name but a few.
- III. *Strengthening wine education.* In recent years, Hong Kong has opened several wine centers, societies, clubs and schools to provide trade-qualified and accredited training. With a more formalized, professional educational system, a strong foundation and a sustainable base for a wine industry can be established. The number of wine-related professional courses grew from 21 in 2007 to 86 in 2009. The number of participants in these courses has reached over 8,500 in 2009, as well as over two times as compared with about 2,400 participants in 2007 (HKTDC, 2013). Furthermore, the Hong Kong wine industry creates innovation environment with over 2,000 knowledgeable wine liquor license holders as

well as training several sommeliers, wine journalists, wine logistics specialists, viticulturists and other wine stakeholders. The high-skilled and well-trained labor could contribute to the sustainable development of wine industry.

- IV. *Developing wine investment tools.* Hong Kong encourages the development of wine investment tools to offer competitive investment options including wine investment funds, wine futures and wine auctions for Hong Kong and Asian investors. As there is free flow of capital, it can attract enterprises do the investment in Hong Kong wine industry. In addition, Hong Kong can attract the private banks and wine auctions to offer wine investment funds. It is forecasted that the demand for wine investment by Asian investors will amount to US\$500 million by 2012 and reach at US\$970 million by 2017.
- V. *Promoting wine fairs or wine exhibitions with low cost inventory buffers in Hong Kong.* Wine is a risky business. The quality of wine is determined by temperature, humidity, light, and shock. The wine, especially for fine wine would face a high risk in wine fairs or exhibitions due to insufficient wine storage facilities, low demand and shrinkage costs. Thus, the wine trading firms could conduct comprehensive research in wine market demand before exhibition. To reduce the risk, we suggest that wine trading firms consider placing wine order either “less quantity with more assortment” or “large quantity with fewer assortments”.
- VI. *Creating express delivery services for wholesalers.* Hong Kong requires promoting the emergence of Hong Kong based distributors for Asian market. Wine logistics service company could provide an express delivery services to deliver the wine from Hong Kong to Asian regions within 24 hours. To facilitate the efficient wine delivery service, Hong Kong wine logistics service company collaborate with logistics parties in different regions so as to provide the “last mile” distribution service. Flexibility with quick response is the first mover advantage in the dynamic business environment.
- VII. *Creating a trademark of Hong Kong traders using reefer containers.* Hong Kong traders use reefer containers to deliver the wine so as to achieve higher customer service level, take care of wine during transport and storage, as well as maintain integrity attitude. As a result, Hong Kong wine traders could build up unique trademark to provide customer confidence and simplify wine customs inspection procedure.

6. Conclusion

This paper discusses the development of the wine industry and wine logistics in Hong Kong. In the coming years, the development of a wine trading and distribution centre not only generate direct benefits to Hong Kong's economy, but also bring indirect benefits from higher demand of linked businesses including storage, trade shows, educational programs, tourism, advertising and promotion, management and consulting services (Hong Kong Trade Development Council, 2013). In this paper, we apply the concept of agility to critically assess Hong Kong's potential evolution into a world-leading centre for wine trading and distribution. To deal with this situation, we provide practical recommendations for the Hong Kong wine industry to encounter the competition and grasp the feasible opportunity in the external environment. They include developing the first free wine port among major economies; Developing wine investment tools; Strengthening wine education; Establishing marketing efforts; Promoting wine fairs or wine exhibitions with low cost inventory buffers in Hong Kong; Creating express delivery services for wholesalers; and creating a trademark of Hong Kong traders using reefer containers are the key determinants to foster Hong Kong as the well-recognized global wine trading and distribution centre. Accordingly, it will give Hong Kong the ‘first mover’ advantage and gain sustainable competitive advantage.

This study is one of the pioneer studies to discuss and analysis on the wine industry, particularly in Hong Kong. It not only explores the internal and external situation of wine industry in Hong Kong, but also applies the concept of agility to identify the key elements of strengthening the role of Hong Kong as a world-leading wine trading and distribution centre and how Hong Kong wine industry utilizes their inherent resources and enhances capabilities to compete with neighboring competitors. Further research is required to carry out a

large-scale longitudinal study in the other countries so as to generalize our findings, and this paper has certainly offered a solid foundation in serving this purpose.

References

- Aguirre, A.B., Hennies, W.T. and Marks, A. (2010), Innovative logistics for the transportation of sand and gravel in Brazil, *International Journal Logistics Systems and Management* 7(4): 490-506.
- Anderson, K. (2001), Where in the world is the wine Industry Going? discussion Paper No. 0101, Centre for International Economic Studies, Adelaide University.
- Anderson, K., Norman, D. and Wittwer, G. (2001), Globalization and the world's wine markets: overview, discussion paper No. 0143, Center for International Economic Studies, Adelaide University, Australia.
- Anderson, K. (2003), Wine's new world, *Foreign Policy*, May-June 47-54.
- ASEAN Secretariat (2008), Roadmap for the integration of logistics services, Jakarta, Indonesia.
- Barney, J. (1991), Firm resources and sustained competitive advantage, *Journal of Management* 17(1): 99-120.
- Barrett, H. R., Browne, A. W., & Ilbery, B. W. (2004), From farm to supermarket: the trade in fresh horticultural produce from sub-Saharan Africa to the United Kingdom, *Geographies of commodity chains*, 19-38.
- Bellak, C.J. and Weiss, A. (1993), A note on the Australian diamond, *Management International Review* 33(2): 109-118.
- Bohle, C., Maturana, S., and Vera, J. (2010), A robust optimization approach to wine grape harvesting scheduling, *European Journal of Operational Research* 200(1): 245-252.
- Booth, R. (1996), Agile manufacturing, *Engineering Management Journal* 6(2):105-112.
- BUD Project, Upgrading and Branding Programme, Hong Kong Sea Transport and Logistics Association, 2013.
- Budd, L. and Hirmis, A.K. (2004), Conceptual framework for regional competitiveness, *Regional Studies* 38(9): 1015-1028.
- Cagliano, R., Caniato, F. and Spina, G. (2004), Lean, agile and traditional supply: how do they impact manufacturing performance, *Journal of Purchasing and Supply Management* 10(4): 151-164.
- Chan, X., Lau, Y.Y. and Ng, J.M.J. (2012), Critical evaluation of ERP implementation on firm performance: a case study of AT&T, *International Journal Logistics Systems and Management* 12(1): 52-69.
- China Daily.com, China will set pace for wine industry growth, http://www.chinadaily.com.cn/sunday/2013-03/10/content_16294916.htm, last accessed in 10 March 2013.
- Christopher, M. (2000), The agility supply chain: competing in volatile markets, *Industrial Marketing Management* 29(1): 37-44.
- Council of Supply Chain Management Professionals (2007), Supply chain management and logistics management definition, www.cscmp.org/Website/AboutCSCMP/Definitions/Definitions.asp, last accessed in 1 March 2014.
- Dalmoro, M. (2013), The formation of country wineries networks for internationalization: an analysis of two new world wines regions, *Journal of Wine Research* 24(2): 96-111.
- Das, S.R. and Joshi, M.P. (2007), Process innovativeness in technology services organizations: roles of differentiation strategy, operational autonomy and risk-taking propensity, *Journal of Operations Management* 25(3): 643-660.
- Department for Transport, United Kingdom's website: <http://www.dft.gov.uk>, last accessed in 2 March 2014.
- Dewald, B.W.A. (2003), Wine consumption in Hong Kong, *International Journal of Wine Marketing* 15(1): 54-68.
- Dierickx, I. and Cool, K. (1989), Asset stock accumulation and sustainability of competitive advantage, *Management Science* 35(12):1504-1511.
- Ellram, L. (1996), The use of the case study method in logistics research, *Journal of Business Logistics* 17(2): 93-115.
- European Commission. (1996), Cohesion and competitiveness: trends in the regions, 6th Periodic Report on Social and Economic Situation and Development of the Regions in the Community, Luxembourg: European Commission.

- European Commission. (1999), Sixth periodic report on the social and economic situation of regions in the EU.
- Ferrer, J.C., Cawley, A.M., Maturana, S., Toloza, S. and Vera, J.(2008), An optimization approach for scheduling wine grape harvest operations, *International Journal of Production Economics* 112(2): 985-999.
- Flint, D.J. and Golcic, S.L. (2009), Searching for competitive advantage through sustainability: A qualitative study in the New Zealand wine industry, *International Journal of Physical Distribution and Logistics Management* 39 (10): 841-860.
- Francis, G., Humphreys, I. and Fry, J. (2002), The benchmarking of airport performance, *Journal of Air Transport Management* 8(4): 239-247.
- Gavetti, G. and Levinthal, D. (2000), Looking forward and look backward: cognitive and experiential search, *Administrative Science Quarterly* 45(1):113-137.
- Gereffi, G. (2001). Shifting governance structures in global commodity chains, with special reference to the internet, *American Behavioral Scientist*, 44(10), 1616-1637.
- Ghemawat, P. (1986), Sustainable advantage, *Harvard Business Review*, 64(5): 53-58.
- Giuliani, E. (2007), The selective nature of knowledge networks in clusters: evidence from the wine industry, *Journal of Economic Geography* 7(2): 139-168.
- Grant, R.M. (1991), Porter's competitive advantage of nations: an assessment, *Strategic Management Journal* 12(7): 535-548.
- Green, K.W., JR., Whitten, D. and Inman, RA. (2008), The impact of logistics performance on organizational performance in a supply chain context, *Supply Chain Management: An International Journal* 13(4):317-327.
- Gunasekaran, A. (1999), Agile manufacturing: a framework for research and development, *International Journal of Production Economics* 62(1): 87-105.
- Hall, C.M. and Mitchell, R. (2008), *Wine Marketing: A Practical Guide*. Elsevier: Oxford.
- HKQAA's website: www.hkqaa.org, last accessed in 2 March 2014
- Hodgetts, R.M. (1993), Porter's diamond framework in a Mexican context, *Management International Review* 33(2):41-54.
- Hoek, R.I., Harrison, A. and Christopher, M. (2001), Measuring agile capabilities in the supply chain, *International Journal of Operations and Production Management* 21(1): 126-147.
- HOFEX, www.hofex.com, last accessed in 22 April 2014
- Hong Kong Trade Development Council, (2010), Hong Kong as a wine trading and distribution centre: opportunity for creating a new industry, press release, Hong Kong Trade Development Council, 17 February 2010.
- Hong Kong Trade Development Council (2013), Wine Industry In Hong Kong, <http://hong-kong-economy-research.hktcdc.com/business-news/vp-article/en/1/1X07WNW7.htm>, last accessed in 4 March 2014.
- Hussain, M., Cholette, S. and Castaldi, R.M. (2007), An analysis of globalization forces in the wine industry: implications and recommendations for wineries, *Journal of Global Marketing* 21(1): 33-47.
- Helfat, C.E. and Peteraf, M.A. (2003), The dynamic resource-based view: capability lifecycles, *Strategic Management Journal* 24(10): 997-1010.
- Hult, G.T.M., Ketchen, D.J., and Nichols, E.L. (2002), An examination of cultural competitiveness and order fulfillment cycle time within supply chains, *Academy of Management Journal* 45(3): 577-586.
- Hult, G.T.M., Snow, C.C., and Kandemir, D. (2003), The role of entrepreneurship in building cultural competitiveness in different organizational types, *Journal of Management* 29(3): 401-426.
- Islam, N. and Quaddus, M. (2005), An appraisal of uncertainties in the western australian wine industry supply chain, 49th Annual Conference of the Australian Agricultural and Resource Economics Society, Australia.
- Ketchen, D.J. and Hult, G.T.M. (2007), Bridging organization theory and supply chain management: the case of best value supply chains, *Journal of Operations Management* 25(2): 573-580.
- Kumar, N., Andersson, D., and Rehme, J., (2010), Logistics of low cost country sourcing, *International Journal of Logistics: Research and Applications* 13(2): 143-160.
- Lai, K.H., (2004), Service capability and performance of logistics service providers, *Transportation Research Part E* 40(5): 385-399.

- Lai, K.H., Cheng, T.C.E., and Yeung, A. (2004), An empirical taxonomy for logistics service providers, *Maritime Economics and Logistics* 6: 199-219.
- Lau, Y.Y., (2009), An application of the Porter's diamond framework: the case of Hong Kong airfreight industry, *Proceedings of International Forum on Shipping, Ports and Airports*, Hong Kong.
- Lee, H.L. (2004), The triple – a supply chain, *Harvard Business Review* 83(10): 102-112.
- Lin, C.T., Chiu, H. and Chu P.Y. (2006), Agility index in the supply chain, *International Journal of Production Economics* 100(2): 285-299.
- Lun, Y.H.V., Lai, K.H., and Cheng, T.C.E. (2006), *Shipping and Transport Logistics*, McGraw Hill, Singapore.
- Lun, Y.H.V., Lai, K.H. and Cheng, T.C.E. (2009), *Intermodal Transport Capability*, *Shipping and Transport Logistics Book Series*, 17-33.
- Mancino, A. and Presti, O.L. (2012), Wine tourism: a business opportunity for winemakers, *International Journal of Business and Globalization* 8(1): 153-169.
- Moon, H.C., Rugman, A.M, and Verbeke, A., (1998), A generalized double diamond approach to the global competitiveness of Korea and Singapore, *International Business Review* 7(2): 135-150.
- Naman, J.L., Slevin, D.P. (1993), Entrepreneurship and the concept of fit: a model and empirical tests, *Strategic Management Journal* 14(2): 137-153.
- National Competitiveness Council. (2006), *Annual Competitiveness Report 2006, Volume 1, Benchmarking Ireland's Performance*, Ireland: National Competitiveness Council, The Irish Government.
- Ng, A.K.Y., and Gujar, G.C., (2009), Government policies, efficiency and competitiveness: the case of dry ports in India, *Transport Policy* 16(5): 232-239.
- Oliver, C., (1997), Sustainable competitive advantage: combining institutional and resource based view, *Strategic Management Journal* 18(9): 697-713.
- Oz, O., (2002), Assessing Porter's framework for national advantage: the case of Turkey, *Journal of Business Research* 55(6): 509-515.
- Perez, C., DE Castro, R., Simons, D., and Gimenez, G. (2010), Development of lean supply chains: a case study of the Catalan pork sector, *Supply Chain Management: An International Journal* 15(1): 55-68.
- Peteraf, M.A., (1993), The cornerstones of competitive advantage: a resource-based view, *Strategic Management Journal* 14(3): 179-191.
- Porter, M.E., (1990), *The Competitive Advantage of Nations*, New York: Free Press.
- Porter, M.E., (1998), *The Competitive Advantage of Nations*, London: Macmillan.
- Porter, M.E., (2003), The economic performance of regions, *Regional Studies* 37(6-7): 549-578.
- Porter, M.E., and Kramer, M.R., (2006), Strategy and society – the link between competitive advantage and corporate social responsibility, *Harvard Business Review* December: 78-92.
- Robbins, S.P., and Coulter, M. (2005), *Management*, New Jersey: Pearson Prentice Hall.
- Shamsuzzoha, A.H.M., and Helo, P.T. (2010), Distributed supply chain in a global environment, *International Journal Logistics Systems and Management* 7(4): 393-411.
- Sharp, J.M., Irani, Z., and Desai, S. (1999), Working towards agile manufacturing in the UK industry," *International Journal of Production Economics* 62(2): 155-169.
- Simpson, J. (2011a). *Creating Wine: The Emergence of a World Industry, 1840-1914*. Princeton University Press.
- Simpson, J. (2011b). Factor endowments, markets and vertical integration, the development of commercial wine production in Argentina, Australia and California, 1870-1914, *Revista de Historia Económica* 29(1), 39.
- Slater, S.F., and Narver, J.C. (1995), Market orientation and the learning organization, *Journal of Marketing* 59(3): 63-74.
- Spawton, T., (1991), The wine marketing environment, *European Journal of Marketing* 25(3): 12-18.
- Tang, O. and Lau, Y.Y. (2013), Logistics aspects of avian influenza pandemic in Hong Kong, *International Journal Logistics Systems and Management*, 14(1): 110-131.
- Teece, D.J., Pisano G., and Shuen, A., (1997), Dynamic capabilities and strategic management, *Strategic Management Journal* 18(7): 509-533.
- The International Wine and Spirit Research's website: <http://www.iwsr.co.uk/>, last accessed in 1 March 2014.
- Valentin, E.K., (2001), SWOT analysis from a resource-based view, *Journal of Marketing Theory and Practice* 9(2): 54-69.

- Van Den Bosch, F., and Van Prooijen, A.A., (1992), The competitive advantage of European nations: the impact of national culture – a missing element in Porter's analysis?, *European Management Journal* 10(2):173-177.
- Vinexpo, www.vinexpo.com, last accessed in 22 April 2014.
- Wine Institute, (2010), *World Wine Production by Country*, San Francisco: CA.
- Xinhua net, Chinese wine market consumption does not affect short-term wine prices, http://news.xinhuanet.com/food/2013-06/25/c_124905488.htm, last accessed in 25 June 2013.
- Yin, R., (1989), *Case study research: Design and methods*. Beverly Hills: Sage Publications.
- Yusuf, Y.Y., Sarhardi, M., and Gunasekaran, A. (1999), Agile Manufacturing: the drivers, concepts and attributes, *International Journal of Production Economics* 62(1): 33-43.
- Zhang, Z., and Sharifi, H. (2000), A methodology for achieving agility in manufacturing organizations, *International Journal of Operations and Production Management* 20(4): 496-512.
- Zhang, A. (2003). Analysis of an international air-cargo hub: the case of Hong Kong. *Journal of Air Transport Management*, 9(2), 123-138.
- Zhou, K.Z., Tse, D.K., and Li, J.J. (2006), Organizational changes in emerging economies: drivers and consequences, *Journal of International Business Studies*, 37(2): 248-263.

High-speed Rail and Airline Cooperation under the Multinomial Logit Model: Model and Properties

Kimitoshi Sato^{1} and Yihsu Chen²*

¹Faculty of Systems Science and Technology, Akita Prefectural University, 84-4 Ebinokuchi, Tsuchiya, Yurihonjo, Akita, 015-0055, Japan. E-mail: kimitoshi-sato@akita-pu.ac.jp.

²National Graduate Institute for Policy Studies (GRIPS), 7-22-1, Roppongi, Minato-ku, Tokyo 106-8677, Japan.
School of Social Sciences, Humanities and Arts, School of Engineering, University of California-Merced, CA, USA.
E-mail: yihsu.chen@ucmerced.edu.

**Corresponding author*

Abstract

Competition between airline and high-speed rail (HSR) has been an active research area for years. One emerging issue that has received relatively little attention is the implications of cooperation between these two sectors or when these two sectors become complement to each other. Cooperation or integration, in the current context, refers to the situation at which an airline uses the HSR to provide continuing short-distance services from a hub to a final destination (a spoke) in its network. We study the cooperation between the airline and the HSR sectors by formulating their joint profit maximization problem using the multinomial logit choice model in a three-node setting. In the three-node setting, the flight connecting a pair of origin (an overseas city for example) and a domestic destination is through a domestic hub. Between the hub and the final destination, there are two choices of transportation modes available, i.e. HSR and airline. The demand for each choice is not only a function of its price but also its service quality, such as total trip time, frequency of services and easiness of connecting from the hub to a nearby HSR station. We have the following preliminary findings in the paper. First, compared to the competition case, the market share of the HSR would increase in conjunction with a decline of the market share of the air travel mode. The joint profit earned by the air and the HSR sectors will be higher as the service quality that jointly offer to customers by the two sectors is improved in the cooperation case. Second, if the share of the HSR in the competition case is greater than the travel by air, its market share will also be greater than the air travel mode when the cooperation of the two sectors occur. Finally, our numeric results suggest that there is a positive gain of the social surplus when the cooperation takes place, and the size of the social surplus increase is positively associated with the improvement of the service quality provided by the air-HSR cooperation. The policy implication from our work is that the benefit of possible air-HSR cooperation should be accounted for when planning for future HSR routes.

Keywords: Integration; Competition; Airline; High-speed rail; Multinomial logit model.

1. Introduction

Traditionally, with the increase of its speed, HSR (High Speed Rail) has become one of most efficient way to commute between a pair of origin and destination whose distance is apart for less than 1000km or traveling time is less than 1.5 hours (Janic 1993, Rothengatter 2011, Givoni, 2005). In this view, HSR is a de facto competitor of the airline as it substitutes the service which otherwise will be provided by the airline. For example, with the introduction of a HSR in Taiwan in 2007 linking a largest cities Taipei and Kaohsiung (apart by 248 km), the domestic airline industry has experienced a significant drop in market share and profit loses (Jeng and Su 2013). However, as alluded to by Givoni and Banister (2006), the relationship between airline and HSR is far from pure competitors. In particular, they argue that the existence of HSR can complement to the airline industry by providing services from a node within an airline network to nearby cities. In fact, this HSR-airline “cooperation” is especially economic desirable for hub-spoke types of network which one commonly seen in most countries. With most airport located distance from city centers, the integration of HSR with local train network can further enhance the benefit associated with HSR-airline

cooperation. Other often cited benefit of HSR-airline cooperation include environmental benefit associated with CO2 emissions (Givoni 2007).

As HSR-airline cooperation remains to be a relatively new concept, there are only a limited number of cases / routes that such cooperation is actually implemented, most of which can be found in Europe Continent. One example is the air-rail services provided by Lufthansa and Deutsche Bahn that link the airline hub Frankfurt to nearby cities, including Stuttgart, Cologne and Bonn. Those three cities are located between 130 and 150 km from Frankfurt with commuting time between 38-65 minutes. Everyday, the number of trips from Frankfurt to Stuttgart, Cologne and Bonn is 23, 43 and 27, respectively. Passengers traveling from a origin to one of these three cities were provided with a combo ticket, which includes an airline ticket to Frankfurt as well as a HSR ticket from Frankfurt to the final destination. Such cooperation provides two obvious benefits. First, luggage will directly be delivered to the final destination, thereby passengers could avoid the hassles of retrieving luggage in airports as well as inconvenience of carrying them during their transit. This could also limit the possible time-delay caused by luggage transit when the airport crew need to take care a large volume of luggage during rush hours. Second, HSR in these three cities is integrated with local train network, therefore eliminating the need for connecting to other forms of ground transportation.

While airline-HSR cooperation is seemingly appealing, its actual implementation is subject to a number of practical challenges. Perhaps the most important one is the fact that airline and HSR are owned by separate entities, who are operated under different objectives and “institutional”. Traditionally, they see each other as rivals and compete for the same consumers. In fact, with Tokyo’s successful bid for hosting 2020 summer Olympics, discussions have been underway to use Shizuoka airport as a hub through which passengers from other countries could visit Tokyo and Osaka during the events. The plan serves for two purposes. One is that two major airports serving Tokyo area, Narita and Haneda, have already constrained by their capacity during busy seasons. Any further demand during the event would likely push their operation over the limit, leading to possible transportation traffic fiasco. Second, in fear of possible disruptions caused by earthquakes or other natural hazards, this airline-HSR cooperation provides a much needed alternative to ensure reliable transportation during the events. Yet, even if it is only at its initial discussion phase, confrontation has been raised by two involving entities: JR (Japan Railway Company) and Shizuoka prefecture. In particular, JR argued that it is engineering challenging and technically impossible to construct an underground facility under the current location of Shizuoka airport to serve the intended purpose of linking airport to ground transportation HSR network. This highlights the difficulty of the government if its intention is to rely on the two parties to voluntarily engage in a health discussion for possible HSR-air cooperation.

Another possible explanation of why there is only little HSR-airline cooperation in practice is that the benefit and trade off of such type of cooperation is not well understood. Competition between airline and HSR industries has been an active research area for years (e.g. Park and Ha 2006, Adler et al. 2010, Yang and Zhang 2012, Behrens and Pels 2012, Gonzalez-Savignat 2004). In particular, two papers conclude that introduction of a new HSR would have a negative impact on the airline industry by decreasing its market share (Gonzalez-Savignat 2004 and Park and Ha 2006). Alder et al. (2012) developed a fairly complete game-engineering model and concluded that EU could benefit from airline-HSR cooperation. Yang and Zhang (2012) studied the competition these two sectors by formulating the objective of HSR as a weighted sum of its profit and social surplus. The paper shows that increase the weight on social surplus would lower the price of both HSR and airline, thereby benefit consumers. This is not a surprising result as the HSR sector includes consumer surplus as its objective. The paper then conducts comparative statics analysis on airport access time, rail speed and other factors. Finally, an empirical study by Behrens and Pels (2012) focuses on London-Paris market and finds that there was intensive competition between airline and HSR. The paper further identifies that frequency, travel time, and easiness to connect to other network are the keys, which determine travelers’ preference. On the other hand, literature on the cooperation between these two sectors is relatively thin (Jiang and Zhang 2014, Givoni and Banister 2006, Cokasova 2006, Socorro and Vicens 2013). Two papers, which are most relevant to our papers, are work by Socorro and Vicens (2013) and Jiang and Zhang (2014). Both papers use a simplified three-node network in which an origin city (a foreign city for example) is linked to a final domestic destination through a domestic hub and consider the cases whether the airport is capacity constrained or not. However, Socorro and Vicens (2013) applied a prescribed rule to ration airport capacity when there is a shortage in capacity. In contrast, Jiang and Zhang (2014) endogenizes the decision of

allocating scarce airport capacity between different markets. The paper further analyzes the impact of economies of traffic frequency, vertical differentiation between nodes, price elasticity and heterogeneous passenger types on the market outcomes. In a way, the framework developed by Jiang and Zhang (2014) is more complete and allows for considerations for other factors, which have practical relevance to consumers' preference.

Our paper also relies on a simple three-node network to examine the market outcomes of airline-HSR cooperation considering airport capacity. However, our work is different from Jiang and Zhang (2014) and Socorro and Vicens (2013) in a number of ways. First, we deploy a multi-nomial logit model to represent consumers' travel demand. Thus, compared to Jiang and Zhang (2014), we allow the factors that are crucially for determining the demand for different transportation modes, such as frequency, travel time, cost, time to airport or HSR station, conformability, to affect the demand nonlinearly. In other words, our approach does not require the marginal effect of these factors on the demand to be constant. Second, with the way we model the demand, the paper allows "non purchase" as an outside option to be available to consumers. That is, when their maximum willingness to pay is less than the cheapest ticket prices, they can decide to cancel the trip. Therefore, our model can more appropriately reflect the decision making process of consumers. Without "non-purchase" option, the analysis might over-estimate the market share of both transportation modes.

2. Notations

Following Jiang and Zhang (2014), we consider a network structure in which there are three cities (A, B and H) with inter-city transport services, AH and HB, being offered on only two links (see Figure 1). AH is operated only by an air sector while HB is served by both the airline and a high-speed rail (HSR) operators. In addition, the air carrier serves the AB market using a hub-and-spoke strategy with H as its hub. That is, there is no direct flight service in the AB market.

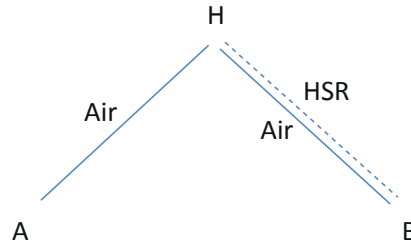


Fig 1. Three cities network

Let M_i be the number of potential customers in the market i where $i = 1, 2, 3$ indicate markets AH, HB and AB, respectively. It represents the city's population or annual number of passengers from the city. Subscript j represents transportation mode, in which $j = a$ is the air service and $j = r$ is the HSR service. We define the set of services in the market i as \mathcal{N}_i . In the market 1 and 2, we have $\mathcal{N}_1 = \{a\}$ and $\mathcal{N}_2 = \{a, r\}$, respectively. In the market 3, the services differ between the competition and cooperation cases, and will be described in detail.

Let $f_{i,j}$ is the price of the transportation mode j in the market i , and \mathbf{f}_i be the vector of the prices in the market i . Here, we assume that the both sectors sell a single fare class and do not consider the discount fares. The consumer utility function for the service j in the market i is defined by

$$U_{i,j} = b_{i,j} - \beta_i f_{i,j} + \epsilon, \quad i = 1, 2, 3, j \in \mathcal{N}_i \quad (1)$$

$$U_{i,0} = u_{i,0}, \quad i = 1, 2, 3, \quad (2)$$

where $u_{i,0}$ is the utility for non-purchase choice, and $b_{i,j}$ is determinate parts of utility is depending on observable attributes of alternative j . The non-purchase customers select neither airline nor HSR. A common assumption of the $b_{i,j}$ is the linear-in-attributes model $b_{i,j} = \boldsymbol{\beta}^T \mathbf{x}_{i,j}$, where $\boldsymbol{\beta}$ is a vector of parameters, and $\mathbf{x}_{i,j}$ is a vector of attribute values for alternative j in market i such as travel time, frequency and measures of quality and etc. Thus, we refer to $b_{i,j}$ as service quality in the rest of this paper. We assume that the ϵ is i.i.d. random variables with a double exponential distribution with cumulative density function $F(x) =$

$\exp\{-e^{-(\frac{x}{\mu}+\gamma)}\}$, where γ is the Euler's constant, and μ is a scale parameter. The mean and variance of ϵ are 0 and $\mu^2\pi^2/6$, $\mu > 0$, respectively. The probability that customers in the market i select a service j is given by

$$P_{i,j}(\mathbf{f}_i) \equiv P(U_{i,j} = \max_{j \in \mathcal{N}_i \cup \{0\}} U_{i,j}) = \frac{e^{\frac{1}{\mu}(b_{i,j} - \beta_i f_{i,j})}}{\sum_{j \in \mathcal{N}_i} e^{\frac{1}{\mu}(b_{i,j} - \beta_i f_{i,j})} + e^{\frac{u_{i,0}}{\mu}}}. \quad (3)$$

The probability of the non-purchase is given by

$$P_{i,0}(\mathbf{f}_i) \equiv P(U_{i,0} = \max_{j \in \mathcal{N}_i \cup \{0\}} U_{i,j}) = \frac{e^{\frac{u_{i,0}}{\mu}}}{\sum_{j \in \mathcal{N}_i} e^{\frac{1}{\mu}(b_{i,j} - \beta_i f_{i,j})} + e^{\frac{u_{i,0}}{\mu}}}. \quad (4)$$

The cost of the service j in the market i , $C_{i,j}(\cdot)$, consists of the proportional and fixed costs:

$$C_{i,j}(x) = c_{i,j}x + I_{i,j}, i = 1, 2, j \in \mathcal{N}_i. \quad (5)$$

In addition, we define the proportional cost in the market 3 as $c_{3,a} = c_{1,a} + c_{2,a}$ and $c_{3,ar} = c_{1,a} + c_{2,r}$.

3. Air-Rail Integration Model without Airport Capacity Constraint

In this section we represent the air-HSR competition and cooperation cases in section 3.1 and 3.2, respectively.

3.1 Competition Case

In the competition case, the air and HSR sectors compete in the route HB, and the air sector is a monopoly in the market $i = 1$ (AH) and $i = 3$ (AB). Thus, the set of available transportation modes in the markets is $\mathcal{N}_1 = \{a\}$, $\mathcal{N}_2 = \{a, r\}$ and $\mathcal{N}_3 = \{a\}$, respectively. Using the choice probability defined in equations (3) and (4), the expected demand for mode j in market i is calculated as the product of the market share and the probability. That is, $d_{i,j} \equiv M_i p_{i,j}$.

The airline's profit is then given by

$$v_a(\mathbf{f}) = \sum_i f_{i,a} d_{i,a} - C_{1,a}(d_{1,a} + d_{3,a}) - C_{2,a}(d_{2,a} + d_{3,a}), \quad (6)$$

where $\mathbf{f} = (f_{1,a}, f_{2,a}, f_{3,a}, f_{2,r})$, a vector of ticket prices in the markets. The airline's maximization problem is given by

$$V_a \equiv \max_{\mathbf{f}_a} v_a(\mathbf{f}), \quad (7)$$

where $\mathbf{f}_a = (f_{1,a}, f_{2,a}, f_{3,a})$. The HSR's profit is given by

$$v_r(\mathbf{f}_2) = f_{2,r} d_{2,r} - C_{2,r}(d_{2,r}), \quad (8)$$

where $\mathbf{f}_2 = (f_{2,a}, f_{2,r})$. Thus, the HSR's maximization problem is given by

$$V_r \equiv \max_{\mathbf{f}_{2,r}} v_r(\mathbf{f}_2), \quad (9)$$

Using the Lambert W function, we can obtain a closed-form expression for the market share, optimal price and total profit for both sectors (details are available upon request due to page limitation). The following proposition summarizes the effect of the service quality on the market share, optimal price and total profit.

Proposition 3.1

- (i) For each sector $j \in \mathcal{N}_i$, the market share $p_{i,j}^*$ and optimal price $f_{i,j}^*$ are increasing in the service quality $b_{i,j}$.

- (ii) The non-purchase probability $p_{i,0}^*$ is decreasing in the service quality $b_{i,j}$ for $j \in \mathcal{N}_i$.
- (iii) The maximal profits of the airline V_a and the HSR V_r are increasing in the service qualities $b_{i,a}$ and $b_{2,r}$, respectively.

This proposition is intuitive. An increase in the service quality of the sector in each market rises its market share and reduces the non-purchase probability. As customers value service quality, an increase in service quality also implies that they are willing to pay more, leading to a high optimal prices. Since the demand and price increase as the service quality increase, the profit of the both sectors increases.

Next, we show the relationship of the market share and optimal price between the air and HSR in the competitive market. We define the difference between the service quality and the proportional cost as a cost-adjusted service quality defined by $\hat{b}_{i,j} \equiv b_{i,j} - \beta_i c_{i,j}$.

Proposition 3.2

In the market 2 which is between H and B, we have following findings.

- (i) The optimal price $f_{2,j}^*$ for $j \in \mathcal{N}_2$ does not depend on the competitor's service quality $b_{2,k}$ for $k \neq j \in \mathcal{N}_2$.
- (ii) The market share $p_{2,j}^*$ is decreasing in the competitor's service quality $b_{2,k}$ for $k \neq j \in \mathcal{N}_2$.
- (iii) If the cost-adjusted service quality of the air sector is greater (less) than that of the HSR sector $\hat{b}_{i,r} \leq (\geq) \hat{b}_{i,a}$, then the market share of the air is greater (less) than that of the air, $p_{2,r}^* \leq (\geq) p_{2,a}^*$.

The interpretation of the proposition is mostly intuitive but might also need some further explanation. Part (i) gives that the relationship between the optimal price and the rival's service quality. In the equilibrium, the price is not affected by rival's service quality. However, as we can see in part (ii), it is not the case for market share. The part (ii) implies that the market share of air (HSR) sector decreases as the service quality provided by the HSR (air) increases in the market 2. By the proposition 3.1 (i), the market share of the air (HSR) increases as its service quality increases. Since the air (HSR) sector does not respond to the change of the rival's service quality by part (i), its market share decreases by increasing the rival's market share. From part (iii), the relationship between the market shares of the both sectors depend not only the service quality but also their proportional costs, because the proportional cost affects the optimal price.

Follow Small and Rosen (1981), the consumer surplus can be expressed as follows;

$$S(f) = \sum_i M_i \frac{\mu}{\beta_i} \log \left(\sum_{j \in \mathcal{N}_i} e^{\frac{1}{\mu}(b_{i,j} - \beta_i f_{i,j})} + e^{\frac{u_{i,0}}{\mu}} \right). \quad (10)$$

We define the consumer surplus in competition case as $S_C \equiv S(f^*)$.

Proposition 3.3

The total consumer surplus S_C is increasing in the service quality $b_{i,j}$.

While the optimal price is increasing in its service quality as alluded to in proposition 3.2, the total consumer surplus increases with the service quality. This is owing to the fact that the rate of change of service quality is greater than that of optimal price with respect to the service quality.

The social welfare is defined as the sum of the total consumer surplus and total profits from air and HSR operators:

$$W_C = S_C + V_C + V_a. \quad (11)$$

From propositions 3.1 (ii) and 3.3, we can easy to see that the social welfare is increasing in the service quality.

3.2 Cooperation Case

In the cooperation case, the air and HSR sectors make decisions jointly to maximize their total profit. The HSR not only operates in the market $i = 2$ (HB) but also in the market $i = 3$ (AB). Thus, customers who travel from A to B can then have choices between the airline ($j = a$) and HSR ($j = ar$) in the route HB, $\mathcal{N}_3 = \{a, ar\}$. We refer to the air-rail service as “ar”. Customers in market $i = 1$ face the same decisions as section 3.1.

The joint profit of HSR and air is given by

$$v_a(\mathbf{f}_{ar}) = \sum_i \sum_{j \in \mathcal{N}_i} f_{i,j} d_{i,j} - C_{1,a}(d_{1,a} + d_{3,a} + d_{3,ar}) - C_{2,a}(d_{2,a} + d_{3,a}) - C_{2,r}(d_{2,r} + d_{3,ar}), \quad (12)$$

where $\mathcal{N}_1 = \{a\}$, $\mathcal{N}_2 = \{a, r\}$, $\mathcal{N}_3 = \{a, ar\}$ and $\mathbf{f}_{ar} = (f_{1,a}, f_{2,a}, f_{3,a}, f_{2,r}, f_{3,ar})$.

Therefore, the joint maximization problem of the sectors is given by

$$V_{ar} \equiv \max_{\mathbf{f}_{ar}} v_{ar}(\mathbf{f}_{ar}). \quad (13)$$

Next proposition provides the impact of the service quality in the markets 2 and 3 on the market share, optimal price and total profit. Since the route AB ($i = 1$) in this instance is with the same setting as the competition case, the properties in the proposition 3.1 hold for $i = 1$. Thus, we consider the markets 2 and 3 except part (iii) in the following proposition.

Proposition 3.4

For the service $j \in \mathcal{N}_i$ in the market $i = 2, 3$, we have following properties.

- (i) The market share $\tilde{p}_{i,j}^*$ is increasing in its service quality $b_{i,j}$, and is decreasing in its partner's service quality $b_{i,k}$ for $j \neq k \in \mathcal{N}_i$.
- (ii) Optimal price $\tilde{f}_{i,j}^*$ is increasing in its own service quality $b_{i,j}$ and the partner's service quality $b_{i,k}$ for $j \neq k \in \mathcal{N}_i$.
- (iii) Maximum total profit V_{ar} is increasing in the service quality $b_{i,j}$ for $j \in \mathcal{N}_i$ and $i = 1, 2, 3$.

Part (i) suggests the market share is positively affected by its service quality but negatively by its partner's service quality. The practical implication is that if the connection between the airport and HSR station is improved, then the increase air-rail market share could relieve airport congestion and reduce the environmental pollution in the domestic route (HB). The part (ii) implies that the optimal price of own sector is increasing in its service quality, through the increase in market share. Although the market share of own sector decreases with better partner's service quality, the impact is outweighed by that of its own service quality, leading to an increase in the optimal price. (i)-(ii) jointly suggests that the joint profit is positive related to overall service quality.

Next proposition shows that the comparison of the market shares and optimal prices between the both sectors in the markets 2 and 3.

Proposition 3.5.

- (i) In the market 2, if the cost-adjusted service quality of the air is greater (less) than that of the HSR $\hat{b}_{2,r} \leq (\geq) \hat{b}_{2,a}$, then the market share of the air is larger (lower) than that of the HSR, $\tilde{p}_{2,r}^* \leq (\geq) \tilde{p}_{2,a}^*$.
- (ii) In the market 3, if the cost-adjusted service quality of the air is greater (less) than that of the air-rail $\hat{b}_{3,ar} \leq (\geq) \hat{b}_{3,a}$, then the market share of the air is larger (lower) than that of the air-rail, $\tilde{p}_{3,ar}^* \leq (\geq) \tilde{p}_{3,a}^*$.

- (iii) In the market 2, if the proportional cost of the HSR is less than that of the air $c_{2,r} \leq c_{2,a}$, then the optimal price of the HSR is lower than that of the air, $\tilde{f}_{2,r}^* \leq \tilde{f}_{2,a}^*$. In addition, the difference between the prices is equal to the difference between the proportional costs, $|c_{2,a} - c_{2,r}|$.
- (iv) In the market 3, if the proportional cost of the HSR is less than that of the air $c_{2,r} \leq c_{2,a}$, then the optimal price of the air-rail is lower than that of the airline $\tilde{f}_{3,ar}^* \leq \tilde{f}_{3,a}^*$. In addition, the difference between the prices is equal to $|c_{2,a} - c_{2,r}|$.

Parts (i) and (ii) summarize the impact of service quality and the proportional cost on the market share in the competitive route. In particular, part (ii) indicates that improvement in the accessibility between the airport and station (or $b_{3,ar}$ increases) results in an enlargement of the market share of air-rail. The parts (iii) and (iv) show that the relationship between the optimal prices of HSR and air is dependent upon the proportional costs for both sectors. Since the air-rail price is lower than the air price in the market 3, the more price-responsive customers would select HSR in the domestic route (HB).

Next, we only compare competition and cooperation cases for the market $i = 2, 3$ because the market 1 is not affected by cooperation.

Proposition 3.6.

- (i) In the market $i = 2, 3$, the optimal price in the cooperation case $\tilde{f}_{i,j}^*$, $j \in \mathcal{N}_i$, is higher than that in the competition case $f_{i,j}^*$.
- (ii) In the market 2, if the cost-adjusted service quality of the HSR is greater than that of the air, $\hat{b}_{2,r} \geq \hat{b}_{2,a}$, then the market share of the air sector in the market 2 decreases compared to the competition case, $\tilde{p}_{2,a}^* \leq p_{2,a}^*$.
- (iii) In the market 3, the market share of the airline in cooperation case is lower than that in competition case, $\tilde{p}_{3,a}^* \leq p_{3,a}^*$.
- (iv) In the market 2, the proportion of the market share of the HSR to that of the air sector in cooperation case is higher than the proportion in the competition case: $1 \leq p_{2,r}^*/p_{2,a}^* \leq \tilde{p}_{2,r}^*/\tilde{p}_{2,a}^*$.
- (v) Reversely, the proportion of the market share of the HSR to that of the air sector in competition case is larger than the proportion in the cooperation case: $\tilde{p}_{2,r}^*/\tilde{p}_{2,a}^* \leq p_{2,r}^*/p_{2,a}^* \leq 1$.

Since the HSR and air sectors are monopoly in cooperation case, as shown in part (i), the optimal prices in the markets 2 and 3 increase compared to the competition case. Part (ii) implies that the market share of the air is reduced by the cooperation when the cost-adjusted service quality of the air is lower than that of the HSR. If the condition of the cost-adjusted service quality does not hold, then these effect on the market share is ambiguous in air-HSR. Part (iii) suggests that the market share of the air sector in the market 3 decreases compared to the competition case. Thus, the market share of the HSR would increase in conjunction with a decline of the market share of the air travel mode. The part (iv) shows that if market share of the HSR is larger than that of the air sector in the competition case, $p_{2,a}^* \leq p_{2,r}^*$, then the HSR share is also larger than the air share in the cooperation case $\tilde{p}_{2,a}^* \leq \tilde{p}_{2,r}^*$. In addition, the difference of the share between the HSR and the air sectors becomes large compared to that of the competition case, $p_{2,r}^*/p_{2,a}^* \leq \tilde{p}_{2,r}^*/\tilde{p}_{2,a}^*$. In the short-medium range market, the market share of HSR is typically larger than that of air in competitive situation. This result suggests that if the cooperation takes place in such market, then the HSR share is further expanded compared to the air share. Thus, the cooperation is effective to relieve airport congestion in such market. Contrary to the part (iv), the part (v) implies that if the market share of the air sector is larger than that of the HSR in the competition case, $p_{2,r}^* \leq p_{2,a}^*$, then the share of the air sector in the cooperation case is also larger than the share of the HSR, $\tilde{p}_{2,r}^* \leq \tilde{p}_{2,a}^*$. In addition, the difference of the share between the HSR and the airline become large compared to competition case, $\tilde{p}_{2,r}^*/\tilde{p}_{2,a}^* \leq p_{2,r}^*/p_{2,a}^*$. In the long-range market, the air share outpaces the HSR share. Thus, this result implies that even if the cooperation takes place in the long-range market, the HSR share does not increase. Therefore, the cooperation should be implemented in the short-medium range market.

The total consumer surplus in cooperation case is defined by $S_I \equiv S(\tilde{f}^*)$ where S is given by equation (10).

Proposition 3.7

The total consumer surplus S_I is increasing in the service quality $b_{i,j}$, $j \in \mathcal{N}_i$, $i = 1, 2, 3$.

For the same reason with the competition case in proposition 3.3, the consumer surplus increases as the service quality increases. The social welfare is defined by the sum of the consumer surplus and the total profit:

$$W_I = S_I + V_{ar}. \quad (14)$$

Similar with the competition case, by propositions 3.4 (iii) and 3.7, the social welfare is increasing in the service quality.

Since it is difficult to compare the total profit for all markets of the competition case and that of the cooperation case, we compare the profit in each market.

Proposition 3.8

- (i) In the market 1, the profit in competition case is equal to that of cooperation case.
- (ii) In the market 2, if the total demand in cooperation case is greater than that in competition case $p_{2,a}^* + p_{2,r}^* \leq \tilde{p}_{2,a}^* + \tilde{p}_{2,r}^*$, then the profit in cooperation case is greater than that in competition case.
- (iii) In the market 3, if the profit in cooperation case is greater than that in competition case.

The comparison between the profit in competition and cooperation cases is also discussed by the proposition 1 in Socorro and Vicens (2013). In their setting, when the both sectors decide the cooperation, the airline stops operating in the market 2 (that is, route HB), which is operated by the HSR as a monopolist. Then, they show that the airline and HSR obtain higher joint profits when they cooperate than when they remain separate. However, in our setting, the airline continues the service in the market 2 after the cooperation takes place. Thus, the effect of the cooperation on the profit in the market 2 is ambiguous. In the case where the total demand increases when the both sectors decide the cooperation instead of the competition, that is, $M_2(p_{2,a}^* + p_{2,r}^*) \leq M_2(\tilde{p}_{2,a}^* + \tilde{p}_{2,r}^*)$, the profit increases by the cooperation.

Proposition 3.9

- (i) In the market 1, the consumer surplus in competition case is equal to that of the cooperation case.
- (ii) In the market 2, the consumer surplus in cooperation case is lower than that in competition case.
- (iii) In the market 3, if the difference between the optimal prices of the air for both cases is relatively small $\tilde{f}_{3,a}^* - f_{3,a}^* \leq (\mu/\beta_3) \log 2$, then the consumer surplus in cooperation case is greater than that in the competition case.

In the market 1, the consumer surplus is not affected by cooperation because the price does not change. In the market 2, since the equilibrium price in cooperation case is larger than that in competition case from proposition 3.6 (i), the consumer surplus reduces when the both sectors cooperate. The effect of the cooperation on the consumer surplus in the market 3 is ambiguous since the air-rail service is operated in cooperation case. However, in the case where the equilibrium price of connecting flight in cooperation case $\tilde{f}_{3,a}^*$ is not much more than that in competition case $f_{3,a}^*$, the air and HSR cooperation increases the consumer surplus. These results are consistent with the proposition 2 in Socorro and Vicens (2013).

The propositions 3.8 and 3.9 indicate that there is a positive gain of the social welfare when the cooperation takes place, if the gain of the total profit is larger than the loss of the consumer surplus.

4. Conclusions

A relatively less explored research area in transportation sector is the implications of cooperation between airline and HSR (High Speed Rail) sector. ‘‘Cooperation’’ refers to the situation in which an airline uses HSR as an alternative to provide customers the continuing service from a hub to a nearby city. This paper studies the cooperation between two sectors by formulating their profit maximization problem using multinomial logit model. We consider here the airport capacity is not constrained. We derive the close-form solution for market

equilibrium and summarize our findings in several propositions. The case where the airport capacity is limited is subject to our future work.

References

- Adler, N., Pels, E. and Nash, C. (2010), High-speed rail and air transport competition: game engineering as tool for cost-benefit analysis, *Transportation Research Part B* 44: 812-833.
- Behrens, C. and Pels, E. (2012), Intermodal competition in the London-Paris passenger market: high-speed rail and air transport, *Journal of Urban Economics* 71 (3): 278-288.
- Cokasova, A. (2006), Analysis of Passenger Viewpoints and of the Practical Shift in Air Rail Intermodal Transport, PhD dissertation, University of Zilina.
- Givoni, M. (2005), Aircraft and High Speed Train Substitution: The Case for Airline and Railway Integration, Unpublished Ph.D. Thesis, University College, London.
- Givoni, M. (2007a), Environmental benefits from mode substitution: comparison of the environmental impact from aircraft and high-speed train operations, *International Journal of Sustainable Transportation* 1(4): 209-230.
- Givoni, M. (2007b), Air-rail intermodality from airlines' perspective, *World Review of Inter-modal Transportation Research* 1 (3): 224-238.
- Givoni, M. and Banister, D. (2006), Airline and railway integration, *Transport Policy* 13 (5): 386-397.
- Gonzalez-Savignat, M. (2004), Competition in air transports: the case of the high-speed train, *Journal of Transport Economics and Policy* 38 (1): 77-108.
- Janic, M. (1993), A model of competition between high-speed rail and air transport, *Transportation Planning and Technology* 17 (1): 1-23.
- Jeng, C.R. and Su, C.H. (2013), The predicament of domestic airline service after the introduction of Taiwan High-Speed Rail, *Transportation Journal* 52 (1): 134-143.
- Jiang, C. and Zhang, A. (2014), Effects of high-speed rail and airline cooperation under hub airport capacity constraint, *Transportation Research Part B* 60: 33-49.
- Park, Y. and Ha, H.K. (2006), Analysis of the impact of high-speed railroad service on air transport demand. *Transportation Research Part E* 42 (2): 95-104.
- Rothengatter, W. (2011), Competition between airlines and high-speed rail, In: Macario, R., van de Voorde, E. (Eds.), *Critical Issues in Air Transport Economics and Business*, Routledge, Oxford, UK.
- Small, K.A. and Rosen, H.S. (1981), Applied welfare economics with discrete choice models, *Econometrica*, 49 (1): 105-130.
- Socorro, M.P. and Vicens, M.F. (2013), The effects of airline and high speed train integration, *Transportation Research Part A* 49: 160-177.
- Yang, H. and Zhang, A. (2012), Effects of high-speed rail and air transport competition on prices, profits and welfare, *Transportation Research Part B* 46: 1322-1333.

Investigating the Change in Firm Performance using Balanced Scorecard: An Empirical Study of Logistics Service Providers in Egypt

Islam El-Nakib

Arab Academy for Science, Technology and Maritime Transport, College of International Transport and Logistics, Alexandria, Egypt.

Abstract

The problem with many Logistics Service Providers (LSPs) in Egypt is to assess their performance that has been changing for many years especially when change became necessary due to severe competition, unstable economy and political environment, and a rapid change in technology. The purpose of this study is to recognize the role and effects of Change Management (CM) on the performance of LSPs in Egypt through using the Balanced Scorecard (BSC). The BSC is one of the practical methods that can be used in evaluating the impact of changes on performance through linking the BSC's four categories (financial, customer relations, internal business processes, and learning and growth) with the 'change' four categories (technological, social, leadership, and structural change). This research follows a quantitative approach using an online questionnaire to collect responses from approximately 450 LSPs in the Egyptian logistics industry to investigate the relationship between CM on performance. Descriptive statistics and inferential analysis are performed to analyze the data collected and achieve the research aim. The findings of this research showed a significant impact of the different types of changes on performance of LSPs through the BSC measurement. These types of changes would then be emphasized as key to drive performance improvement. This research would contribute into filling the gap in literature in the field of LSP in Egypt, nevertheless in the Middle East and North Africa (MENA) region and draw the attention of researchers to this topic that can support the effectiveness of the supply chain business in Egypt. This research could influence LSPs in Egypt to use the BSC as a tool to assess their performance. In addition, it provides a novel approach in the method of assessing the impact of change on the performance of LSPs in Egypt for further recommended developments.

Keywords: Logistics Service Providers, Balanced Scorecard, Change Management, Performance measurement, Egypt.

1. Introduction

Logistics Service Providers (LSPs) provide multiple logistics services for customers comprising *inter alia* customer service, inventory management, transportation, warehousing, cross-docking, packaging, cargo handling, freight forwarding and several logistics and supply chain activities (Liu and Lyons, 2011). The emergence of LSPs is closely associated with the outsourcing phenomenon of the early 1980s. Supply chain stakeholders have tended to outsource all or part of their logistics activities previously performed in-house to one or more specialty firms or LSPs in order to concentrate on their core competences (Liu et al., 2010). Ron et al. (2011) stated that the global market has witnessed significant development of the LSPs industry. This is attributed to the increasing concern of business managers to delegate the management of non-core activities to LSPs in order to focus on core competencies, which results in appropriate quality and priced products based on customers' desires (Bourlakis and Melewar, 2011). Thus, logistics performance in supply chains, such as lead-time, flexibility and on-time delivery is created by customers, suppliers and LSPs, and should be a shared responsibility (Forslund, 2012). Moreover, the management of performance in supply chains is no longer based on functional hierarchies, ownership, or intra-company power but rather based on cross-company relationships, which have an important role in the competitiveness of LSPs (El-Nakib, 2011). It is important that performance measurement systems are dynamic, so that performance measures remain relevant and continue to reflect the issues of importance to the business (Kennerley and Neely, 2002). Forslund (2012) stated that the business environment is getting more competitive, claiming that the acquiring, analyzing and reporting of performance data is a success factor for LSPs and their customers. However, the BSC has evolved,

from the performance measurement tool originally introduced, to a tool for implementing strategies and a framework for strategy refinement by determining the alignment of organization's human, information and organizational capital with its strategy.

Farooq and Hussain (2011) stated that organizational change refers to the adoption of an idea, procedure, process, or behavior that is new to an organization. Recent developments have reinforced that learning from the best practices adjust the overall system for better change results. Simultaneously, the increasing turbulence in global supply chains would necessitate the adoption of a more proactive and entrepreneurial policy within the organization. Thus, the most well developed view is that change is generally motivated by events in an organization's environment. Some problems or surprises such as shortfall in expected performance, unexpected moves by competitors, shifts in technology, or new customer demand triggers a change (Svensson and Wagner, 2012). On the other hand, the logistics industry plays a significant role for the prosperity of the Egyptian economy, especially that the quality of the Egyptian products have been deteriorating and their prices have been increasing constantly. The International Finance Corporation (IFC, 2009 and 2011) reports have presented a comprehensive overview of Egypt's logistics sector. It represents a USD multi-billion market, with planned investments of \$7.5 billion in 2015 (IFC, 2011).

This research examines the LSPs' competitiveness in Egypt, through discovering the impact of change on performance through the BSC tool. It is essential to have an effective management of change, to reach effective performance. Therefore, to achieve this objective, literature related to BSC and change are reviewed. Studies presenting the successful employment of BSC for valuable CM are also appraised. In the light of the literature review, hypotheses were formulated, then the research design and analysis followed.

2. Literature Review

In this section, three significant aspects will be discussed: 1) an overview of the BSC and its role in measuring the performance of companies using Key Performance Indicators (KPIs) and its relation with the LSPs business. 2) change management and its impact on performance of LSPs. 3) an overview of the logistics industry in Egypt will be presented in order to cover all the relevant literature of this research.

2.1. Balanced Scorecard (BSC): An Overview

Kaplan and Norton (1992) provided a systemic framework that translates the strategic objectives of the organization into a coherent set of KPIs. Janeš (2013) mentioned that KPIs are determined based on experiences by organizations. Furthermore, an expanded range of KPIs may be confirmed or some of them may also be phased out. Thus, it is possible to find measurable perspectives of the current business processes, since the chosen KPIs are significant for determining the outcome of business processes in the future. Analysis of many qualitative and quantitative research studies about the implementation of KPIs, performed globally, showed the generally favorable influence of the KPI's on the fulfilment of the sustainable strategy. The performance evaluation of companies is the increasing emphasis on intangible measures and non-financial perspectives (Janeš, 2013). Kaplan and Norton (2000) said the BSC retains financial metrics as the ultimate outcome measures for company success, but supplements these with metrics from three additional perspectives - customer, internal process, and learning and growth- that proposed as the drivers for creating long-term shareholder value. The concept was developed as an innovative business performance measurement system, in the belief that "existing performance measurement approaches, primarily relying on financial accounting measures, were becoming obsolete" (Kaplan and Norton, 2004). This innovative approach considered the intangible or "soft" factors that had previously been considered as immeasurable, and as such, of little value. Therefore, the four perspectives of BSC according to Kaplan and Norton, (1992; 2000; 2004 and 2009) are financial, customer relations, internal business processes, and learning and growth that are highlighted as follows:

- *Financial Perspective:* Kaplan and Norton (2000) do not disregard the traditional need for financial data as timely and accurate funding data will always be a priority, and managers will do whatever necessary to provide it. In fact, often there is more than enough handling and processing of financial

data. With the implementation of a corporate database, it is hoped that more of the processing can be centralized and automated.

- *Customer Perspective*: recent management philosophy has shown an increasing realisation of the importance of customer focus and customer satisfaction in any business. These are leading indicators: if customers are not satisfied, they will eventually find other suppliers that will meet their needs. Poor performance from this perspective is thus a leading indicator of future decline, even though the current financial picture may look good.
- *Internal Business Process Perspective*: this perspective refers to internal business processes. Metrics based on this perspective allow the managers to know how well their business is running, and whether its products and services conform to customer requirements.
- *Learning and Growth Perspective*: this perspective includes employee training and corporate cultural attitudes related to both individual and corporate self-improvement. In a knowledge-worker organization, people are the main resource. In the current climate of rapid technological change, it is becoming necessary for knowledge workers to be in a continuous learning mode.

According to Salem et al. (2012) the BSC has several advantages as well disadvantages. They stated that it is a strategic initiative that follow "best practices" methodologies cascade through the entire organization, in addition to increase creativity and unexpected ideas. BSC helps to align key performance measures with strategy at all levels of an organization and provides management with a comprehensive picture of business operations. Therefore, it is not just another project, it is a continuous cyclical management process. The methodology facilitates communication and understanding of business goals and strategies at all levels of an organization. Maximized Cooperation - Team members are focused on helping one another succeed. Moreover, BSC helps to reduce the vast amount of information the company IT systems process into essentials e.g. unique competitive advantage, reduced time-frames, improved decisions and better solutions and improved processes (Salem, et al., 2012).

On the other hand, in terms of disadvantages, Salem et al. (2012) mentioned that the causality relationships between the areas of measurement in the BSC are unidirectional and too simplistic. In addition, the BSC neglects the time dimension. This critical point of the BSC starts from the assumption that the linkage between different points of time must be understood. Moreover, the lack of the validation and the reliance of BSC on few measures make a critical point of BSC. BSC lacks the mechanism for maintaining the relevance of defined measures. This leads to reducing the validation of BSC and the possibility to miss some critical measures. Furthermore, the lack of the integration between top-levels and operational levels' measures point out that BSC fails to identify performance measurements as two-ways process. The critical points of BSC is its lack of the integration between the top and operational levels, which may not lead to strategic coherence. This critical point refers to the ability of low levels to understand the implementation of BSC. Furthermore, the absence of the integration limits the use of BSC from the higher levels only. As a result, the strategic plans of the organization may fail because of the weakness of the coherence and the integration between the organization's levels (Salem, et al., 2012).

The role of BSC in outlining the LSPs logistics performance is significant. Rajesh et al. (2012) highlighted on outsourcing the logistics and supply chain operations through LSPs to be one of the most significant attributes to companies in the global market competition. Logistics outsourcing became a way to increase company's profitability and to sustain their competitive advantages (Banomyong and Supatn, 2011). The increasing focus on core competencies opened up many business opportunities and challenges for LSPs. Moreover, the importance of outsourcing functions for LSPs is to be considered for performance management in all supply chain operations and activities. The switch from domestic competition to a global competition has underscored the evolving nature of strategic management systems and the pertinence of research into the extent to which performance measures achieve a degree of balance for LSPs (Krauth et al., 2005). It is evident that there is a need for a framework for implementing the strategic performance measurement system for LSPs. The profound importance of the BSC to the business and academic communities alike (Kuo, 2011). Rajesh et

al. (2012) has also highlighted the fundamental role of the four dimensional perspectives of the BSC for small, medium and large scale LSPs. Nevertheless, there has been minimal empirical strategic management research concerned with the extent and manner of performance measurement of LSPs (Forslund, 2012). This is despite the labor, resource and infrastructure intensive nature of most LSPs operations.

The revolution of technology is accelerating a global transformation of the logistics and supply chains competitive environment. Thus, traditional organizational management is not an appropriate strategy for such environment (Rajesh et al., 2012). In addition, companies must sustain their competitive competences and advantages through continuous enhancement and innovation of their performance (Kuo, 2011). According to De Waal (2010), he explained the performance management systems were explained as the formal, information-based routines and procedures managers use to maintain or alter patterns in organizational activities. Consequently, these systems focus on using financial and non-financial information that influence managerial decision making processes. Moreover, an increasing number of profit and non-profit organizations are implementing performance management systems such as the BSC to obtain better organizational performance (Janeš, 2013). Therefore, Krauth et al. (2005) stated that, the increasing focus on core competencies opened up many business opportunities for LSPs who are under great pressure e.g. the day-to-day operations and the long-term strategic objectives. A good insight in performance information and therewith steering mechanisms for planning is important. Companies focused on financial indicators and neglected the non-financial and non-numerical values, which can give valuable information. Such indicators though are more difficult to measure and compare (De Waal, 2010).

2.2. *Change Management (CM)*

Farooq and Hussain (2011) referred to several researchers (Lewis, 1951; Van De Venn and Poole, 1995 and Struckman and Yammario, 2003) to differentiate between the term *Change* and organizational change. Many organizational events are commonly classified as change, including restructuring, downsizing, mergers and acquisitions, strategic change, and cultural change. Change is defined as “an empirical observation of difference in form, quality, or state over time in an organizational entity” (Kaplan, 2012). Furthermore, organizational change is also defined as “a managed system, process, and/or behavioral response over time to a trigger event” (Struckman and Yammario, 2003). This definition focuses on change as a process or action. Many of the organizations competing in the fast-changing business environment are in a constant search for a robust strategy to survive the new global economic order, which makes achieving improved performance continuously imperative. The relationship between change interventions and organizational learning is examined. It seeks to identify the factors that affect organizational learning and its influences on organizational effectiveness (Farooq and Hussain, 2011). Due to the growth of technology, modern organizational change is largely motivated by exterior innovations rather than internal moves. When these developments occur, the organizations that adapt quickest create a competitive advantage for themselves, while the companies that refuse to change are left behind (Scott et al., 2013). This can result in drastic profit and/or market share losses (Briody et al., 2012). Organizational change directly affects all departments from the entry-level employee to senior management. Regardless of the many types of organizational change, the critical aspect is a company’s ability to win the buy-in of their organization’s employees on the change. Effectively managing organizational change is a four-step process: recognizing the changes in the broader business environment, developing the necessary adjustments for their company’s needs, training their employees on the appropriate changes and winning the support of the employees with the persuasiveness of the appropriate adjustments (Levin and Ward, 2011). Thus, the four categories of change, which are technological, social, leadership, and structural change are highlighted as follows:

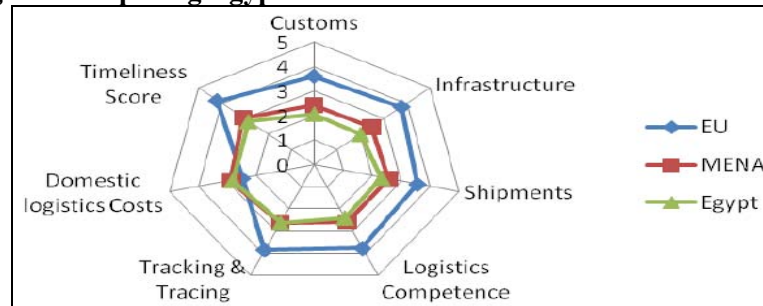
- *Technological*: the efforts that affect the lead-time that it takes to acquire, process and finalize transactions has become a distinguishing feature in the buying decision that creates more autonomy for the stakeholders.
- *Social*: the involvement of employees in the implementation of a change and coping with innovative programs. Moreover, this category reflects how far they are connected with the communicated change programs as well as how they feel that imparting knowledge about change plan reduces resistance among them.

- *Leadership*: the managers have acquired requisite skills and abilities to implement change and employees have the opportunities to participate in the planning process. In addition, the top management in the company is able to identify the key individuals with enthusiasm and help to break down goals into specific responsibilities for each team member.
- *Structural Change*: how the structural change has taken place in the company and the level of free communication across hierarchy is encouraged here to foster a feeling of togetherness.

2.3. Logistics Industry in Egypt

Efficient logistics is a necessary condition for a country's overall development and economic growth (Lowson, 2007). Egypt can make improvements in most of the areas. In that context, a good way to measure a country's logistics capability is the Logistic Performance Index (LPI). The LPI is a benchmarking tool created to help countries identify the challenges and opportunities they face in their performance on trade logistics for improvement. According to LPI criteria (IFC, 2011), Egypt lags slightly behind the regional average and is clearly behind the EU. Egypt's biggest weaknesses according to the LPI are in the Infrastructure (2.00) and Customs (2.08) categories (World Bank, 2013). IFC (2009) stated that, there is a clear relationship between logistics performance, lead-times, and export performance. World Bank (2013) has shown that a 10 percent reduction in overall lead-time results in a 4.3 percent export increase in countries in the Middle East and North Africa (MENA). Moreover, there is a clear link between the performance of a country's logistics sector and its overall level of development (IFC, 2011). The LPI is positively correlated with the country's Gross Domestic Product (GDP) per capita at Purchasing Power Parity (PPP). Countries with a high LPI typically have a high GDP-PPP (World Bank, 2013). Figure 1 reveals the status of the logistics sector by comparing the LPI criteria between Egypt, EU and MENA countries.

Fig 1. Comparing Egypt and other Countries based on LPI Criteria



Source: IFC (2009, 2011)

The logistics services sector is not only important for private sector and economic development, but it is equally important in and of itself as an economic sector with significant growth and investment potential (Banomyong and Supatn, 2011). In addition, the LSPs sector in Egypt represents a multi-billion dollar market, with planned investments of \$7.5 billion by 2015 (IFC, 2011 and GAFI 2013). Thus, strengthening the Egyptian logistics sector has numerous benefits. By having an efficient and competitive logistics industry, Egypt will be able to increase its exports and reach different markets with high quality standards. Moreover, having strong and strategic policies in place will attract further investment into the sector, ensuring its sustainability. Furthermore, this sector would open up new opportunities, attract new players and help to increase the income of all stakeholders.

3. Methodology

After reviewing the literature, it has been proven that BSC is adopted to monitor the performance of companies for continuous development and improvements. However, there has been no empirical study to date that shows the relation between change and performance of Egyptian LSPs with using the BSC as a framework for performance measurement. The methodology used in this research was adapted from Farooq and Hussain (2011) specifically the questionnaire conducted (See Appendix 1) on Indian companies and the

BSC perspective on change and performance. The major research question is formulated as follows: “*What is the impact of Technological, Social, leadership and Structural Changes on the performance of LSPs in Egypt?*”. To answer this question the following hypotheses are outlined as follow and illustrated in Figure 2:

H1: There is significant relationship between Change and Egyptian LSPs Performance.

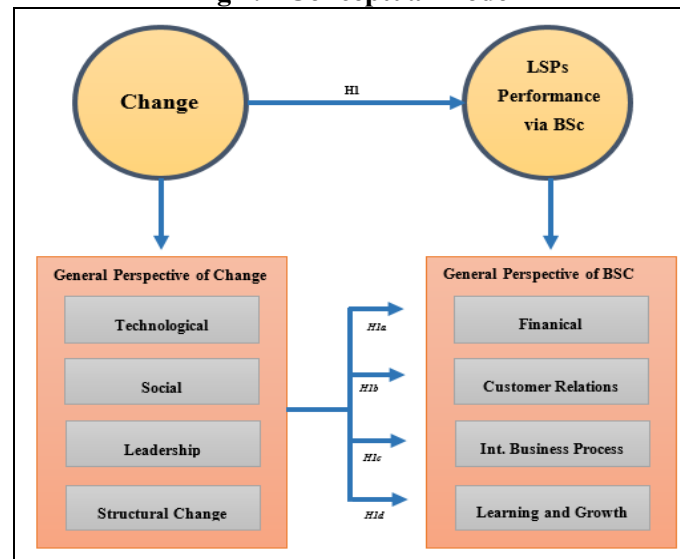
H1a: There is significant relationship between Technological Change and LSPs Performance.

H1b: There is significant relationship between Social Change and LSPs Performance.

H1c: There is significant relationship between Leadership Change and LSPs Performance.

H1d: There is significant relationship between Structural Change and LSPs Performance.

Fig 2. Conceptual Model



The purpose of the questionnaire is to test the relation and the impact of change on the performance of LSPs in Egypt with using the BSC. The change elements serve as the independent variables that influence the performance of LSPs, which is the dependent variable presented through the four main components of the BSC. The sample frame for this research consisted of 450 LSPs companies in the Egyptian logistics industry.

A pilot was conducted with fifteen academics and logistics managers of LSP companies in Egypt and the choice of the final measures used in the instrument was revised as a result of the pilot study. The respondents of the pilot study were given the opportunity to omit and suggest these measures depending on their actual usage. Senior managers were contacted by telephone to give them some idea of the research before sending out Emails, which contain the questionnaire URL, since they are more aware of the application of BSC and change occurring in the organization. Based on the results of the telephone calls, the website of the online questionnaire was useful to track the respondents who had agreed to participate. The main reasons for not participating in the study were either management policy of non-participation or a lack of time. Follow-up telephone calls were also made.

The online questionnaire had 43 statements (Appendix 1) that was completed by 279 Egyptian LSP companies during the period from September 2013 to February 2014 resulting in a response rate of 62%. The questionnaire was based on five-point Likert scale with choices ‘strongly agree’, ‘agree’, ‘neutral’, ‘disagree’ and ‘strongly disagree’. The first section of the questionnaire included some demographic questions about the organization, the respondent details such as their years of experience and their job position. The second section of the questionnaire covered the four elements of BSC i.e. financial, customer, internal process, and learning and growth perspectives. The third section covered the change five elements: general, technological, social, leadership, and structural change. The researcher also added a fifth element to the questionnaire (general) that reflects the general aspects of the BSC and change.

4. Findings and Data Analysis

Table 1. Factor Loadings and Reliabilities

Scale	Items	Mean	Std. Deviation	Factor Loading	Cronbach's Alpha
General Perspective of BSC	G1	3.4373	1.58529	.953	.944
	G2	3.5197	1.30803	.921	
	F1	3.6631	1.15105	.839	
	F2	3.5054	1.17795	1.000	
Financial	F3	3.5699	1.30630	.997	.948
	F4	3.4731	1.23141	.998	
	F5	3.5699	1.30630	.997	
	F6	3.3369	1.08012	.999	
Customer Relations	C1	3.4086	1.22829	.993	.930
	C2	2.8280	1.30817	.942	
	C3	3.2760	1.19614	.989	
	C4	3.2939	1.19937	.991	
Internal Business Processes	P1	3.1362	1.35023	.995	.861
	P2	3.3369	1.08012	.999	
	P3	3.2043	1.10159	.991	
	P4	3.1254	1.32302	.997	
	P5	3.3477	1.06493	.992	
	P6	3.6057	1.29002	.999	
	P7	3.2867	1.21303	.996	
Learning and Growth	LG1	3.4982	1.09240	.990	.928
	LG2	3.4659	1.17747	.949	
	LG3	2.9821	1.20088	.992	
	LG4	3.2079	1.62705	.989	
General perspective of Change	LG5	3.0143	1.51722	.987	.845
	LG6	2.8208	1.37689	.977	
	GC1	2.9391	1.52434	.965	
Technological	GC2	2.7778	1.33872	.894	.861
	T1	3.1685	1.02326	.982	
	T2	3.4552	1.17098	.998	
Social	T3	2.9391	1.11878	.931	.883
	SO1	3.5627	1.23010	.973	
	SO2	3.4014	1.08793	.992	
	SO3	3.3369	1.08012	.999	
	SO4	3.2151	1.27665	.997	
	SO5	2.9462	1.35471	.988	
Leadership	SO6	3.0430	1.57713	.995	.835
	L1	3.2043	1.40061	1.000	
	L2	3.7634	1.36817	.975	
	L3	3.1720	1.03142	.998	
	L4	3.2437	1.05159	.998	

	L5	3.0251	1.27062	.992	
Structural Change	ST1	2.7849	1.40284	.982	.969
	ST2	3.0609	1.16601	.984	

To analyze the data, two stages have been conducted. The first stage, the reliability and validity of the measurement of responses are evaluated and established. The reliability and validity of the instrument was determined with factor analysis and computing Cronbach alpha. The value of Cronbach alpha for the entire instrument as well as for each construct was more than 0.976. Variables with low factor loadings (less than 0.500) were deleted and the questionnaire was refined. In the second stage, the hypothesized relationships are tested by inferential analysis i.e. Pearson's Correlation, ANOVA, t-values and the coefficient of determination. The reliability of data in Table 1 shows the significance difference on mean scores of change and BSC. In addition, Cronbach's alpha values are well above the minimum threshold of 0.6 (Nunnally, 1978), suggesting that each construct is internally consistent. Factor loadings also exceed the suggested minimum of 0.4 (Carmines and Zeller 1979), thereby providing support for a high degree of individual item reliability (Hulland, 1999). This implies that BSC as well as change practices are directly handled similarly in LSP sector in Egypt.

The Pearson's correlation matrix in Table 2 shows the significant relationship between the change on the performance of Egyptian LSPs. Therefore, hypothesis 1 is accepted. Analysis also shows significant relationship between the four change areas; technological, social, leadership and structural change with the performance of the LSPs that make H1a, H1b, H1c and H1d are accepted. This implies that balanced scorecard perspectives and change positively influence the performance of Egyptian LSPs. If balanced scorecard is used properly, change will be effective leading to effective and high performance. Table 3 provides the path coefficients along ANOVA, t-values and the coefficient of determination. Moreover, it summarizes the hypotheses tested results. Figure 3 graphically depicts the correlation value for each hypothesized relationship.

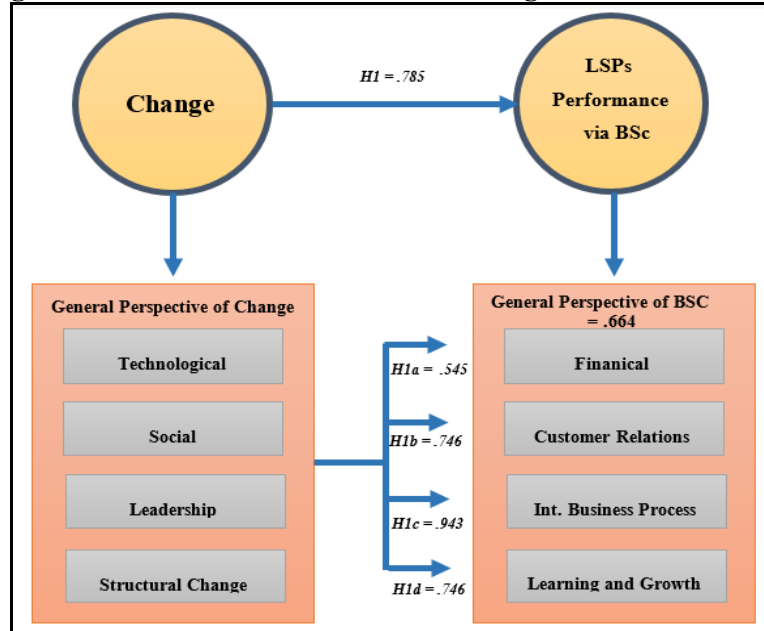
Table 2. Pearson's Correlation Matrix

	G	F	P	LG	GC	T	S	L	SC
General (BSC)	1.000								
Financial	.451	1.000							
Customer Relations	.825	.638	1.000						
Internal Business Processes	.587	.737	.804	1.000					
Learning and Growth	.825	.638	1.000	.804	1.000				
General (Change)	.247	.370	.347	.661	.347	1.000			
Technological	.307	.673	.467	.872	.467	.515	1.000		
Social	.722	.757	.892	.914	.892	.328	.783	1.000	
Leadership	.807	.591	.854	.885	.854	.402	.751	.949	1.000
Structural Change	.194	.108	.180	.564	.180	.685	.628	.346	.522

Table 3: Structural Model and Hypothesis Testing Summary

Path	ANOVA	Standardized coefficient	t value	Result	Conclusion
GC, T, S, L, ST → G	107.456	.529	10.366	Significant	Supported
GC, T, S, L, ST → F	145.585	.587	12.066	Significant	Supported
GC, T, S, L, ST → C	190.440	.638	13.800	Significant	Supported
GC, T, S, L, ST → P	194.175	.938	45.144	Significant	Supported
GC, T, S, L, ST → LG	136.201	.638	13.800	Significant	Supported

Fig 3. Structural Model Results Presenting Value of Correlation



5. Discussion and Conclusions

In order to assess performance companies need to realize where they are, where they are going and what needs to be done to get to where they want to be in the future and what are the influential issues that affect their progress. Without reliable performance measurement tools, it is impossible to address changes that face the business, as change effort offers both short-and long-term impact on companies' performance. Therefore, BSC has proven to be a powerful mean of translating strategy into action and ensuring that companies focus on what really matters to their success. It helps managers to clarify the value proposition as well as the drivers and enablers of success and coping with the changes. The primary aim of this study was to investigate the impact of change on the LSPs performance in Egypt. In particular, the study examined and analyzed the BSC as a tool of measuring performance, which has proven a remarkable strong relation between the two variables. Furthermore, statistical analysis has substantiated the influence of change on the LSP's performance and reveals significance of research. In addition, it provided a visual framework that integrates the companies' strategic objectives across these four perspectives. As findings of the research presented that Egyptian LSPs companies have incorporated the dimensions of BSC as a performance measurement tool and use it to create change and improve performance. Another significant outcome of the research, is the evidence that change, is highly influencing the internal business processes for the Egyptian LSPs, then the customers relations, and the financial performances. Therefore, this result supports the argument that performance is affected by change through the use of BSC. The contribution of this research is measuring and evaluating day-to-day business operations from the following four perspectives: finance, customer, internal business process, and learning and growth, to trigger the change effects and to work on comparatively new initiatives for further improvements and developments in Egyptian LSPs strategies.

However, the critical weakness of Balanced Scorecard; which is the absence of time in the concept, is not fully explored by the research. The research fails to fully incorporate the challenge of time, which is a critical weakness with Balanced Scorecard, and how he hopes to address this in the logistics industry. In addition to this, Balance Scorecard (BSC) is used in measuring and monitoring performance due to a change that has occurred in an organizational strategic objectives in financial term, adoption of BSC model fail to address predictive organizational future performance, hence a comprehensive BSC approach that incorporate predictive performance with consideration for Stakeholder Satisfaction Factors (SSF) should be encouraged. Though, this could be an aspect for further research.

Acknowledgements

The author would like to thank Dr Ayesha Farooq and Ms Zareen Hussain - Faculty of Management Studies and Research, India for their help and support. In addition, the author would like to thank the Egyptian International Freight Forwarding Association (EIFFA) CEOs and managers in Egypt for their precious collaboration in the research.

References

- Banomyong, R. and Supatn, N. (2011), Selecting logistics providers in Thailand: a shippers' perspective, *European Journal of Marketing* 45(3): 419-437.
- Bourlakis, M., and Melewar, T. (2011), Marketing perspectives of logistics service providers: present and future research directions, *European Journal of Marketing* 45(3): 300-310.
- Briody, E., Pester, T., and Trotter, R. (2012), A story's impact on organizational-culture change, *Journal of Organizational Change Management* 25(1): 67-87.
- Carmines, E. and Zeller, R. (1979) *Reliability and validity assessment*. Sage: Beverly Hill.
- Chapman, R., Soosay, C., and Kandampully, M. (2003), Innovation in logistics services and the new business model, *International Journal of Physical Distribution and Logistics Management* 33(7): 630-650.
- De Waal, A. (2010), Performance-driven behavior as the key to improved organizational performance, *Measuring Business Excellence* 14(1): 79-95.
- El-Nakib, I. (2011), The supply and demand of logistics services in Egypt: the case of Logistics Service Providers and the Egyptian industrial sector, in *The 23rd NOFOMA 2011 Conference*, Harstad, Norway, pp.12-26.
- Farooq, A. and Hussain, Z. (2011), Balanced scorecard perspective on change and performance: a study of selected Indian companies, *Procedia - Social and Behavioral Sciences* 24(1): 754-768.
- Forslund, H. (2012), Performance management in supply chains: logistics service providers' perspective, *International Journal of Physical Distribution & Logistics Management* 42(3): 296-311.
- GAFI (2013), *Invest in Egypt: logistics and transportation*. Cairo: General Authority for Investment.
- Hepworth, P. (1998), Weighing it up - a literature review for the balanced scorecard, *Journal of Management Development*, 17(8): 559-563.
- Hulland, J. (1999), Use of partial least squares (PLS) in strategic management research: are view off our recent studies, *Strategic Management Journal* 20(2): 195-204.
- IFC (2009), *MENA Logistics: an assessment of opportunities and constraints in the logistics industry in Egypt*, working paper, International Finance Corporation, World Bank, Washington DC.
- IFC (2011), *Sustainable Investment in the Middle East and North Africa Region Report*, Working Paper, International Finance Corporation, World Bank, Washington DC.
- Janeš, A. (2013), Empirical verification of the balanced scorecard, *Industrial Management & Data Systems*, 114(2): 203-219.
- Kaplan, R. (2012), The balanced scorecard: comments on balanced scorecard commentaries, *Journal of Accounting & Organizational Change* 8 (4): 539-545.
- Kaplan, R., and Norton, D. (1992), The balanced scorecard - Measures that drive performance, *Harvard Business Review* 70 (1): 71-79.
- Kaplan, R., and Norton, D. (2000), Having trouble with your strategy? Then map it, *Harvard Business Review* 78, (5): 167-176.
- Kaplan, R., and Norton, D. (2004), *Strategy Maps: Converting intangible assets into tangible outcomes*, Harvard Business School Publishing: Boston.
- Kaplan, R., and Norton, D. (2009), Conceptual foundations of the balanced scorecard. In *Handbook of Management Accounting Research*, Ed. Chapman, C., Hopwood, A. and Shields, M., Elsevier: Oxford.
- Kennerley, M. and Neely, A. (2002), A framework of the factors affecting the evolution of performance measurement systems, *International Journal of Operations & Production Management* 22(11): 1222-1245.
- Krauth, E., Moonen, H. Popova, V. and Schut, M. (2005), Understanding Performance Measurement and Control in Third Party Logistics. *ECIS 2005*: 1163-1174.
- Kuo, T. (2011), How to improve organizational performance through learning and knowledge?, *International Journal of Manpower* 32(5/6): 581-603.

- Levin, G., and Ward, J. (2011), Program management complexity a competency model. CRC Press: Boca Raton.
- Lewin, K. (1951), Field theory in social science. Harper: New York.
- Liu, C. and Lyons, A. (2011), An analysis of third-party logistics performance and service provision, *Transportation Research Part E: Logistics and Transportation Review* 47(4): 547-570.
- Liu, X., Grant, D., McKinnon, A. and Feng, Y. (2010), An empirical examination of the contribution of capabilities to the competitiveness of logistics service providers: A perspective from China, *International Journal of Physical Distribution & Logistics Management* 40(10): 847-866.
- Lowson, R. (2007), Operational management and operations strategies: an SME perspective, *International Journal of Procurement Management* 1(1/2): 180-209.
- Nunnally, J. (1978), Psychometric theory. McGraw-Hill: New York.
- Rajesh, R., Pugazhendhi, S., Ganesh, K., Ducq, Y. and Lenny, S. (2012), Generic balanced scorecard framework for third party logistics service provider, *International Journal of Production Economics* 140 (1): 269-282.
- Ron, H., Kemp, G., Van der Vorst, G. and Omta, O. (2011), Logistics Outsourcing by Taiwanese and Dutch food processing industries, *British Food Journal*, 113(4): 88-113.
- Salem, M., Norlena, H. and Nor, H. (2012), Balanced scorecard: weaknesses, strengths, and its ability as performance management system versus other performance management systems, *Journal of Environment and Earth Science* 2 (9): 1-9.
- Scott, S., Allan, B. and Margaret, P. (2013) Who Said Change Was Easy, SAS Global Forum 2013, San Francisco, April 28- 1 May.
- Struckman C. and Yammario F. (2003), Organizational change: A categorization scheme and response model with readiness factors. *Research in organizational change and development* 14(1): 1-50.
- Svensson, G. and Wagner, B. (2012), Implementation of a sustainable business cycle: the case of a Swedish dairy produce, *Supply Chain Management: An International Journal* 17(1): 93-97.
- Van De Ven, A. and Poole M. (1995), Explaining development and change in organizations, *Academy of Management Review* 20 (3): 510-540.
- World Bank's website: www.worldbank.org/lpi, last accessed December 2013.

Appendix 1: The Online Questionnaire

This questionnaire is designed to investigate the change in firm performance using Balanced Scorecard: An Empirical Study of Logistics Service Providers in Egypt. Please indicate whether the given features exist in your organization using the key below (Strongly Agree, Agree, Neutral, Disagree, Strongly Disagree). Your responses will be kept confidential and will be used for academic purpose only. Your cooperation and feedback for the same would be appreciated and highly valued.

Please tick (✓) in the appropriate box.

#	STATEMENTS
G1	The company has a clear business strategy.
G2	The company has a strategic measurement system in place
F1	Top executives of the company have an explicit financial strategy for each business unit.
F3	Financial targets are clearly communicated.
F4	The company makes efforts to include additional financial data to satisfy shareholders.
F5	The company monitors performance through a cost-benefit analysis regularly.
F6	The company was able to meet its financial targets last fiscal year.
C1	Shareholders see your company as a financially stable.
C2	The company aims at providing best service at the reasonable price.
C3	Specific strategies are in place to provide specific customer needs.
C4	Customer's feedback is the channel to understand as to how product can be improved.
P1	Promoting customer loyalty is an area of strategic importance.
P2	The business process as a whole is good to ensure sustained profitable operations in the company.
P3	Code of Ethics is followed to ensure ethical business operations.
P4	The company has an efficient Process Infrastructure in place.
P5	Business support processes are suitably designed and function properly in the company.
P6	The company has a system to measure various Internal Process Performances.
P7	The company implement any technological changes immediately.
LG1	A centralized business hierarchy is more efficient than a decentralized one.
LG2	The company promotes individual learning and growth.
LG3	There is focus on 'learning' rather than just 'training'.
LG4	The company encourages innovations.
LG5	The expectations of the management out of a training program, is clearly communicated to the trainee to help him train better.
LG6	Employees with limited skills and knowledge are considered to be developed for better performance.
Gc1	Individual objectives are expertly aligned with the company objectives to ensure that both grow and none suffers.
Gc2	The company anticipates the environmental changes.
T1	The company responds to environmental changes promptly.
T2	The amount of time that it takes to acquire, process and finalize transactions has become a distinguishing feature in the buying decision.
T3	The company believes that cutting the time spent on a procedure attracts significant profits.
So1	Computers have decentralized work, which has created more autonomy for the workers here.
So2	The company involves people in the implementation of a change.
So3	The pressure to cope up with innovative programs can be frustrated.
So4	Everybody in the company is connected with the communicated change program.
So5	The company feels that imparting knowledge about change plan reduces resistance among employees.
So6	The management feels that it is necessary to deal with the emotional responses of those affected by the changes.
L1	In your company, employees adapt themselves to the changed culture.
L2	The managers have acquired requisite skills and abilities to implement change.
L3	People are given opportunities to participate in the planning process.
L4	Top management in the company is able to identify the key individuals with enthusiasm.
L5	Change managers in the company help to break down goals into specific responsibilities for each team member.
ST1	People are educated about change through one- to- one discussion, presentations and other techniques in the company.
ST2	In last years, structural change has taken place in the company.
ST3	Free communication across hierarchy is encouraged here to foster a feeling of togetherness.

Effective Bundle Double Auctions for Carrier Collaboration

Su Xiu Xu*, Meng Cheng, Shuyan Lin and George Q. Huang

HKU-ZIRI Lab for Physical Internet, Department of Industrial and Manufacturing Systems Engineering, The University of Hong Kong, Hong Kong. *Email: xusuxiu@gmail.com.

Abstract

This paper aims to propose effective auction mechanisms for the carrier collaboration problem with bilateral exchange (CCPBE), which is the problem of how to realize the potential of carrier collaboration over a bilateral exchange transportation network. Buyers (transportation service purchasers) offer the lanes with the highest marginal costs for subcontracting, while sellers (transportation service providers) are allowed to bid on bundles of the lanes. We construct a bundle double auction (BDA) for the simple collaboration environment in which each carrier asks for or supplies one full truckload of transportation service for a targeted lane. The BDA mechanism realizes incentive compatibility, individual rationality, budget balance, and asymptotical efficiency. We generalize the BDA mechanism to the *one-unit demand case* in which the lane offered by each buyer is only required to be covered with one truckload once. We further consider the *multi-unit demand case* in which each carrier asks for or supplies one or multiple truckloads of transportation service for a targeted lane. In such a case, we first propose the BDA-1 mechanism, which is incentive compatible for sellers, but not for buyers. The BDA-1 mechanism is also individually rational and budget-balanced. We then propose the BDA-2 mechanism, which is incentive compatible, individually rational and budget-balanced. However, the BDA-1 mechanism may realize higher welfare than the BDA-2 mechanism. Finally, the BDA-2 can be extended to the *bundle demand case* in which each buyer may ask for a bundle of lanes and each lane may include multiple truckloads.

Keywords: Carrier collaboration; bilateral exchange; mechanism design; effective auctions.

1. Introduction

The purpose of this paper is to propose effective auction mechanisms for the following version of the *carrier collaboration problem* (CCP). Consider a carrier collaboration market with multiple origin-destination pairs (*lanes*), multiple full truckload (FTL) carriers, and a market-clearing broker. Each carrier is a self-interested player who is attempting to maximize his own utility. The problem faced by the market-clearing broker is to design an effective mechanism that aims to maximize social welfare. Under such a mechanism, transportation service purchasers (*buyers*) offer the lanes with the highest marginal costs for subcontracting. However, transportation service providers (*sellers*) are allowed to ask for bundles of the lanes offered by the buyers.

To minimize the total transportation cost, each carrier needs to find the optimal set of cycles covering his lanes. Given the optimal set of cycles and the trading mechanism, the subsequent problem faced by each carrier is to determine the optimal request (typically, bid). Since multiple buyers and sellers, and a market-clearing broker are involved in the CCP, the problem stated above is called the *carrier collaboration problem with bilateral exchange* (CCPBE). In a word, the CCPBE is the problem of how to realize the potential of carrier collaboration over a bilateral exchange transportation network.

This paper focuses on truck transportation, which is the backbone of worldwide logistics businesses. For example, trucking represents 28.13% (the largest proportion) of the U.S. for-hire transportation services GDP in 2011 (NTS, 2012). However, according to European Environment Agency (2010), the average weight utilization of trucks in Europe is under 60%. Similarly, the average operational costs of trucking in the U.S. are expected to rise significantly in recent years as compared to 2009, due mostly to a continuous increase in fuel prices and driver wages (ATRI, 2012). To increase truck utilization and the profitability of trucking service, many companies have begun experimenting with collaborative transportation networks. Leanlogistics,

IBM-Nistevo and Transplace are examples of collaborative logistics pioneers focused on SaaS/Cloud technologies to increase transportation efficiency.

In the literature, there are two mechanisms for the CCP: (i) *centralized mechanism*, in which a centralized decision maker with complete information about all carriers determines the optimal reassignment of lanes among those carriers to minimize the total transportation cost (Krajewska and Kopfer, 2006; Ergun et al., 2007; Krajewska et al., 2008; Kuo et al., 2008; Özener and Ergun, 2008); and (ii) *decentralized mechanism*, in which each carrier is self-interested player and by which the collaborative activities are managed to yield to individually and collectively desirable solutions (Song and Regan, 2003; Figliozzi, 2006; Özener et al., 2011). Most of the centralized mechanisms focus on cooperative game (Krajewska and Kopfer, 2006; Krajewska et al., 2008) and complex optimization problem (Ergun et al., 2007; Kuo et al., 2008; Özener and Ergun, 2008). The decentralized mechanisms are usually proposed in terms of non-cooperative game (Özener et al., 2011) and auction mechanism design (Figliozzi, 2006; Berger and Bierwirth, 2010; Kuo and Miller-Hooks, 2012). The auction-based carrier collaboration is the focus of this paper.

In fact, there has been relatively little attention devoted to effective auctions for the CCP. Furthermore, most research on decentralized mechanisms for the CCP merely focuses on one-to-one or one-to-many exchange schemes. It is known that many-to-many bilateral exchange schemes (such as NASDAQ) allow simultaneous bidding from both buyers and sellers, and clear the market one at a time based on the received asks and bids (e.g., Myerson and Satterthwaite, 1983; McAfee, 1992; Chu, 2009; Xu and Huang, 2013). Hence, bilateral exchange scheme is more time efficient and practically attractive than one-sided scheme in a large market. To our best knowledge, this paper is the first proposing effective auction mechanisms for the CCPBE. In the literature, this paper is also the first proposing effective auction mechanisms for the combinatorial bilateral exchange setting where each agent may ask for or supply bundles of goods.

2. The Model

2.1. Problem Description

Consider a transportation market with multiple origin-destination pairs, multiple full truckload (FTL) carriers, and a third-party auctioneer. The FTL carriers operate from individual depots and use a homogeneous fleet (e.g., a light or medium truck fleet). Each carrier has two sets of lanes: the first lanes have to be served by the carrier himself (*self-served lanes*), and the second ones can be served by any carriers (*flexible lanes*). Only the flexible lanes can be reassigned during carrier collaboration. Each carrier is a self-interested player who is attempting to maximize his own utility. The problem faced by the third-party auctioneer is to design an effective auction mechanism for carrier collaboration that aims to minimize the total transportation cost. In the auction mechanism, carriers can only offer the (flexible) lanes with the highest marginal costs for sub-contraction. However, carriers are allowed to bid on bundles of the lanes. In the basic model, we focus on the simple collaboration environment in which each carrier ask for or supplies one full truckload of transportation service for a targeted lane. The carriers' real costs consist of two parts: *lane covering cost* and *repositioning cost*. Lane covering cost is associated with moving loads on lanes. Repositioning cost is also called *empty movement cost*, which is associated with moving empty vehicles from the destination of one lane to the origin of the next in order to generate tours. To minimize the total transportation cost, each carrier needs to find the optimal set of cycles covering his lanes. We refer to this optimization problem as the simplified version of the lane covering problem (LCP) defined by Ergun et al. (2007). The LCP can be solved in polynomial time since it can be formulated as a minimum-cost flow problem (Ergun et al., 2007).

The simplified lane covering problem (S-LCP) is stated as follows. Given a complete directed Euclidean graph $G = (K, A)$, where K is the set of nodes $\{1, 2, \dots, |K|\}$, A is the set of arcs, and $L \subseteq A$ be the lane set. Let c_{ij} be the cost of covering arc $(i, j) \in A$. Let θ be the repositioning cost coefficient, where $0 < \theta \leq 1$. Then the repositioning cost along $(i, j) \in A$ is θc_{ij} . The S-LCP can be formulated as the following integer program:

$$\mathbf{P1:} \quad z(L) = \min \sum_{(i,j) \in L} c_{ij} x_{ij} + \theta \sum_{(i,j) \in A} c_{ij} y_{ij} \quad (1)$$

$$s.t. \quad \sum_{j \in K} x_{ij} - \sum_{j \in K} x_{ji} + \sum_{j \in K} y_{ij} - \sum_{j \in K} y_{ji} = 0, \quad \forall i \in K, \quad (2)$$

$$x_{ij} \geq 1, \quad \forall (i, j) \in L, \quad (3)$$

$$y_{ij} \geq 0, \quad \forall (i, j) \in A, \quad (4)$$

$$x_{ij}, y_{ij} \in \mathbb{Z}, \quad (5)$$

where x_{ij} represents the number of times lane $(i, j) \in L$ is covered, and y_{ij} represents the number of times lane $(i, j) \in A$ is traversed as a repositioning arc. The objective of **(P1)** is to cover the lane set L at minimum cost. Constraints (2) guarantee the flow balance for all the nodes in the network. Constraints (3) guarantee that each lane $(i, j) \in L$ should be covered with one truckload at least once.

2.2. Auction Setting

In the generalized BDA, sellers (or buyers) are allowed to ask for bundles of objects, while buyers (or sellers) are only allowed to bid on at most a single object. We say that a carrier who offers a single lane is a “buyer” (transportation service purchaser), and the one who bids on bundles of lanes is a “seller” (transportation service provider). We assume that each carrier cannot both be the buyer and the seller during one BDA. A carrier’s profit could be negative if he is both the buyer and the seller in one BDA. Therefore, our assumption here is to guarantee *ex post* individual rationality, which implies that all agents (buyers and sellers) have nonnegative utility/profit from participation (Krishna, 2009).

It is well known that no bilateral/double exchange can be simultaneously *allocatively efficient*, *budget-balanced* (even in the ex ante case), and *individually rational* (Myerson and Satterthwaite, 1983). Allocative efficiency implies that the allocation solution maximizes social welfare, while (ex post weak) budget balance implies that the third-party auctioneer does not run at a deficit (Krishna, 2009). Moreover, it is clear that no bundle or combinatorial auction (even in the one-sided case) can ensure allocative efficiency if *incentive compatibility* is sacrificed. Incentive compatibility implies that truthful bidding reaches an *ex post Nash equilibrium* (Krishna, 2009).

Definition 1. Truthful bidding is an *ex post Nash equilibrium* if for each carrier, suppose the other carriers in the auction bid truthfully, then this carrier maximizes his utility/profit by truthful bidding.

Definition 2. A bid is called *atomic bid* if it is a single indivisible bid. An *XOR bid* defines that the bidder can serve at most one out of a set of atomic bids.

In our BDA for carrier collaboration, buyers submit atomic bids while sellers submit XOR bids. Clearly, each bid consists of two parts: a single lane or a bundle of lanes, and a specified price. For buyers, the specified price is called *bid price*. For sellers, such a bidding price is called *ask price*.

Due to the *impossibility theorem* (Myerson and Satterthwaite, 1983), we turn to a weaker notion. This notion is called *asymptotical efficiency*, which implies that the market inefficiency under the mechanism compared to the maximal social welfare (i.e., the ratio of welfare loss) converges to zero as the maximal social welfare approaches infinity.

3. Bundle Double Auction (BDA)

In this work, we will propose an effective BDA mechanism for carrier collaboration by extending the McAfee’s trade reduction mechanism (McAfee, 1992) to the bundle bilateral exchange environment.

3.1. Model

Let M be the set of buyers and N be the set of sellers. Let D denote the set of offered lanes, where each lane $d \in D$. Each lane $d \in D$ is specified by one origin and one destination. Put another way, D is the set of demand types. Let S_n be the set of atomic bids submitted by seller $n \in N$. Let b_m be the bid price of buyer $m \in M$, and s_n be an atomic bid (ask price) of seller $n \in N$, where $s_n \in S_n$. If all the agents bid truthfully, the maximal social welfare $V(M, N)$ can be solved by the following integer program:

$$\mathbf{P2}: \quad V(M, N) = \max \sum_{m \in M} b_m \alpha_m - \sum_{n \in N} \sum_{s_n \in S_n} s_n \beta(s_n) \quad (6)$$

$$s.t. \quad \sum_{n \in N} \sum_{s_n \in S_n} q^d(s_n) \beta(s_n) = \sum_{m \in M, d_m = d} \alpha_m, \quad \forall d \in D, \quad (7)$$

$$\sum_{s_n \in S_n} \beta(s_n) \leq 1, \quad \forall n \in N, \quad (8)$$

$$\alpha_m = \{0, 1\}, \quad \forall m \in M, \quad (9)$$

$$\beta(s_n) = \{0, 1\}, \quad \forall n \in N, \quad (10)$$

where α_m denotes whether buyer $m \in M$ trades in the efficient allocation, and $\beta(s_n)$ denotes whether the atomic bid of seller $n \in N$, s_n , is selected. The objective of $(\mathbf{P2})$ is to find an efficient allocation that maximizes social welfare. The variables $(\alpha_m, \beta(s_n))$ ($m \in M$, $n \in N$) specify the lane allocation. The variable $q^d(s_n)$ represents the number of truckloads for lane d in seller n 's atomic bid s_n . Constraints (7) ensure the supply and demand balance. Constraints (8) ensure the XOR bids for all the sellers.

It is clear that the winner determination problem (WDP) in one-sided combinatorial auctions is NP-hard (e.g., de Vries and Vohra, 2003; Chen et al., 2009; Huang and Xu, 2013; Xu and Huang, 2014). The problem $(\mathbf{P2})$ is also NP-hard since the WDP in one-sided combinatorial auctions is a special case of $(\mathbf{P2})$. An excellent review of the WDP algorithms can be found at de Vries and Vohra (2003). If all information is public, the maximal social welfare can be obtained by clearing the market. However, this centralized solution is usually not available because agents may misreport their real valuations.

3.2. BDA Mechanism

To induce both the buyers and sellers to submit their bids truthfully, we design a BDA mechanism for the problem $(\mathbf{P2})$. We first solve the problem $(\mathbf{P2})$ and obtain an efficient allocation. Ties are broken arbitrarily. Let M' be the set of trading buyers under the efficient allocation, where $M' \subseteq M$. Let N' be the set of trading sellers under the efficient allocation, where $N' \subseteq N$. Let M'_d be the set of trading buyers with lane d , where $m'_d \in M'_d$ and $M'_d \subseteq M'$. Let H be the set of bundle preferences under the efficient allocation, where each bundle $h \in H$. Let N'_h be the set of trading sellers with bundle preference h , where $n'_h \in N'_h$ and $N'_h \subseteq N'$. Let n_h^* index the trading seller with highest bid for bundle h , where $n_h^* \in N'_h$. The procedure of the BDA mechanism is as follows:

- Collect one sealed atomic bid from each buyer and one sealed XOR bid from each seller.
- Solve the problem $(\mathbf{P2})$ and obtain an efficient allocation.
- Sort the trading buyers' bid prices for each lane $d \in D$ in descending order. Similarly, sort the trading sellers' ask prices for each bundle $h \in H$ in ascending order.
- Remove the trading seller with highest bid for each bundle $h \in H$ (i.e., seller n_h^* is removed).
- Remove the trading buyers with lowest bids accordingly. Let m_d^* index the removed trading buyer with highest bid for lane d , where $m_d^* \in M'_d$.
- Set the indiscriminate market-clearing price $b_{m_d^*}$ for each winning buyer with lane d , where $b_{m_d^*}$ is the bid

price of the buyer m_d^* . Similarly, set the indiscriminate market-clearing price $s_{n_h}^*$ for each winning seller with bundle preference h , where $s_{n_h}^*$ is the ask price of the seller n_h^* . \square

Note that: the least profitable trades are removed arbitrarily.

3.3. An Example

A simple example of BDA mechanism is now provided (Table 1). The efficient allocation involves 8 trading buyers and 6 trading sellers. There are two lanes (a, b) and three types of bundles (a, b, ab).

Table 1. An example of BDA mechanism						
Trading buyers (M')			Trading sellers (N')			
Lane	a	b	Bundle	a	b	ab
Bid price	7	7	Ask price	3	3	6
	6	6		<u>3.5</u> #	<u>3.5</u> #	<u>7</u> #
	<u>5</u> #	<u>5</u> #				
	4 #	4 #				

The symbol “#” is adopted to mark the removed trading agents. According to the BDA mechanism, for example, the trading seller with ask price \$7 for bundle ab can be removed first. Then, two trading buyers with the same bid price \$4 for lane a and lane b are removed accordingly. Likewise, the trading sellers with the same ask price \$3.5 for bundle a and bundle b are removed first, followed by two trading buyers with the same bid price \$5 for lane a and lane b . The removing of the least profitable trades can be arbitrary. We use the underline “_” to mark the market-clearing prices. The payoff of the third-party auctioneer is $20-14=\$6$.

3.4. Properties

Theorem 1. *Truthful bidding is an ex post Nash equilibrium in the BDA mechanism.*

Theorem 2. *The BDA mechanism is individually rational and budget-balanced.*

Theorem 3. *If both the valuations and the number of bundle preferences $|H|$ are bounded, then the BDA mechanism is asymptotically efficient. (Note: All proofs are available upon request.)*

4. Generalized FTL Collaboration

4.1. Model

In this section, we consider a general FTL collaboration environment in which each carrier asks for or supplies one or multiple full truckloads of transportation service for a targeted lane. In the general setting each lane may be covered with one full truckload several times. For each carrier, the goal is to minimize the total transportation cost. This optimization problem is indeed the lane covering problem (LCP) defined by Ergun et al. (2007). The LCP can be formulated as the following integer program:

$$\mathbf{P3:} \quad z(L) = \min \sum_{(i,j) \in L} c_{ij} x_{ij} + \theta \sum_{(i,j) \in A} c_{ij} y_{ij} \quad (11)$$

$$s.t. \quad \sum_{j \in K} x_{ij} - \sum_{j \in K} x_{ji} + \sum_{j \in K} y_{ij} - \sum_{j \in K} y_{ji} = 0, \quad \forall i \in K, \quad (12)$$

$$x_{ij} \geq r_{ij}, \quad \forall (i,j) \in L, \quad (13)$$

$$y_{ij} \geq 0, \quad \forall (i,j) \in A, \quad (14)$$

$$x_{ij}, y_{ij} \in Z, \quad (15)$$

where x_{ij} represents the number of times lane $(i,j) \in L$ is covered with one full truckload; y_{ij} represents the number of times lane $(i,j) \in A$ is traversed as a repositioning arc; and r_{ij} represents the number of times lane

$(i, j) \in L$ is required to be covered with one full truckload, where $r_{ij} \geq 1$ and $r_{ij} \in \mathbb{Z}$. The objective of **(P3)** is to cover the lane set L at minimum cost. Constraints (12) guarantee the flow balance for all the nodes in the network. Constraints (13) guarantee that each lane $(i, j) \in L$ should be covered in the general setting.

4.2. Market (I)

We first consider the one-unit demand case in which the lane offered by each buyer is only required to be covered with one truckload once, while one bundle preference of each seller may contain multiple truckloads of transportation service for a targeted lane. Such a case is called *market (I)*. The main difference between market (I) and the basic model is that in the basic model, $q^d(s_n) = \{0, 1\}$, $\forall n \in N$; while in market (I), $q^d(s_n) \geq 0$, $q^d(s_n) \in \mathbb{Z}$, $\forall n \in N$. If all the agents bid truthfully, the maximal social welfare $V(M, N)$ can be solved by the integer program **(P2)**.

Observation 1. (1) In market (I), the BDA mechanism is incentive compatible, individually rational, and budget-balanced. (2) In market (I), if both the valuations and the number of bundle preferences $|H|$ are bounded, then the BDA mechanism is asymptotically efficient.

4.3. Market (II)

We now turn to the multi-unit demand case in which each carrier asks for or supplies one or multiple truckloads of transportation service for a targeted lane. Such a case is called *market (II)*, which is a natural extension of market (I). The main difference between market (II) and market (I) is that in market (II), the lane offered by each buyer may be required to be covered with one truckload several times (multi-unit demand).

Observation 2. The BDA mechanism is not valid for market (II).

BDA-I Mechanism

According to the proof of Observation 2, the atomic bids of buyers may result in the imbalance of supply and demand under the BDA mechanism. We now assume that the buyers' bids are divisible. We continue to let α_m be the transaction quantity of buyer $m \in M$, where $0 \leq \alpha_m \leq |d_m|$ and $\alpha_m \in \mathbb{Z}$. Recall that b_m is the unit bid price of buyer m . Then, the maximal social welfare $V(M, N)$ can be solved by the following integer program:

$$\mathbf{P5:} \quad V(M, N) = \max \sum_{m \in M} b_m \alpha_m - \sum_{n \in N} \sum_{s_n \in S_n} s_n \beta(s_n) \quad (16)$$

$$s.t. \quad \sum_{n \in N} \sum_{s_n \in S_n} q^d(s_n) \beta(s_n) = \sum_{m \in M, d_m = d} \alpha_m, \quad \forall d \in D, \quad (17)$$

$$\sum_{s_n \in S_n} \beta(s_n) \leq 1, \quad \forall n \in N, \quad (18)$$

$$\alpha_m = \{0, 1, \dots, |d_m|\}, \quad \forall m \in M, \quad (19)$$

$$\beta(s_n) = \{0, 1\}, \quad \forall n \in N. \quad (20)$$

Constraints (17) ensure the supply and demand balance. Constraints (18) ensure the XOR bids for all the sellers, while constraints (19) ensure the divisible bids for all the buyers.

The procedure of the *BDA-I mechanism* is as follows:

- Collect one sealed divisible bid from each buyer and one sealed XOR bid from each seller.
- Solve the problem **(P5)** and obtain an efficient allocation.
- Sort the trading buyers' unit bid prices for each lane $d \in D$ in descending order. Similarly, sort the trading sellers' ask prices for each bundle $h \in H$ in ascending order.

- Remove the trading seller with highest bid for each bundle $h \in H$ (i.e., seller n_h^* is removed).
- Label the trading truckloads with lowest unit prices *accordingly*. Let m_d^* index the labeled trading buyer with highest unit price for lane d , where $m_d^* \in M'_d$. Let $|d_m^*|$ be the number of truckloads of buyer m_d^* for lane d . Let $|d'_m|$ be the number of buyer m_d^* 's truckloads that are *labeled accordingly*.
- Remove all the labeled trading buyers with lane d if $|d_m^*| = |d'_m| \geq 1$. If $|d_m^*| > |d'_m| \geq 1$, remove the labeled trading buyers with index $m_d < m_d^*$, and meanwhile remove the labeled truckloads of buyer m_d^* .
- Set the indiscriminate market-clearing price $b_{m_d^*}$ for each winning buyer with lane d , where $b_{m_d^*}$ is the unit price of the buyer m_d^* . Similarly, set the indiscriminate market-clearing price $s_{n_h^*}$ for each winning seller with bundle preference h , where $s_{n_h^*}$ is the ask price of the seller n_h^* . \square

Theorem 4. (1) The BDA-1 mechanism is incentive compatible for sellers, but not for buyers. (2) The BDA-1 mechanism is individually rational and budget-balanced.

An example of the BDA-1 mechanism for market (II) is provided as follows (see Figure 1). In this example, the efficient allocation involves 7 trading buyers and 4 trading sellers. Notice that, there is one trading buyer who needs two truckloads for lane a with unit bid price \$5.

Fig 1. An example of BDA-1 mechanism for market (II)

	Trading buyers (M')			Trading sellers (N')	
Lane	a	b	Bundle	b	$2a1b$
Bid price	7	7	Ask price	3	10
One buyer	$\begin{cases} 5 \\ 5 \wedge \\ 4 \wedge \end{cases}$	$\begin{cases} 6 \\ 5 \wedge \\ 4 \wedge \end{cases}$		<u>3.5</u> #	<u>11</u> #

We use the symbol “#” to mark the removed trading sellers, the symbol “ \wedge ” to mark the trading truckloads that are *labeled accordingly*, and the underline “ $_$ ” to mark the market-clearing prices. According to the BDA-1 mechanism, two trading sellers with ask prices \$3.5 and \$11 are removed first. Then, as shown in Figure 1, 4 truckloads with lowest unit prices are labeled accordingly. For the trading buyer who needs two truckloads for lane a , only one truckload is labeled. Hence, three buyers are removed; that is, the trading buyer with bid price \$4 for lane a , and two trading buyers with bid prices \$4 and \$5 for lane b are removed. After removing 4 labeled truckloads, the remaining demand is equal to the remaining supply. The payoff of the third-party auctioneer is $20 - 14.5 = \$5.5$.

BDA-2 Mechanism

Under the BDA-1 mechanism, the buyers' bids are assumed to be divisible. We now consider the case where buyers' bids are *strongly indivisible*. The definition of strongly indivisible bid can be stated as follows.

Definition 3. A bid is called *strongly indivisible bid* if it is a single indivisible bid, and can only be mapped by a single agent of the other side.

In market (I I), if each buyer's bid is strongly indivisible, then its bid is atomic and its demand for transportation service can only be satisfied by one seller. In the transportation industry, when a buyer (transportation service purchaser) coordinates with multiple sellers for the pickup and loading, high transaction costs may occur.

In the case of strongly indivisible bids, one bundle may correspond to different sets of demands. For example,

if there are three types of demands $(a, 2a, b)$, then the bundle $3alb$ corresponds to either the set of demands $\{a, a, a, b\}$ or the set $\{a, 2a, b\}$. For simplicity of notation, we still use H to denote the set of all possible bundle preferences. Let H_e be the set of bundle preferences, each of which is associated with a fixed set of demands, where $e \in E$ and E is the set of matching patterns by which H is associated with demands. Consider the example that there are three types of demands $(a, 2a, b)$ and $H = \{a, 3alb\}$. Then, only two (matching) patterns are available, $|E| = 2$. Thus, we have that $H_1 = \{\{a\}, \{a, a, a, b\}\}$ and $H_2 = \{\{a\}, \{a, 2a, b\}\}$.

Since each demand is strongly indivisible, every multi-unit demand can be viewed as a whole. That is, $q^d(s_n, H_e) = \{0, 1\}$, $\forall n \in N, \forall e \in E$. Let D denote the set of strongly indivisible demands, where each demand $d \in D$. Let b_m be the bid price of buyer m for its strongly indivisible demand. Let $V_1(M, N)$ be the maximal social welfare that can be realized in terms of a single pattern $e \in E$.

Definition 4. An allocation is called *single-pattern efficient allocation* if it maximizes the social welfare in terms of a single pattern $e \in E$.

Then, $V_1(M, N)$ can be solved by the following integer program:

$$\mathbf{P6:} \quad V_1(M, N) = \max \sum_{e \in E} \gamma(H_e) \left[\sum_{m \in M} b_m \alpha_m(H_e) - \sum_{n \in N} \sum_{s_n \in S_n} s_n \beta(s_n, H_e) \right] \quad (21)$$

$$s.t. \quad \sum_{n \in N} \sum_{s_n \in S_n} q^d(s_n, H_e) \beta(s_n, H_e) = \sum_{m \in M, d_m = d} \alpha_m(H_e), \quad \forall d \in D, \forall e \in E, \quad (22)$$

$$\sum_{s_n \in S_n} \beta(s_n, H_e) \leq 1, \quad \forall n \in N, \forall e \in E, \quad (23)$$

$$\sum_{e \in E} \gamma(H_e) = 1, \quad (24)$$

$$\alpha_m(H_e) = \{0, 1\}, \quad \forall m \in M, \forall e \in E, \quad (25)$$

$$\beta(s_n, H_e) = \{0, 1\}, \quad \forall n \in N, \forall e \in E, \quad (26)$$

$$\gamma(H_e) = \{0, 1\}, \quad \forall e \in E, \quad (27)$$

where $\gamma(H_e)$ denotes whether H_e ($\forall e \in E$) is selected under the single-pattern efficient allocation; $\alpha_m(H_e)$ denotes whether buyer $m \in M$ trades in the single-pattern efficient allocation given H_e ($\forall e \in E$); and $\beta(s_n, H_e)$ denotes whether the atomic bid of seller $n \in N$, s_n , is selected under the single-pattern efficient allocation given H_e ($\forall e \in E$). The variables $(\alpha_m(H_e), \beta(s_n, H_e), \gamma(H_e))$ ($m \in M, n \in N, e \in E$) specify the efficient allocation in the single-pattern sense. The objective of (P6) is to find an single-pattern efficient allocation that maximizes the social welfare in terms of a single pattern $e \in E$. Constraints (22) ensure the supply and demand balance given H_e ($\forall e \in E$). Constraints (23) ensure the XOR bids for all the sellers. The fact that $q^d(s_n, H_e) = \{0, 1\}$ ($\forall n \in N, \forall e \in E$) and constraints (25) guarantee the strongly indivisible bids for all the buyers.

Let H_e^* be the bundle set in the single-pattern efficient solution. The single-pattern efficient solution defines the optimal pattern by which H_e^* is associated with demands. Let n_h^* index the trading seller with highest bid for bundle h , where $n_h^* \in N'_h$. The procedure of the *BDA-2 mechanism* is as follows:

- Collect one strongly indivisible bid from each buyer and one XOR bid from each seller.
- Treat every multi-unit demand as a whole; that is, $q^d(s_n, H_e) = \{0, 1\}$, $\forall n \in N, \forall e \in E$.

- Solve the problem (P6) and obtain a single-pattern efficient allocation.
- Sort the trading buyers' bid prices for each demand $d \in D$ in descending order. Similarly, sort the trading sellers' ask prices for each bundle $h \in H_e^*$ in ascending order.
- Remove the trading seller with highest bid for each bundle $h \in H_e^*$ (i.e., seller n_h^* is removed).
- Remove the trading buyers with lowest bids accordingly. Let m_d^* index the removed trading buyer with highest bid for demand d , where $m_d^* \in M'_d$.
- Set the indiscriminate market-clearing price $b_{m_d^*}^*$ for each winning buyer with demand d , where $b_{m_d^*}^*$ is the bid price of the buyer m_d^* for its strongly indivisible demand. Similarly, set the indiscriminate market-clearing price $s_{n_h^*}^*$ for each winning seller with bundle preference h , where $s_{n_h^*}^*$ is the ask price of the seller n_h^* . \square

Definition 5. A mechanism is *asymptotically efficient in the single-pattern sense* if the ratio between efficiency loss and $V_1(M, N)$ goes to zero as maximal social welfare $V(M, N)$ approaches infinity.

Theorem 5. (1) In market (II), the BDA-2 mechanism is incentive compatible, individually rational, and budget-balanced. (2) In market (II), if both the valuations and the number of bundle preferences $|H|$ are bounded, then the BDA-2 mechanism is asymptotically efficient in the single-pattern sense.

We now provide an example of the BDA-2 mechanism for market (II) (see Table 2). There are three types of demands $D = \{a, 2a, b\}$ and two bundle preferences $H = \{b, 3a1b\}$. Then, it follows that $|E| = 2$, $H_1 = \{\{b\}, \{a, a, a, b\}\}$, and $H_2 = \{\{b\}, \{a, 2a, b\}\}$. In this example, the efficient allocation involves 8 trading buyers, 4 trading sellers, and $H_e^* = H_2 = \{\{b\}, \{a, 2a, b\}\}$.

Table 2. An example of BDA-2 mechanism for market (II)						
Trading buyers (M')				Trading sellers (N')		
Demand	a	$2a$	b	Bundle	b	$3a1b$
Bid price	7	12	7	Ask price	3	14
	<u>6</u> #	<u>10</u> #	6		<u>3.5</u> #	<u>15</u> #
			<u>5</u> #			
			4 #			

According to the BDA-2 mechanism, for example, the trading seller with ask price \$15 are removed first. From $H_e^* = H_2 = \{\{b\}, \{a, 2a, b\}\}$, it follows that the buyer with bid price \$6 for demand a , the buyer with bid price \$10 for demand $2a$, and the buyer with bid price \$4 for demand b are removed accordingly. Similarly, the seller with ask price \$3.5 for bundle b is removed first, followed by the buyer with bid price \$5 for demand b . The exchange prices are marked by the underline “ ”. As a result, the payoff of the third-party auctioneer is $26 - 18.5 = \$7.5$.

Observation 3. If in the BDA-1 mechanism the distance between each buyer's real valuation and its bid price is small enough, then the BDA-1 mechanism realizes higher welfare than the BDA-2 mechanism. Furthermore, in such a case, the BDA-1 mechanism is asymptotically efficient.

Observation 4. If the distance between each agent's real valuation and its bid price is small enough, then the repeated BDA-2 mechanism is asymptotically efficient.

4.4. A Key Extension

Indeed, the BDA-2 mechanism can be directly extended to the *bundle demand case* where each buyer may ask for a bundle of lanes and each lane may include multiple truckloads.

Observation 5. (1) *In the bundle demand case, the BDA-2 mechanism is incentive compatible, individually rational, and budget-balanced.* (2) *In the bundle demand case, if both the valuations and the number of bundle preferences $|H|$ are bounded, then the BDA-2 mechanism is asymptotically efficient in the single-pattern sense.*

To our best knowledge, the BDA-2 mechanism is among the first that realizes incentive compatibility, individual rationality, and budget balance in the combinatorial bilateral exchange environment where each agent may ask for or supply bundles of goods.

5. Conclusions

This paper develops effective auctions for the carrier collaboration problem with bilateral exchange (CCPBE), which is the problem of how to realize the potential of carrier collaboration over a bilateral exchange transportation network. This paper is among the first proposing effective auctions for the CCPBE. In the literature, this paper is also among the first proposing effective auctions for the combinatorial bilateral exchange environment where each agent may ask for or supply bundles of goods. We proposed three effective auctions (denoted by BDA, BDA-1, and BDA-2) for different collaboration settings. We believe our proposed auctions can apply to other exchange environments.

References

- ATRI, (2012), American Transportation Research Institute 2012, An Analysis of the Operational Costs of Trucking: A 2012 Update. Available from: <http://atri-online.org/2012/09/17/an-analysis-of-the-operational-costs-of-trucking-a-2012-update/>
- Berger, S., Bierwirth, C. (2010), Solutions to the request reassignment in collaborative carrier networks, *Transportation Research Part E* 46 (5): 627-638.
- Chen, R.L.Y., Ahmadbeygi, S., Choh, A., Beil, D.R., Sinha, A. (2009), Solving truckload procurement auctions over an exponential number of bundles, *Transportation Science* 43 (4): 493-510.
- Chu, L.Y. (2009), Truthful bundle/multiunit double auctions, *Management Science* 55 (7): 1184-1198.
- de Vries, S., Vohra, R.V. (2003), Combinatorial auctions: A survey, *INFORMS Journal on Computing* 15 (3): 284-309.
- EEA, (2010), European Environment Agency 2010, Load factors for freight transport (TERM 030), Available from: <http://www.eea.europa.eu/data-and-maps/indicators/load-factors-for-freight-transport/load-factors-for-freight-transport-1>.
- Ergun, Ö., Kuyzu, G., Savelsbergh, M. (2007), Reducing truckload transportation costs through collaboration, *Transportation Science* 41 (2): 206-221.
- Figliozzi, M. (2006), Analysis and evaluation of incentive-compatible dynamic mechanisms for carrier collaboration, *Transportation Research Record* 1966: 34-40.
- Huang, G.Q., Xu, S.X. (2013), Truthful multi-unit transportation procurement auctions for logistics e-marketplaces, *Transportation Research Part B* 47: 127-148.
- Krajewska, M., Kopfer, H. (2006), Collaborating freight forwarding enterprises, *OR Spectrum* 28 (3): 301-317.
- Kuo, A., Miller-Hooks, E. (2012), Developing responsive rail services through collaboration, *Transportation Research Part B* 46 (3): 424-439.
- Kuo, A., Miller-Hooks, E., Zhang, K., Mahmassani, H. (2008), Train slot cooperation in multi-carrier, international rail-based intermodal freight transport, *Transportation Research Record* 2043: 31-40.
- Krajewska, M. A., Kopfer, H., Laporte, G., Ropke, S., Zaccour, G. (2008), Horizontal cooperation among freight carriers: Request allocation and profit sharing, *The Journal of the Operational Research Society* 59 (11): 1483-1491.
- Krishna, V. (2009), *Auction Theory*. Second Edition. Academic Press.
- Myerson, R.B., Satterthwaite, M.A. (1983), Efficient mechanisms for bilateral trading, *Journal of Economic*

- Theory 29 (2): 265-281.
- McAfee, R.P. (1992), A dominant strategy double auction, *Journal of Economic Theory* 56 (2): 434-450.
- NTS (2012), National Transportation Statistics 2012, Department of Transportation, U.S., Available from: http://www.rita.dot.gov/bts/sites/rita.dot.gov/bts/files/publications/national_transportation_statistics/html/table_03_01.html.
- Özener, O.Ö., Ergun, Ö. (2008), Allocating costs in a collaborative transportation procurement network, *Transportation Science* 42 (2): 146-165.
- Özener, O.Ö., Ergun, Ö., Savelsbergh, M. (2011), Lane-exchange mechanisms for truckload carrier collaboration, *Transportation Science* 45 (1): 1-17.
- Vickrey, W. (1961), Counterspeculation, auctions, and competitive sealed tenders, *The Journal of Finance* 16 (1): 8-37.
- Xu, S.X., Huang, G.Q. (2013), Transportation service procurement in periodic sealed double auctions with stochastic demand and supply, *Transportation Research Part B* 56: 136-160.
- Xu, S.X., Huang, G.Q. (2014), Efficient auctions for distributed transportation procurement, *Transportation Research Part B* 65: 47-64.

Application of Fuzzy Quality Function Deployment on the Service Quality Improvement for International Logistics in Shipping Company

Yi-Chih Yang^{a*} and Chi-Yu Sung^b

^aDepartment of Shipping and Transportation Management, National Kaohsiung Marine University, Kaohsiung City, Taiwan, hgyang@mail.nkmu.edu.tw.

^bSale representative, Evergreen marine corporation, Taipei City, Taiwan.

*Corresponding Author

Abstract

This paper attempts to analyze the maritime cargo logistics by using the customer-oriented base on service quality method, and to figure out service quality improvement for the international logistics operated by shipping company, and to determine the priority of service improvement based on the weight which was calculated by combining fuzzy set theory with quality function deployment. This article endeavors to deliver the voice of customer to the company for the purpose of maximum improvement effect. A couple of findings illustrated as: (1) Customer pays more attention on accuracy and efficiency of inquiry process responding from internal sales staff, especially for the first-timed inquiry of the new customers; (2) Company should stress education and training of professional manpower to improve the competitive advantage of sustainable development. (3) Sales department is very important to customer service quality improvement of international logistics business engaged by shipping company.

Keywords: Maritime Logistics; Service Quality; Fuzzy Set Theory; Quality Function Deployment.

1. Introduction

Today maritime transport market has faced different challenges and changes, such as, in the process of cargo transportation, the operators have to combine together the various industries (e. g. customs clearance, warehousing, logistics and trucks, etc.) to form so called “one-stop service” for the sake of achieving the advantages of low cost and high efficiencies to meet with diverse needs of our customers. Shipping companies have to not only set up the logistics business but also needs to ensure their services to meet with customer expectations, otherwise traditional maritime transport service sooner or later will lead to loss of a major customer base.

Marcus and Damianidou (1991) conducted a survey of implementation status of quality management project in U.S. maritime industry, by way of in-depth interviews with major U.S. Liner companies, to understand the various implementation methods of quality management projects. They discovered that a company performed quality management project will be more dominant than its competitors in the competitive advantage. Ronald et al (1998) used cause and effect to identify correlation between quality management elements and logistics operating performance, and finally proposed quality management in the process of cargo transportation has a significant causality with logistics performance and customer satisfaction. Winser (1999) conducted exploratory investigation on a comparison between the enterprises introduced quality improvement plan to increase market share and reduce the cost of the enterprise and another enterprises without introduction of quality improvement programs in U.S. transportation industry to understand the business success factors and current status of the enterprises introduced formal quality improvement plan.

After reviewed recent maritime transportation literatures, Vinodh and Chintha(2011) applied Fuzzy QFD to identified lean competitive base, lean decision domains, lean attributes and lean enablers for the organization. Shon and Choi(2001) used Fuzzy QFD to convey fuzzy relationship between customer needs and design specification for reliability in the context of supply chain management. Liang et al.(2006) applied FQFD to

identify service management requirement for an ocean freight forwarder. There is the less of the paper applying Fuzzy QFD to identify service quality of international logistics operated by shipping company, how to reflect shipper requirements to international logistics industry to enhance their service quality based on improvement priority generated by FQFD has formed one of key research motivation for this paper.

International shipping companies have provided not only traditional sea/land transportation service, but also extended service scope to “one-stop service” including transport, warehousing, packing, simple processing, and logistics services, therefore how to delivery cargoes from the departure place to the destination place via these associated various functions based on the principles of low operation cost and high working efficiency to meet diversified requirements of their customers has formed an critical important issue. Meanwhile, In terms of the international logistics business in shipping companies, how to meet different customers’ needs and provide unique services to enhance their loyalty has become another important issue.

This article is for export cargo flow of logistics company owned by liner shipping companies through service quality analysis and Quality Function Deployment to quantify consumer-oriented satisfactory. Finally, improvement priorities of service quality are generated by weight value of QFD, our finding attempts to suggest maritime logistics industry to provide customers with better service, maintain competitive advantage and increase customer loyalty.

Main research purpose of this study were described as follows:

1. Analyzing current status of international logistics in shipping companies;
2. Using the theory of service quality and Fuzzy QFD to generate improvement indicators for service quality of international logistics operated by shipping company;
3. Proposing some appropriate suggestions for service quality improvement on international logistics business in shipping company.

2. Current status of international logistics in shipping companies

Table 1 shown operating service scope of various logistics company owned by global Top 10 shipping companies, majority of logistics companies provide basic services including sea/air cargo forwarding, transportation service, warehousing, distribution and value added service. Small parts of logistics companies provide refrigerated cargo handling and project management service.

In the global top 10 container shipping companies had invested and owned logistics companies which its proportion approximately up to 80%. it represents shipping company starts to introduce the concept of global logistics thanks to increasing global competition and complex channel and network structure of international route. How to take advantage of the global logistics business model to improve the operating efficiency of the shipping industry and reduce the total cost will become a very important issue in the shipping industry (Lin and Zhang, 2008). In recent years, due to severe climate change and people’s awareness of environmental protection, green logistics concepts born out, Maersk logistics was the first to help enterprises in the process of transporting goods towards Green, but also can lessen all logistics costs.

Table 1. Global logistics companies and its service scope owned by liner shipping company

	Maersk Logistics	Yes Logistics	Evergreen Logistics	P&O Nedlloyd Logistics	COSCO Logistics	APL Logistics	MOL Logistics	NYK Logistics	OOCL Logistics	K Line Logistics
Air cargo forwarding	●	●	●		●	●	●	●	●	●
Sea cargo forwarding	●	●	●		●	●	●	●	●	●
Green logistics	●									
Supply chain management	●	●	●	●		●			●	●

Warehouse and distribution service		•	•	•	•	•	•	•	•	•
Value added service	•	•	•		•		•	•		
Inventory management service			•	•						•
Intermodal transport service		•			•	•			•	
Custom clearance service		•	•				•			
Consolidation service		•	•		•	•	•	•		
Special cargo handling		•	•		•				•	
Project management				•		•				
Cargo tracking		•	•		•					•
Reefer service		•							•	

3. Research Methodology

3.1 Research Framework

In order to understand shipping companies operating the international logistics, especially for improvement direction of sea transport cargo export process, with reference to Bossert (1991) proposed the architecture of the house of quality, the article divided international logistics service quality operated by maritime industry into dimensions of customer requirements and service technical requirements.

The fuzzy set theory seeks to extract of the chief possible outcome from a multiplicity of information expressed in vague and imprecise terms. Fuzzy set theory treats vague data as possibility distributions in terms of set memberships. Once determined and defined, probability distribution membership sets can be effectively used in logical reasoning. After fuzzy set theory was introduced by Zadeh(1965), this theory was developed as a tool for solving problems in which the descriptions of activities, observations, and judgments are subjective, vague, and imprecise. Because measurements of technical difficulty, cost, and time may also incorporate uncertainty, linguistic variables and triangular fuzzy numbers can be used as effective means of representing imprecise information (Ding, 2006).

To aggregate all information generated by different averaging operations, we use the grade of membership to demonstrate their strength after considering all approaches. For the aforementioned reasons, triangular fuzzy numbers characterized by the use of min, max and geometric mean operations are used to convey the opinions of all experts (Chen, 2005).

The article uses fuzzy quality function deployment method to extend interface tool of quality house. According to weight values and ranks for each item in the dimensions, it can become improvement priority indicators of service quality. Reach architecture of the paper shown in Figure 1.

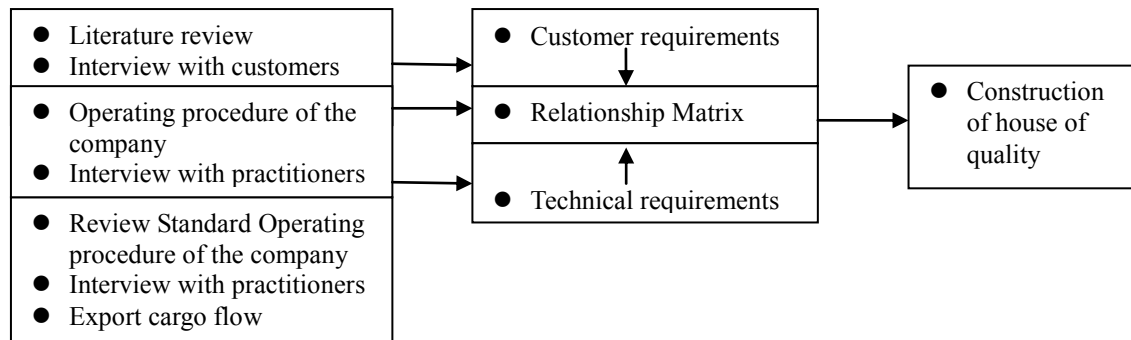
Fuzzy QFD computation steps are illustrated as follows:

Step 1: Identify customer requirements.

Step 2: Measure the degree of importance of each customer requirement attribute to reflect the voice of the

- customer requirements.
- Step 3: Measure the degree of satisfaction of each customer requirement attribute to reflect the satisfaction of overall customer requirements.
- Step 4: Calculate the priorities of customer requirements.
- Step 5: Develop technical requirements to represent the service provider's responses to customer requirements.
- Step 6: Construct a relationship matrix of house of quality to link the technical requirements with customer requirements.
- Step 7: Determine the fuzzy relationship strength of each technical requirement and each customer requirement attribute.
- Step 8: List the priority order of technical requirement based on overall customer requirements.

Fig 1. Research framework of FQFD



3.2 Data collection and Assessment Criteria

This paper discusses the considerations of the shipper in the choice of the international logistics service provider, its attempt to figure out what factors are considered as important for the shipper, and to provide industry operator recommendations for service improvement. The survey target of the questionnaire can be divided into the freight forwarder and shipper, the former data collection is based on the Maritime Freight Forwarders Association of Taipei and Kaohsiung area providing a total of more than 500 freight forwarder lists, by means of random sampling to 50 companies of the Kaohsiung area and 100 companies of Taipei area. The latter is collected the list of more than 600 export manufacturers from name lists provided from Kaohsiung and Taipei manufacturers Association, and withdrawn random sampling number is 100 export manufacturers, therefore there are a total of 250 questionnaire targets(e.g. 150 freight forwarders +100 manufacturers).

With reference to the characteristics of the international logistics industry and previous research literatures, the dimensions of customer requirements is based on measure dimensions of service quality proposed by Parasuraman et al(1985). Measure dimensions were selected based on specific characteristics of international logistics industry, followed by literature review, expert interviews and pre-test questionnaire to confirm the contents of the dimensions. Finally, the article captures the four service quality dimensions: Reliability (Integrated transport service), Responsiveness (Fast responding service), Competence (Customized service) and communication (Interactive platform service), and sorted out 20 assessment items shown in Table 2.

Table 2. Framework of service quality requirements

Dimension	Assessment Criteria	Related literature
A. Reliability (Integrated transport service)	A1. Sea and air transport services A2. Multi-countries consolidation services A3. Cargo arrival quickly and punctually A4. Logistics processing services A5. Cargo safety transport capability	Parasuraman et al.(1985) Park et al. (2004) Lin et al.(2005) Chen and Chou(2006) Liang et al.(2006) Wang(2007)

B. Responsiveness (Fast responding service)	B1. Properly and quickly respond to customer's inquiry	Parasuraman et al(1985) Lin et al.(2005)
	B2. Sales man advance understanding of customer requirements	Liang et al.(2006)
	B3. Provide technological messages for customer inquiries	
	B4. Efficiency of cargo claim handling	
	B5. Efficiency of employee handling for customer's demand	
C. Competence (Customized service)	C1. Provide flexible and customized service	Parasuraman et al(1985)
	C2. Competence and efficiency of employee's handling emergency case	Park et al. (2004) Lin et al. (2005)
	C3. Employees used expertise to solve the problem for customer	Liang et al.(2006) Chen and Chou(2006)
	C4. Provide comprehensive transportation and logistics consultant service	Wang(2007)
	C5. Provide customized services at a reasonable charge.	
D. Communication (Interactive platform service)	D1. Efficiency of responding to customer complains	Parasuraman et al(1985) Park et al. (2004)
	D2. Provide related business consultancy with cordial and polite attitude.	Lin et al.(2005) Liang et al.(2006)
	D3. Employee's Immediate responding to customer 's phone call	Wang(2007)
	D4. Instant conversion service of EDI file in the internet	
	D5. Provide Free Trade Zone service	

4. Empirical Analysis

4.1 Description of respondents' profile

A total of 250 questionnaires were distributed by mail to personnel at maritime freight forwarders and export manufactures in Taipei and Kaohsiung area from April to May in 2011, and 75 questionnaires were returned, for a response rate of 30%. Among the respondents, 54.4% were affiliated with the freight forwarders, and 45.6% were affiliated with export manufacturers respectively. With regard to the respondents' job titles, 23.5% were managers or deputy managers and 25% were staff members; in terms of working experience, 35.3% had less than 5 years of experience and 29.4% had 6-10 years. The respondents' occupations, job titles, and working experience suggested that their opinions were competent and representative. The fact that almost all the respondents worked at freight forwarders and export manufactures may indicate that the results are representative of the views in QFD.

4.2 Descriptive Statistics of customer requirement dimensions

In the importance degree, overall mean value is 4.2933, it represents the service quality item in the questionnaire were recognized as highly important by survey respondents, maritime industry could try to move toward the direction of meeting customer's inquiry in the operation of international logistics. According to table 3 listed Top 3 are B1 (Properly and quickly respond to customer's inquiry), A5 (Cargo safety transport capability) and C3 (Employees used expertise to solve the problem for customer). It indicated that the customer attach more importance on freight inquiry channel with the company, whether internal employees can quickly respond to customer's question will become one of re-consumption indicators for the customer in the future. Therefore, enterprise should grasp the customer at first-time consumption experience and left the deep impression to the customer, attempting to consolidate exiting customer but also explore potential customer. Moreover, the customer used to lay the emphasis on security problems and damage problems of transporting goods from the place of departure to the destination during sailing period, aiming to safely and

quickly delivery to the consignee in the hands and to prevent subsequent complicated processing procedures from losing customer opportunities.

In addition to satisfaction aspect, overall mean value is 3.822 which Respondents are nearly stratified with overall performance of exiting transportation services provider, on the other hand, it also represents some service items need to further enhance. Top three of satisfactory degree are (1) Cargo safety transport capability (2) Provide related business consultancy with cordial and polite attitude. (3) Properly and quickly respond to customer's inquiry. Transportation services provider satisfaction, and also on behalf of the goods still need more than some of the need to further enhance the satisfaction, the top three were (1) can really safe arrival, and the company is able to assist in the rapid withdrawal (2) the company's employees to provide business consulting attitude cordial and polite employees of the company and (3) properly respond quickly to customer's inquiry.

Table 3. Summary of importance degree and satisfactory degree

Assessment Criteria	Degree of Importance			Assessment Criteria	Degree of Satisfactory		
	Mean	S.D.	Rank		Mean	S.D.	Rank
B1 Properly and quickly respond to customer's inquiry	4.6471	0.61	1	A5 Cargo safety transport capability	4.1471	0.69	1
A5 Cargo safety transport capability	4.6471	0.66	2	D2 Provide related business consultancy with cordial and polite attitude.	4.1176	0.70	2
C3 Employees used expertise to solve the problem for customer	4.6029	0.64	3	B1 Properly and quickly respond to customer's inquiry	4.0294	0.71	3
A3 Cargo arrival quickly and punctually	4.5882	0.55	4	B2 Sales man advance understanding of customer requirements	4.0147	0.74	4
B2 Sales man advance understanding of customer requirements	4.5882	0.67	5	A3 Cargo arrival quickly and punctually	3.9853	0.63	5
C2 Competence and efficiency of employee handling emergency case	4.5588	0.61	6	C4 Logistics processing services	3.9559	0.67	6
B5 Efficiency of employee handling for customer's demand	4.5294	0.70	7	B5 Efficiency of employee handling for customer's demand	3.9265	0.83	7
D2 Provide related business consultancy with cordial and polite attitude.	4.5000	0.69	8	C3 Employees used expertise to solve the problem for customer	3.8971	0.69	8
D3 Employee's Immediate responding to customer 's phone call	4.4412	0.63	9	D3 Employee's Immediate responding to customer 's phone call	3.8824	0.76	9
D1 Efficiency of responding to customer complains	4.4412	0.65	10	C2 Competence and efficiency of employee's handling emergency case	3.8824	0.82	10

4.3 Improvement priority of customer requirement dimensions

By applying the cognitive service quality gap mode proposed by Parasuraman, Zeithaml and Berry (1985) to quality function deployment method to Investigate the cognitive gap between expected importance and cognitive satisfaction by customers recognized on international logistics service operating by shipping companies, the paper finally discovered most required improvement priorities for the company. Cognitive gap is obtained by subtracting importance degree from satisfaction degree based on mean value. The greater cognitive gap value is higher ranking order of the items, for an example of C3, $0.7058(\text{cognitive gap}) = 4.6029(\text{important degree average}) - 3.8971(\text{average satisfaction})$, cognitive gap is expressed by a percentage, hence C3's cognitive distance is 70.58%. The greatest cognitive gap of Top 3 are C3 (Employees used expertise to solve the problem for customer), C2 (Competence and efficiency of employee's handling emergency case) and B1 (Properly and quickly respond to customer's inquiry). It represents three items which respondents consider most important, but still are not satisfied with these service items.

This result coincides with the table 4, international business logistics service providers should move toward strengthening education and training of internal staff's service quality and professional knowledge for the sake of their providing service to meet the customer expectations and helping firms to seize business opportunities.

Table 4. Gap analysis between expected service quality and cognitive service quality

<i>Measurements</i>	<i>I. D. Mean</i>	<i>S.D Mean</i>	<i>Cognitive Gap %</i>	<i>Priority</i>
C3 Employees used expertise to solve the problem for customer	4.6029	3.8971	70.58	1
C2 Competence and efficiency of employee handling emergency case	4.5588	3.8824	67.64	2
B1 Properly and quickly respond to customer's inquiry	4.6471	4.0294	61.77	3
B5 Efficiency of sales man handling for customer's demand	4.5294	3.9265	60.29	4
A3 Cargo arrival quickly and punctually	4.5882	3.4412	60.29	5
D1 Efficiency of responding to customer complains	4.4412	3.8529	58.83	6
B2 Sales man advance understanding of customer requirements	4.5882	4.0147	57.35	7
D3 Employee's Immediate responding to customer 's phone call	4.4412	3.8824	55.88	8
B4 Efficiency of cargo claim handling	4.3088	3.7794	52.94	9
A5 Cargo safety transport capability	4.6471	4.1471	50.00	10

4.4 Reliability test and validity test

The reliability analysis of the overall dimensions obtained Cronbach's α value by 0.944, it represents the variable condition of these measurement items are ideal. Regarding to factor loading value in every dimension, except overall explained variance of dimension A. (44.99) is low compared with the other three dimensions, and the rest has reached more than 65%, the paper anticipated the A4 and A5 items pulled down factor loading value of dimension A. According to Wu (2005) argument claimed that ordinary reliability of more than 0.8 is considered good, however the measurement is intended only to compare two groups on average level of reliability scale, even if only 0.5 or 0.6 may also be adopted reluctantly.

Because the purpose of this article is to compare relatively difference between importance degree and satisfactory degree of international logistics service quality operated from respondents' opinion, this article chose factor loading values of 0.6 as for the lower limit threshold. A4 and A5 are deleted owing to their figures being under 0.6, after they are deleted A dimension's explained variance ability had reached 68.80%, consequently, A1 to A3 s' factor loading values depicted 0.83,0.80 and 0.72 respectively which reached the high level of reliability(refer to Table 5).

Table 5. Factor analysis for customer requirement dimensions

<i>Dimensions</i>	<i>Code</i>	<i>Cronbach's α</i>
A. Integrated transport service	A1~A5	0.944
B Fast responding service	B1~B5	
C Customized demand service	C1~C5	
D Interactive platform service	D1~D5	

To validate the survey measurement of customer requirement dimensions, the paper employed exploratory factor analysis with the principle component method and varimax rotation to identify validation test. The factor loading value of asked items of the four dimensions are greater than 0.5, hence there is a convergent validity. In addition to discriminate validity analysis, Zhang(1998) claimed each asked items in the components (factors) 's factor loadings are greater than 0.5, more items meet this criteria, then the discriminate validity can be identified. This article found that this questionnaire has a high discriminate validity as 20 asked items' factor loading values were greater than 0.5.

4.5 Technical requirement dimensions

By means of data collection and expert interview with Evergreen Logistics, Yes Logistics, APL Logistics and OOCL Logistics on standard operating procedures of exports goods and their physical operations, the article had determined the technical requirements dimensions. Mainly it can be divided into two layers, the first layer

is the departments involved in export cargo flow tasks, the second layer is the job content of those departments. Service industry characteristics can be reflected in the international logistics industry, this study chose four departments (e.g. Sales department, document department, customer service department and warehouse department) which are interacted with customers frequently, as well as 13 quality technology operations(refer to Table 6).

Table 6. Description of service quality technical requirement attribute

<i>Department Name</i>	<i>Attributes</i>
Sales Department	Business consultant of trans-pacific and Far East/European shipping route Business consultant of costal shipping rout. Booking space and planning schedule Maintain and develop customer
Document Department	Typewriting export B/L documents Typewriting export manifest documents
Customer service Department	Claims for cargo damage Special cargo consulting services Handling service of customer complain
Warehouse Department	Confirmation of warehouse and storage information, arrangement of on-site operation Arrangement of consolidation operation Value-added logistic service Free Trade Zone operation service

4.6 *Improvement priority of technical requirement dimensions*

Most improvement priority of Top 3 including Business consultant of trans-pacific and Far East/European shipping route, Business consultant of costal shipping route, and Maintain/Develop customer. Furthermore, the top three job contents are concentrated in the business sector, it represents sales department plays important role in international logistics business operated by shipping company.

Sales man is living in the front line, the customer often directly contact with sales man while he encountered cargo damage and delay delivery issues, hence the sales man's crisis management and emergency event processing capabilities has relatively become important, our recommend is that the enterprise should strengthen marketing and sales education and training, case sharing programs for the sake of improving value added service quality and emergency case handing ability of sales man.

Table 7: Correlation matrix of FQFD

	Sales Department												
	Business consultant of trans-pacific and Far East/European shipping route			Business consultant of trans-pacific and Far East/European shipping route			Booking space and planning schedule		Maintain /Develop customer				
Sales Dep.	Business consultant of trans-pacific and Far East/European shipping route	1.00	1.00	1.00	1.00	1.00	0.29	0.50	0.64	0.70	0.30	0.57	0.70
Document Dep.	Business consultant of trans-pacific and Far East/European shipping route	0.10	0.29	0.50	1.00	1.00	1.00	1.00	0.64	0.70	0.30	0.57	0.70
	Business consultant of costal shipping rout.	0.50	0.64	0.70	0.70	0.70	0.70	1.00	1.00	1.00	0.50	0.64	0.70
	Booking space and planning schedule	0.30	0.57	0.70	0.30	0.57	0.70	0.70	0.70	0.70	1.00	1.00	1.00
	Maintain and develop customer	0.30	0.57	0.70	0.50	0.64	0.70	0.30	0.34	0.50	0.30	0.37	0.70
Customer service Dep.	Typewriting export B/L documents	0.30	0.52	0.70	0.50	0.59	0.70	0.30	0.30	0.30	0.30	0.30	0.30
	Typewriting export manifest documents	0.30	0.52	0.70	0.50	0.59	0.70	0.10	0.17	0.30	0.30	0.44	0.50
	Claims for cargo damage	0.30	0.57	0.70	0.30	0.57	0.70	0.10	0.21	0.70	0.30	0.46	0.70
	Special cargo consulting services	0.30	0.57	0.70	0.30	0.57	0.70	0.10	0.20	0.50	0.30	0.48	0.70
Warehouse Dep.	Handling service of customer complain	0.30	0.57	0.70	0.30	0.57	0.70	0.30	0.48	0.70	0.30	0.34	0.50
	Confirmation of warehouse and storage information, arrangement of on-site operation	0.30	0.57	0.70	0.30	0.57	0.70	0.30	0.54	0.70	0.30	0.57	0.70
	Arrangement of consolidation operation	0.30	0.57	0.70	0.30	0.48	0.70	0.30	0.34	0.50	0.70	0.70	0.70
	Value-added logistic service	0.30	0.44	0.50	0.30	0.48	0.70	0.30	0.34	0.50	0.50	0.54	0.70
	Free Trade Zone operation service												

(Complete positive correlation: 1 point; ◎highly correlation :0.7 point; ◯Moderate correlation:0.5point; △Low correlation:0.3 point; ×No correlation:0.1 point)

;

Table 7. Correlation matrix of FQFD (continued)

Document Department					Customer Department					Warehouse Department							
Typewriting export B/L documents	Typewriting export manifest documents	Claim service for cargo damage	Special cargo consulting service	Handling service of customer complain	Confirmation of warehouse and storage data, arrangement of on-site operation					Arrangement of consolidation operation	Value-added logistic service	Free Trade Zone operation service					
0.30	0.52	0.70	0.30	0.52	0.70	0.30	0.52	0.70	0.30	0.57	0.70	0.30	0.57	0.70	0.30	0.57	0.70
0.50	0.59	0.70	0.50	0.59	0.70	0.50	0.59	0.70	0.30	0.57	0.70	0.30	0.57	0.70	0.30	0.48	0.70
0.30	0.34	0.50	0.30	0.30	0.30	0.10	0.21	0.70	0.10	0.20	0.50	0.30	0.48	0.70	0.50	0.34	0.50
0.30	0.37	0.70	0.30	0.30	0.30	0.30	0.44	0.50	0.30	0.48	0.70	0.30	0.34	0.50	0.30	0.70	0.70
1.00	1.00	1.00	0.50	0.59	0.70	0.30	0.42	0.70	0.30	0.42	0.70	0.30	0.34	0.50	0.30	0.34	0.50
0.50	0.59	0.70	1.00	1.00	1.00	0.30	0.39	0.50	0.30	0.39	0.50	0.30	0.34	0.50	0.30	0.34	0.50
0.30	0.46	0.70	0.30	0.46	0.70	1.00	1.00	1.00	0.50	0.64	0.70	0.30	0.48	0.70	0.30	0.39	0.50
0.30	0.37	0.70	0.30	0.34	0.50	0.50	0.59	0.70	1.00	0.59	0.70	0.30	0.42	0.70	0.30	0.34	0.50
0.30	0.42	0.70	0.30	0.39	0.50	0.50	0.64	0.70	1.00	1.00	1.00	0.30	0.46	0.70	0.30	0.39	0.50
0.30	0.34	0.50	0.30	0.34	0.50	0.30	0.48	0.70	0.30	0.46	0.70	1.00	1.00	0.50	0.64	0.42	0.70
0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.57	0.70	0.30	0.39	0.50	0.50	0.59	0.70	1.00	0.30	0.48
0.30	0.34	0.50	0.30	0.34	0.50	0.30	0.39	0.50	0.30	0.39	0.50	0.30	0.42	0.70	0.30	1.00	1.00
0.30	0.37	0.70	0.30	0.37	0.70	0.30	0.30	0.30	0.10	0.21	0.70	0.30	0.42	0.70	0.30	0.42	0.70
(Complete positive correlation: 1 point; ◎highly correlation :0.7 point; ◉Moderate correlation:0.5point; △Low correlation:0.3 point; ✕No correlation:0.1 point)																	

(Complete positive correlation: 1 point; ◎highly correlation :0.7 point; ◯Moderate correlation:0.5point; △Low correlation:0.3 point; ✕No correlation:0.1 point)

Table 8. Relationship matrix of FQFD

	Sales Department									
	<i>Business consultant of trans-pacific and Far East/Euro shipping route</i>	<i>Business consultant of costal shipping route</i>	<i>Booking space and planning schedule</i>	<i>Maintain /Develop customer</i>						
Integrated transport service	Sea and air transport services	0.09	0.12	0.16	0.04	0.10	0.16	0.01	0.07	0.16
	Multi-countries consolidation services	0.04	0.11	0.21	0.04	0.08	0.15	0.04	0.10	0.21
	Cargo arrival quickly and punctually	0.07	0.10	0.15	0.07	0.10	0.15	0.07	0.10	0.15
	Logistics processing services	0.04	0.09	0.23	0.04	0.09	0.23	0.04	0.11	0.23
	Cargo safety transport capability	0.01	0.09	0.28	0.01	0.09	0.28	0.01	0.09	0.28
Fast responding service	Properly and quickly respond to customer's inquiry	0.07	0.13	0.20	0.07	0.14	0.20	0.04	0.08	0.14
	Sales man advance understanding of customer requirements	0.06	0.11	0.14	0.09	0.12	0.14	0.06	0.11	0.14
	Provide technological messages for customer inquiries	0.03	0.09	0.17	0.03	0.09	0.17	0.06	0.10	0.17
	Efficiency of cargo claim handling	0.04	0.10	0.24	0.04	0.10	0.24	0.04	0.10	0.24
	Efficiency of sales man handling for customer's demand	0.09	0.11	0.13	0.07	0.11	0.13	0.09	0.11	0.13
Customized service	Provide flexible and customized service	0.07	0.10	0.14	0.07	0.10	0.14	0.07	0.11	0.14
	Competence and efficiency of employee's handling emergency case	0.06	0.11	0.16	0.06	0.11	0.16	0.06	0.11	0.16
	Employees used expertise to solve the problem for customer	0.06	0.12	0.18	0.06	0.12	0.18	0.06	0.12	0.18
	Provide comprehensive transportation and logistics consultant service	0.06	0.10	0.16	0.06	0.10	0.16	0.06	0.10	0.16
	Provide customized services at a reasonable charge	0.06	0.09	0.15	0.06	0.09	0.15	0.06	0.10	0.15
Interactive platform service	Efficiency of responding to customer complains	0.07	0.11	0.14	0.07	0.11	0.14	0.07	0.12	0.19
	Provide related business consultancy with cordial and polite attitude	0.06	0.15	0.28	0.06	0.15	0.28	0.06	0.15	0.28
	Employee's Immediate responding to customer 's phone call	0.07	0.15	0.23	0.07	0.15	0.23	0.07	0.15	0.23
	Instant conversion service of EDI file in the internet	0.07	0.11	0.17	0.07	0.11	0.17	0.07	0.11	0.17
	Provide Free Trade Zone service	0.05	0.10	0.17	0.05	0.10	0.17	0.05	0.10	0.17

Table 8. Relationship matrix of FQFD (continued)

Document		Department		Customer Service				Department		Warehouse				Department		Customer					
Typewriting export B/L documents		Typewriting export manifest documents		Claim service for cargo damage		Special cargo consulting service		Handling service for customer claim		Confirmation of warehouse and storage data, arrangement of on-site operation				Arrangement of consolidation operation		Value-added logistic service	sided weight value				
0.07	0.09	0.12	0.04	0.08	0.12	0.04	0.06	0.12	0.04	0.07	0.16	0.04	0.06	0.12	0.04	0.07	0.12	0.04	0.07	0.12	0.048
0.04	0.07	0.15	0.04	0.07	0.15	0.01	0.03	0.09	0.01	0.05	0.21	0.01	0.04	0.15	0.04	0.09	0.21	0.04	0.09	0.21	0.049
0.04	0.07	0.11	0.04	0.06	0.11	0.07	0.09	0.15	0.04	0.07	0.15	0.04	0.07	0.11	0.04	0.07	0.11	0.04	0.07	0.11	0.049
0.04	0.07	0.16	0.01	0.05	0.16	0.01	0.06	0.16	0.07	0.10	0.23	0.01	0.06	0.16	0.01	0.06	0.16	0.04	0.11	0.23	0.048
0.01	0.06	0.20	0.01	0.05	0.12	0.07	0.14	0.28	0.04	0.09	0.28	0.04	0.09	0.20	0.04	0.08	0.28	0.01	0.03	0.12	0.046
0.01	0.05	0.14	0.01	0.04	0.14	0.01	0.04	0.14	0.01	0.05	0.20	0.01	0.04	0.14	0.01	0.03	0.09	0.04	0.07	0.11	0.049
0.04	0.08	0.14	0.04	0.06	0.14	0.04	0.06	0.14	0.04	0.08	0.14	0.04	0.06	0.14	0.04	0.06	0.10	0.04	0.06	0.10	0.049
0.03	0.08	0.17	0.03	0.08	0.17	0.01	0.04	0.17	0.06	0.11	0.17	0.03	0.08	0.17	0.03	0.07	0.17	0.03	0.07	0.17	0.050
0.01	0.05	0.17	0.01	0.05	0.17	0.04	0.14	0.24	0.04	0.10	0.24	0.07	0.14	0.24	0.01	0.04	0.17	0.01	0.03	0.10	0.051
0.04	0.06	0.09	0.04	0.06	0.09	0.04	0.07	0.09	0.07	0.09	0.13	0.07	0.09	0.13	0.04	0.06	0.09	0.04	0.06	0.13	0.050
0.04	0.06	0.14	0.04	0.06	0.14	0.04	0.06	0.10	0.04	0.07	0.10	0.04	0.07	0.14	0.04	0.05	0.06	0.07	0.09	0.10	0.048
0.01	0.04	0.12	0.01	0.04	0.16	0.09	0.13	0.16	0.06	0.10	0.16	0.06	0.12	0.16	0.01	0.03	0.16	0.01	0.03	0.07	0.052
0.01	0.04	0.13	0.01	0.04	0.13	0.06	0.12	0.18	0.06	0.11	0.18	0.06	0.12	0.18	0.01	0.03	0.13	0.01	0.03	0.13	0.052
0.04	0.07	0.16	0.04	0.07	0.16	0.04	0.07	0.16	0.04	0.08	0.16	0.04	0.08	0.16	0.04	0.05	0.07	0.04	0.06	0.11	0.048
0.04	0.06	0.15	0.04	0.06	0.15	0.04	0.08	0.15	0.04	0.06	0.15	0.04	0.08	0.15	0.04	0.05	0.06	0.04	0.08	0.11	0.049
0.01	0.04	0.14	0.01	0.04	0.14	0.07	0.13	0.19	0.04	0.08	0.19	0.07	0.12	0.19	0.01	0.04	0.08	0.01	0.05	0.14	0.051
0.01	0.05	0.20	0.01	0.06	0.20	0.01	0.06	0.28	0.01	0.07	0.28	0.01	0.06	0.28	0.01	0.04	0.12	0.01	0.06	0.20	0.045
0.04	0.08	0.16	0.04	0.07	0.10	0.01	0.05	0.16	0.01	0.05	0.23	0.01	0.06	0.23	0.01	0.04	0.10	0.01	0.06	0.23	0.050
0.07	0.12	0.17	0.07	0.13	0.17	0.01	0.03	0.07	0.01	0.04	0.17	0.01	0.03	0.07	0.04	0.07	0.12	0.04	0.07	0.12	0.054

4.7 Improvement priority of technical requirement dimensions

The weight value of technical requirement dimensions were calculated by fuzzy approach, value size can determine improvement priority of an enterprise. As Table 7 and 8 shown absolute weight with considering correlation matrix. For clear understanding the difference the paper used an example of A1 (Business consultant of trans-pacific and Far East/European shipping route) for explanation.

Table 9. Ranking order of technical requirements

<i>Job content</i>	<i>Absolute weight</i>	<i>Defuzzy</i>	<i>Relative Weight (%)</i>	<i>Rank</i>
<u><i>Sales Department</i></u>				
Business consultant of trans-pacific and Far East/European shipping route	0.194 0.578 1.409	0.652	8.58	2
Business consultant of costal shipping route	0.221 0.593 1.432	0.671	8.82	1
Booking space and planning schedule	0.217 0.487 1.231	0.566	7.44	9
Maintain /Develop customer	0.222 0.562 1.356	0.638	8.38	3
<u><i>Document Department</i></u>				
Typewriting export B/L documents	0.194 0.466 1.319	0.563	7.39	11
Typewriting export manifest documents	0.193 0.448 1.143	0.522	6.86	12
<u><i>Customer Service Department</i></u>				
Claim service for cargo damage	0.198 0.507 1.256	0.580	7.63	8
Special cargo consulting service	0.187 0.487 1.366	0.583	7.67	6
Handling service of customer complain	0.180 0.499 1.347	0.588	7.72	5
<u><i>Warehouse Department</i></u>				
Confirmation of warehouse and storage data, arrangement of on-site operation	0.182 0.487 1.355	0.581	7.64	7
Arrangement of consolidation operation	0.192 0.517 1.308	0.595	7.82	4
Value-added logistic service	0.199 0.483 1.260	0.565	7.43	10
Free Trade Zone operation service	0.180 0.419 1.176	0.505	6.64	13

Absolute weight value with considering correlation matrix, in terms of QFD's roof, it represents a matrix roof which is to identify the interrelationships of each technical characteristics. Absolute weight values of technical requirement dimensions are taken into account, then the fuzzy minimum absolute weight=roof of the technical requirement value multiplied by the customer sided weight value.

Therefore fuzzy minimum absolute weight values of A1 are
 $(1.00 * 0.048) + (0.10 * 0.0494) + (0.50 * 0.0498) + \dots + (0.30 * 0.0527) = 0.194$

Fuzzy geometric mean absolute weight values,
 $(1.00 * 0.048) + (0.29 * 0.0494) + (0.64 * 0.0498) + \dots + (0.44 * 0.0527) = 0.578$

The fuzzy maximum absolute weight values
 $(1.00 * 0.048) + (0.50 * 0.0494) + (0.70 * 0.0498) + \dots + (0.50 * 0.0527) = 1.409$

In order to facilitate comparison, absolute weight value is required to become relative weight value by way defuzzification(e. g. transform from three values into one value), according to Chen and Hsieh (2000)'s argument proposed calculation formula: $(a+4b+c) / 6$, a, b, c, representing minimum value, intermediate, and maximum value respectively, absolute weight value of A1 by defuzzified approach is equal to $(0.194 + 0.578 + 1.409) / 6 = 0.652$, afterward, related weighting algorithm approach can be obtained by defuzzified value of A1/all defuzzified values(e. g. from A1~D5), the relative weights of A1 = $0.652 / 7.609 = 8.58\%$, consequently, this figure can determine improvement priority of technology needs in the QFD.

Table 9 shown most improvement priority of Top 3 including Business consultant of trans-pacific and Far East/European shipping route, Business consultant of costal shipping route, and Maintain/Develop customer. Furthermore, the top three job contents are concentrated in the business sector, it represents sales department plays important role in international logistics business operated by shipping company.

Sales man is living in the front line, the customer often directly contact with sales man while he encountered cargo damage and delay delivery issues, hence the sales man's crisis management and emergency event processing capabilities has relatively become important, our recommend is that the enterprise should strengthen marketing and sales education and training, case sharing programs for the sake of improving value added service quality and emergency case handing ability of sales man.

5. Conclusions

This paper attempts to analyze the export cargo logistics by using the customer-oriented base on service quality method, and to figure out service quality improvement for the Maritime logistics operated by shipping company, and to determine the priority of improvement service based on the weight which was calculated by combining fuzzy set theory with quality function deployment.

This article endeavors to deliver the voice of customer to the company for the purpose of maximum improvement effect in order to provide customers with better service, increase customer loyalty and satisfaction and to maintain a competitive advantage. As Bottani and Rizzi (2006) advocated logistics performance improvement enables enterprises to increase customer satisfaction and increase market share.

The empirical examination results are stated that there are three important service items recognized by the customer for international logistics business in shipping company are: (1) properly and quickly respond to customer's inquiry. (2) Cargo safety transport capability (3) Employees used expertise to solve the problem for customer. The reason of no. 1 item can be attributed that customer pays more attention on accuracy and efficiency of inquiry process responding from internal sales staff, especially for the first-timed inquiry of the new customers; internal sales staffs are not familiar with the process and the relevant provisions in the initial inquiry stage, they should be more patient and cautious to provide customers with the information they need, so that the company can get a better first impression of new clients and win their satisfaction and loyalty. In addition, the cargo can be delivered to the consignee in the hand safely without extraordinary case, if cargo damage claims events occur. Staff can provide some fast and reasonable solution

to the customer that is belonged to the second most important item.

On the other hand, there are three most dissatisfied service items considered by the customer on the international logistics business operated by shipping company are as follows: (1) Instant conversion service of EDI file in the internet; (2) Provide Free Trade Zone service; (3) Provide comprehensive transportation and logistics consultant service. Not all liner shipping companies owned logistics companies can do real-time exchange service between Internet/EDI services, the local shipping companies headquartered in Taiwan, it is quite efficient in Internet/EDI files conversion.

Conversely, foreign shipping companies' headquarters on the abroad, it spends much time on data conversion process and lost this competitive advantage compared with domestic shipping companies. Moreover, along with tendency of the Asian countries established many free trade zones, shipping companies could take advantage of free trade port zone to promote comprehensive transpiration and logistics service for their customer with best supply chain solutions, cheaper transportation and logistics cost, shorter lead time of cargo flow process, lower the pressure of capital flow and enhance Taiwan's overall industrial competitiveness.

On the technical requirements aspect, technical quality is the source of enterprises improving service technology, this article used deployment of internal quality technology for international logistics business operating by shipping company as the service quality requirements. Quality technologies were introduced into the house of quality based on fuzzy set theory, in accordance with the quality Technical experts confirmed the correlation coefficient, the paper finally discovered service quality deployment table of international logistics operated by shipping company. Our finding showed that the sales department is very important to service quality improvement of international logistics engaged by shipping company.

Although maritime industry is belonged to traditional industries, however practical operation businesses of entire maritime supply chain is complex and diverse, sales man providing customer best solutions with professional knowledge and working experience is helpful for business improvement, therefore, a company should stress education and training of professional manpower to improve the competitive advantage of sustainable development. Our finding are consistent with opinion of Liang et al (2006) claimed that employees can receive good education and training to strengthen their emergency responding capabilities and professional knowledge in order to access favorable customers and increase customer loyalty.

Finally, sales department is identified as service improvement priority in technology needs analysis, as the shipping industry is a traditional industry, main sale representatives of the company have to familiar with different industry markets, figure out characteristics of peak or off-season, also play a bridge between the company and its customers, to solve the problems of transportation, bills of lading, and customs clearance, sometimes they have to become a customer advisor to analysis industry dynamics and give optimal suggestions. In order to improve the quality of the company's business, our suggestion is that a company should strengthen education and training of sales man, use special case studying shared by business representatives, and formulate a set of standard operating procedures.

References

- Bossert, J. L. (1991), *Quality function deployment-a practitioner's approach*. Milwaukee: ASQC Quality Press.
- Bottani, E. and Rizzi, A. (2006), Strategic management of logistics service: A fuzzy QFD approach, *International Journal of Production Economics* 103(2): 585-599.
- Chen, S.Y. (2005), *Multivariate analysis*, 4th edition, Taipei: Hwatai publication co.
- Chen, S.H. and Hsieh, C.H. (2000), Optimization of fuzzy production inventory model under fuzzy parameters, *Proceedings of the Fifth joint Conference on Information Sciences (JCIS'2000)* 1:1098-1101.
- Chen, C.H. and Chou, S.Y. (2006), A BSC Framework for air cargo terminal design: procedure and case study, *Journal of Industrial Technology* 22(1): 1-10.
- Ding, J. F. (2006), Using fuzzy AHP to investigate key factors influencing the quality of service delivery system for port of Kaohsiung, *Advanced in Fuzzy Sets and Systems* 1(1): 63-81.

- Liang G. S., Pan, H. L. Ding J. F. (2004), Assessment studies of key competencies for ocean freight forwarders: applying Fuzzy multi-criteria decision making, *Shipping Quarterly* 13(3): 29-47.
- Liang, G. S., Chou, T. Y., Kan, S. F. (2006), Applying fuzzy quality function deployment to identify service management requirements for an ocean freight forwarder, *Journal of Total Quality Management* 17: 539-554.
- Lin, K., Han, T. C., and Ling, F. I. (2005), A rational approach to handling fuzzy perceptions in airport cargo terminal service strategies. *Journal of Eastern Asia society for Transportation Studies* 6: 693-707.
- Liang, G.S. (2008), Applying fuzzy quality function deployment to identify service management requirements for customer quality needs, *Journal of Quality & Quantity* 44: 47-57.
- Lin, K. and Zhang, Z. Q. (2008), *Operation and management of the shipping industry*, 6th edition, Taipei: Shipping Digest co.
- Marcus, H. S. and Damianidou, E. (1991), Quality management in marine transportation, *The Proceedings of ocean technologies and opportunities in Pacific for the 90's*, 474-476.
- Parasuraman, A., Valarie A. Zeithaml, and Leonard L. Berry, (1985), A conceptual model of service quality and its implications for future research, *Journal of Marketing* 49: 41-50.
- Park, J. W., Robertson, R., Wu, C. L. (2004), The effect of airline service quality on passengers' behavioral intentions: a Korean case study, *Journal of Air Transport Management* 10: 435-439.
- Ronald D. Anderson and Roger E. Jerman. (1998), Quality management influences on logistics performance, *Transportation Research Part E* 34: 137-148.
- Shon, S. Y. and Choi, I. S. (2001), Fuzzy QFD for supply chain management with reliability consideration, *Reliability Engineering & System Safety* 72: 327-334.
- Vinodh, S. and Chintha, S. K. (2011), Application of fuzzy QFD for enabling leanness in a manufacturing organization, *International Journal of Production Research* 49(6): 1627-1644.
- Wang, R. T. (2007), Improving service quality using quality function deployment: the air cargo sector of China airlines, *Journal of Air Transport Management* 13: 221-228.
- Wisner, J. D. (1999), A study of successful quality improvement programs in the transportation industry, *Benchmarking: An International Journal* 6: 147-163.
- Wu, W.Y. (2005), *Business Research methods*, 2nd edition, Taipei: Hwai Tai Publishing.
- Zadeh, L.A. (1965), Fuzzy sets, *Information and Control* 8: 338-353.

The Optimization Model for the Location of Water Emergency Supplies Reserve Bases and the Configuration of Salvage Vessels

Jing Lu, Yun-fei Ai and Li-li Zhang

School of Transportation Management, Dalian Maritime University, Dalian, 116026, China.

Abstract

Emergency management becomes a hot topic with emergencies occurring frequently. Therefore, reasonable configuration of emergency resources is greatly important to ensure the timely and effective salvage after the emergency occurs. In this paper, it studied the location of water emergency supplies reserve bases and the configuration of salvage vessels, including the location of reserve bases, the distribution of demands, and the configuration of salvage vessels. It established an optimization model with the objective of minimizing the total cost, which contains the cost of building emergency supplies reserve bases, the cost of emergency supplies reserve and the cost of configuration of salvage vessels. In view of the model, it designed a mixed heuristic algorithm and a traditional genetic algorithm. The example analysis results show that the hybrid algorithm is more efficient. The final results could achieve the stated objectives, and provide a reference for the configuration decision of emergency resource. So the study of this paper was practical.

Keywords: Emergency management; Location of water emergency supplies reserve bases; Configuration of salvage vessels; Hybrid heuristic algorithm; Genetic algorithm.

1. Introduction

Emergency management becomes a hot topic with emergencies occurring frequently. The configuration of water emergency resources can be divided into three parts: the location of emergency supplies reserve bases, the allocation of the emergency supplies and the configuration of the salvage vessels. The problem is impacted by the natural conditions, the distribution and the quantity of the demand points and the performance of the salvage vessels etc. In this paper, we study the location problem of water emergency supplies reserve bases and the configuration of salvage vessels. It occurs during the prevention phase, but it can ensure timely and efficient salvage when the emergencies happen.

Where and when the emergencies will occur is uncertain, so the covering model is widely used in the location problem of emergency facilities. It can consider the entire demand area or a predefined part to be served. The set covering model was first developed by Toregas et al. (1971). Its goal was to achieve complete coverage of the area with the minimal construction costs or the minimum number of facilities. Church and Reville (1974) developed the maximal coverage location problem, which is the so called MCLP. Its goal was to achieve the maximum possible part of the demand area with the certain number of facilities. Schilling et al. (1979) extended the MCLP by developing the tandem equipment allocation model that allows for having two different types of service units in the system. Daskin and Stern (1981) modified the original MCLP to maximize the number of demand areas covered more than once. It was the so called backup coverage problem.

Gendreau et al. (1997) developed a double standard model of maximal coverage that includes two time limits, one for covering the entire demand area and another for covering part of it. In recent years, these models have been extensively used to solve various regular emergency service location problems. Segall (2000) presented the background on the hospital facility location model as a prelude to describing some quantitative methods for determining the optimal capacity and location of emergency medical facilities within service areas of potential occupational accidents. Araz et al. (2007) considered the location problem of emergency service vehicles. A multi-objective maximal covering location model was proposed and the model addressed the issue of determining the best base locations for a limited number of vehicles so that the service level objectives were optimized. Geroliminis (2009) develop a model for locating emergency vehicles on urban networks

considering both spatial and temporal demand characteristics such as the probability that a server was not available when required. Canbolat (2011) studied the problem where locations of each demand point were random. Sometimes the probability that a server was not available when required, so it was a practical problem.

Traditionally, the location problem of the emergency supplies reserve bases and the configuration of the rescue vehicles were studied separately. There were only a few papers considering the location and allocation as a whole. The location-allocation problem essentially was first raised by Curry and Skeith (1969). Wesolowsky and Truscott (1975) studied the location and distribution problem, and used the bender decomposition method to solve the distribution centre location problem. Marianov and Serra (2002) studied the multi-service centre location-allocation problem constrained by the waiting or queuing time. Sha and Huang (2012) studied the location-allocation problem of engineering emergency blood supply systems, and proposed a multi-period location -allocation model. Hector et al.(2013) studied the location- dispatching problem of emergency medical services, they integrated the location and dispatching decision into a single framework.

The capability of salvage vessel, the emergency response time, and the natural conditions such as wind, flow will influence the location of water emergency supplies reserve bases and the configuration of salvage vessels. So the problem is different to the previous studies. We established a optimization model. The objective function of the model was minimizing the total cost. And in view of the model, we designed a hybrid heuristic algorithm. The upper genetic algorithm solved the location of water emergency supplies reserve bases and the lower greedy algorithm solved the configuration of salvage vessels.

2. Problem Description

The water area is divided into several water units, and each unit is represented by its center. The demand of each water unit is known. If the emergency supplies reserve base can cover the center of the water unit, we consider that the water unit is covered by the reserve base. There are several water emergency supplies reserve base candidates. Each of the candidates has a coverage radius. If the distance between the water unit and the candidate is larger than the coverage radius of the candidate, we consider that the candidate will not provide emergency service for this water unit. The speed of the salvage vessel, the emergency response time and the natural conditions such as wind, flow will influence the coverage radius of water emergency supplies reserve base. We propose that the coverage radius of water emergency supplies reserve base is a vector set. Based on the gravity model, we put forward the allocation method of the water units' demand between the water emergency supplies reserve bases. It is necessary to take into account the fairness and efficiency when configuring the emergency resources, so we propose that the location of water emergency supplies reserve bases should not only achieve the full coverage of the water units, but also achieve the multi-coverage of the key water units. We introduce the concept of covering reliability which indicate the possibility that an emergency supplies reserve base can cover a water unit, and then we use the calculate method of reliability which was often used in the parallel system to calculate the reliability of the water unit being covered by multiple water emergency supplies reserve bases. The configuration of salvage vessels should not only meet the reliability requirement of the water units, but also meet the capacity on demand of the water units.

Model assumptions:

- 1) Salvage vessels do not involve round-trip transportation;
- 2) We configure one kind of salvage vessel in each of the water emergency supplies reserve bases.

3. Optimization Model

3.1 Parameters

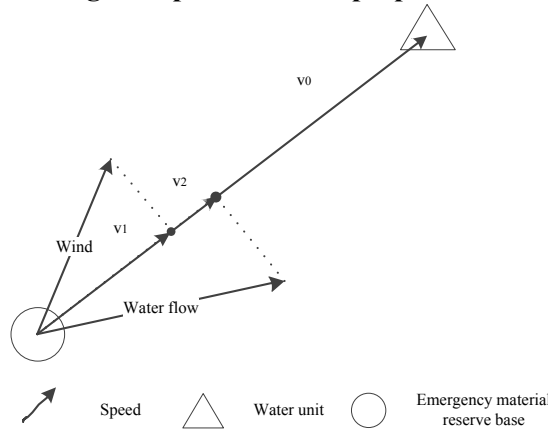
$i = 1, 2, \dots, I$ index of the water units; $j = 1, 2, \dots, J$ index of the water emergency supplies reserve base candidates; $k = 1, 2, \dots, K$ index of salvage vessels; r_j^k the coverage radius of reserve base j when it deploys

k type of vessel, the coverage radius is a vector set; r_{ij}^k is the projection of r_j^k toward the direction i , it will be explained later in this paper; d_{ij} is the distance between water unit i and candidate j , if $d_{ij} \leq r_{ij}^k$, then water unit i can be covered by the candidate j with type k vessel; z_j^k is a 0-1 variable, if the reserve base candidate j is selected and deploys the k type of salvage vessel, then $z_j^k = 1$, otherwise $z_j^k = 0$; $N_i = \{j | d_{ij} \leq r_{ij}^k\}$ is the set of emergency supplies reserve bases that can cover water unit i ; η_{ij} is a 0-1 variable, for water unit i and emergency supplies reserve base j , if $d_{ij} \leq r_{ij}^k$, then $\eta_{ij} = 1$, otherwise $\eta_{ij} = 0$; $N_j = \{i | d_{ij} \leq r_{ij}^k\}$ is the set of water units that emergency supplies reserve base j could cover; t_{ij}^k is the sailing time of vessel k from emergency supplies reserve base j to water unit i ; γ is a 0-1 variable, if the candidate j is selected, then $\gamma_j = 1$, otherwise $\gamma_j = 0$; w_i^1 the importance of water unit i ; w_j^2 the quality of service that emergency supplies reserve base j ; u_{ij} the attraction that water unit i feels from emergency supplies j ; q_i the demand for emergency supplies of water unit i ; w the threshold of w_i^1 , if $w_i^1 \geq w$, then water unit i should be covered more than once; λ_j^k the reliability of emergency supplies reserve base j with a k type of salvage vessel; μ_i the reliability that water unit i be covered, μ_0 the minimum requirement of μ_i ; C_j the fixed construction cost of emergency supplies reserve base j ; c_j unit reserve cost of emergency supplies reserve base j ; a_k the configuration cost of type k salvage vessel; b_k the capacity of k kind of salvage vessel; β_j^k the number of type k salvage vessel that deployed in emergency supplies reserve base j .

3.2 Coverage Radius of Emergency supplies Reserve Base

Water emergency supplies are transported by salvage vessels. So the coverage radius of emergency supplies reserve base is equal to the maximum distance that the salvage vessel can achieve under the wind, water flow and other natural conditions within the emergency response time. In accordance with the vessel's performance without regard to external factors, the service radius of the salvage vessel is $R = V * T$, where V is the vessel speed, and T is the emergency response time. However, the speed of salvage vessel is influenced by wind, water flow and other natural conditions. So the actual sailing speed of salvage vessel is a result of the vector superposition, shown in figure 1.

Fig 1. Speed vector superposition



$$V_{ij}^k = v_{ij}^k + v_1^k + v_2^k \quad (1)$$

v_{ij}^k the sailing speed of type k salvage vessel from emergency supplies reserve base j to water unit i

without the influence of water flow and wind; v_1^k is the influence of wind, v_2^k is the influence of water flow, V_{ij}^k is the sailing speed of type k salvage vessel considering the influence of wind and water flow. We use the constant wind and constant water flow from the meteorological statistics.

$$r_{ij}^k = V_{ij}^k * t \quad (2)$$

Different salvage vessels have different sailing speed. So r_{ij}^k is the coverage radius of emergency supplies reserve base j considering the deployed salvage vessel. The parameter r_j^k is a vector collection. The parameter r_{ij}^k is the projection of r_j^k towards water unit i .

3.3 Allocation of Demand between Emergency supplies Reserve Bases

Based on the traditional gravity model, we propose the improved attraction model, as

$$u_{ij}^k = \eta_{ij} * w_j^2 / t_{ij}^k \quad (3)$$

$$t_{ij}^k = d_{ij} / V_{ij}^k \quad (4)$$

The attraction is positive to service quality and negative to arrival time. If water unit i could not be covered by emergency supplies reserve base j , then it cannot feel the attraction of emergency supplies reserve base j . The parameter η_{ij} can achieve that goal. When water unit i is covered by multiple emergency supplies reserve bases, the demand for emergency supplies should be reserved by all of them. The allocation model is:

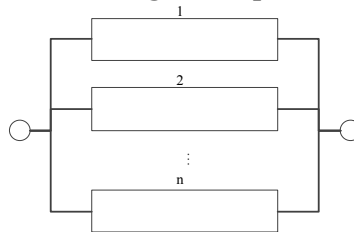
$$M_{ij}^k = q_i * \frac{u_{ij}^k}{\sum_{j \in N_i} u_{ij}^k} \quad (5)$$

The parameter M_{ij}^k is the proportion of water unit's demand that emergency supplies reserve base j occupied.

3.4 The Reliability of Water Unit Being Covered

The number of emergency supplies reserve base candidates that can cover water unit i is n . The necessary condition that water unit i could be effective monitored by the emergency supplies reserve bases is that at least one emergency supplies reserve base can cover it. It is a parallel system. The system block diagram is shown in figure 2.

Fig 2. Block diagram of parallel system



The reliability of water unit i that being covered is:

$$\mu_i = 1 - \prod_{j \in N_i} (1 - \lambda_j^k)^{\rho_j^k} \quad (6)$$

3.4 Model

Based on the previous analysis, we establish the optimization model. The objective function of the model is:

$$\min Z_1 = \sum_{j=1}^J y_j * C_j + \sum_{j=1}^J \sum_{k=1}^K \sum_{i=1}^I z_j^k * M_{ij}^k * c_j + \sum_{j=1}^J \sum_{k=1}^K z_j^k * \beta_j^k * a_k \quad (7)$$

s.t.

$$\sum_{j \in N_i} y_j \geq 1 \quad (8)$$

$$\sum_{j \in N_i, w_i^j \geq w} y_j \geq 2 \quad (9)$$

$$\sum_{k=1}^K z_j^k = 1 \quad (10)$$

$$\beta_j^k * b_k \geq \sum_{i=1}^I M_{ij}^k \quad (11)$$

$$1 - \prod_{j \in N_i} (1 - \lambda_j^k)^{\beta_j^k} \geq \mu_0 \quad (12)$$

$$y_j, \eta_{ij}, z_j^k \in \{0,1\} \quad (13)$$

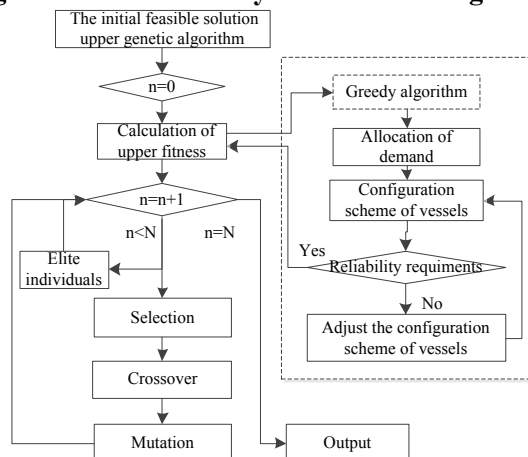
The objective function (7) is the total cost, the first part is the fixed construction cost of emergency supplies reserve bases, the second part is the reserve cost of the emergency supplies, the third part is the configuration cost of salvage vessels; the constraint (8) achieves that all the water units are covered at least by one emergency supplies reserve bases; the constraint (9) achieves the multiple coverage of important water units; the constraint (10) achieves that each emergency supplies reserve base only deploys one kind of salvage vessel; the constraint (11) achieves that the configuration of salvage vessels in the emergency supplies reserve base should meet the demand of transportation capacity; the constraint (12) achieves that the reliability of water unit i be covered is greater than the minimum requirement of reliability; (13) is the 0-1 variables constraint.

4. Heuristic Algorithm

4.1 Hybrid Heuristic Algorithm

The model is a NP-Hard problem. There are a variety of heuristic algorithm methods, such as genetic algorithm, particle swarm algorithm and greedy algorithm. In this paper, we design a hybrid heuristic algorithm model. The upper genetic algorithm solves the location of water emergency supplies reserve bases and the lower greedy algorithm solves the configuration of salvage vessels. The specific process of hybrid heuristic algorithm is shown in figure 3.

Fig 3. Flow chart of hybrid heuristic algorithm

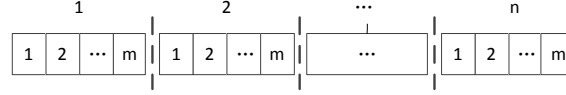


4.1.1 Upper Genetic Algorithm

(1) The chromosome coding of upper genetic algorithm

The upper genetic algorithm uses binary encoding, as shown in figure 4. The gene groups 1,2,...,n are the corresponding emergency supplies reserve base candidates. The genes 1,2,...,m are the vessel types. So the total length of the chromosome is $n*m$.

Fig 4. Chromosome coding of the upper genetic algorithm



(2) Initial population and fitness function

The initial population is generated randomly. If the chromosome is feasible, it will be kept in the population. When the number of the chromosomes reaches M , we get the initial population. The fitness function is:

$$f = I - Z \quad (14)$$

The parameter f is the fitness value of the chromosome. The parameter Z is the objective function value of the chromosome. I is a relatively large number.

(3) Elitist individuals

In each generation, the algorithm finds top-ranking individuals as the elite individuals which will be kept separately. Then carry on selection, crossover and mutation. The elite individuals replace the individuals with the relatively low fitness value, and go into the next generation.

(4) Penalty function

If the individual isn't feasible, then a penalty function is used, as:

$$f' = f - P \quad (15)$$

The parameter P is a constant variable, f' is the new fitness of the chromosome.

(5) Genetic operators and termination condition

The algorithm uses the roulette method to choose the individuals that can enter the next generation. Use single-point crossover and single-point mutation operation. When the iteration reaches the maximum number, the calculation finishes.

4.1.2 Lower Greedy Algorithm

The calculation steps of the greedy algorithm are following:

Step 1, determine the allocation results of demands among the emergency supplies reserve bases based on the upper location results.

Step 2, determine the type and number of salvage vessels in each emergency supplies reserve base. The transportation capacity in the emergency supplies reserve bases must be larger than the demand of the water units that could be covered by the emergency supplies reserve bases.

Step 3, judge whether the reliability of water unit i covered is greater than the minimum requirement of

reliability, if true, then go to step 5, or go to step 4.

Step 4, find the water units that do not meet the reliability requirement and the corresponding emergency supplies reserve bases. Find the emergency supplies reserve base that corresponding the most number of water units that do not meet the reliability requirement, then increase the number of salvage vessels in it. Then go to step 3.

Step5, find the optimal configuration plan of salvage vessels, stop.

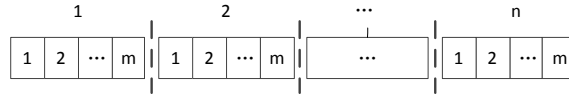
4.2 Genetic Algorithm

We also design a traditional genetic algorithm to solve the model, as followings.

(1) Chromosome coding

The traditional genetic algorithm use real number encoding, as shown in figure 5. The groups 1,2,...,n are the emergency supplies reserve base candidates, the genes 1,2,...,m are the vessels of each emergency supplies reserve base. So the total length of the chromosome is also $n*m$.

Fig 5. Chromosome coding of traditional genetic algorithm



(2) Initial population and fitness function

The initial population is generated randomly. If the chromosome is feasible, it will be kept in the population. When the number of the chromosomes reaches M , we get the initial population. The fitness function is:

$$f = I - Z \quad (17)$$

The parameter f is the fitness value of the chromosome. The parameter Z is the objective function value of the chromosome. I is a relatively large number.

(3) Elitist individuals

In each generation, the algorithm finds top-ranking individuals as the elite individuals which will be kept separately. Then carry on selection, crossover and mutation. The elite individuals replace the individuals with the relatively low fitness value, and go into the next generation.

(4) Penalty function

If the individual isn't feasible, then a penalty function is used, as:

$$f' = f - P \quad (18)$$

The parameter P is a constant variable, f' is the new fitness of the chromosome.

(5) Genetic operators

Use the roulette method to choose the individuals that could enter into the next generation. In view of the coding of the chromosome, the algorithm does single-point crossover in the odd position. Do two-point mutation operation.

(6) Termination conditions

When the iteration reaches the maximum number, the calculation finishes.

5. Case Study

In this case, the region includes 20 water units. There are 10 emergency supplies reserve base candidates and two kinds of salvage vessels. As shown in table 1-3. The example gives the speed matrix of salvage vessels sailing to each water units from the emergency supplies reserve base candidate (In practice, the sailing speed of different kind of salvage ships have a little difference, we assume that they have the same sailing speed), as shown in table 4. $w = 5$, $T = 40$ minutes, $\mu_0 = 0.98$.

Table 1. Data of water units

NO.	Coordinates	Importance	Demand	NO.	Coordinates	Importance	Demand
1	(1,1)	4	90	11	(1,6)	2	90
2	(3,1)	3	80	12	(3,6)	3	100
3	(5,1)	7	100	13	(5,6)	4	90
4	(7,1)	9	70	14	(7,6)	8	80
5	(9,1)	3	100	15	(9,6)	1	90
6	(1,3)	2	80	16	(1,9)	1	60
7	(3,3)	4	90	17	(3,9)	3	100
8	(5,3)	4	90	18	(5,9)	5	90
9	(7,3)	6	100	19	(7,9)	7	70
10	(9,3)	3	90	20	(9,9)	2	90

Table 2. Data of emergency supplies reserve base candidates

NO.	Coordinates	Attraction	Fixed construction cost	Unit reserve cost
1	(0,1)	5	80	0.8
2	(0,9)	6	90	0.85
3	(3,0)	6	100	0.9
4	(5,0)	6	110	0.95
5	(7,0)	7	120	0.8
6	(10,2)	7	120	0.85
7	(10,6)	7	110	0.85
8	(10,8)	6	100	0.9
9	(2,10)	6	90	0.95
10	(8,10)	5	80	0.85

Table 3. Data of salvage vessels

Type	Configuration cost	Transportation capacity	Reliability
Big	100	120	0.9
Small	80	80	0.8

Table 4. Speed matrix of salvage vessel

		Emergency supplies reserve base candidates									
		1	2	3	4	5	6	7	8	9	10
Water units	1	9.8	10	10	9.8	9.9	9.9	10	10	10	10
	2	9.5	9.5	9.5	9.5	9.7	9.7	9.5	9.8	9.5	10
	3	10.5	9.9	9.9	9.8	9.8	9.8	9.9	9.5	9.9	9
	4	10	9.7	9.7	9.5	10	10	9.7	10.5	9.7	9
	5	9.5	9.8	9.8	10.5	10.2	10.2	9.8	10	9.8	9
	6	9.9	10	10	10	10	9.8	10	9.5	10	10
	7	9.7	10.2	10.2	9.5	9.5	10	10.2	9.9	10.2	10

8	9.8	9.9	10	9.8	9.9	10.2	9.5	9.7	9.9	9.9
9	10	9.7	10.2	10	9.7	10	9.9	9.8	9.7	9.9
10	10.2	9.8	9.9	10.2	9.8	9.5	9.7	10	9.8	9.7
11	10.1	10	9.7	10.1	10	9.9	9.8	10.2	10	9.8
12	10.3	10.2	9.8	10.3	10.2	9.7	10	10.1	10.2	10
13	9.8	10	10	9.8	10.1	9.8	10.2	10.3	10.1	10.2
14	9.7	9.5	10.2	9.7	10.3	10	10.1	9.8	10.3	10
15	9.9	9.9	10	9.9	9.8	10.2	10.3	9.7	9.8	9.5
16	10	9.7	9.5	10	9.7	10.1	9.8	9.9	9.7	9.9
17	10.1	9.8	9.9	10.1	9.9	10.3	9.7	10	9.9	9.7
18	10.2	10	9.7	10.2	10	9.8	9.9	10.1	10	9.8
19	10	10.2	9.8	10	10.1	9.7	10	10.2	10.1	10
20	9.8	9.9	10	9.8	10.2	9.9	10.1	10	10.2	10.2

The population of the upper genetic algorithm is 200. The length of the chromosome is 20. The crossover probability is 0.9. The mutation probability is 0.1. The number of iterations is 200. The MATLAB computing time is 7.55s. The genetic algorithm iteration is shown in figure 5. The location result is shown in figure 6.

Fig 5. Genetic algorithm iteration figure

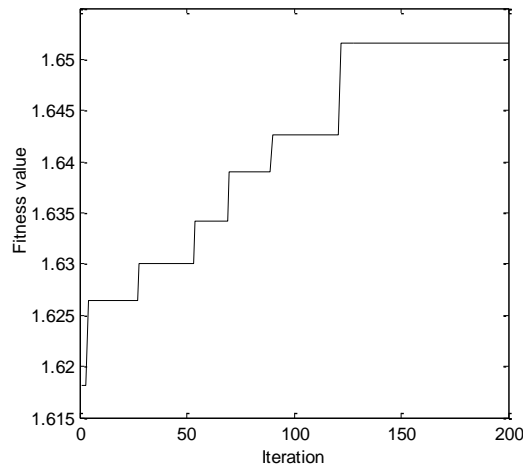
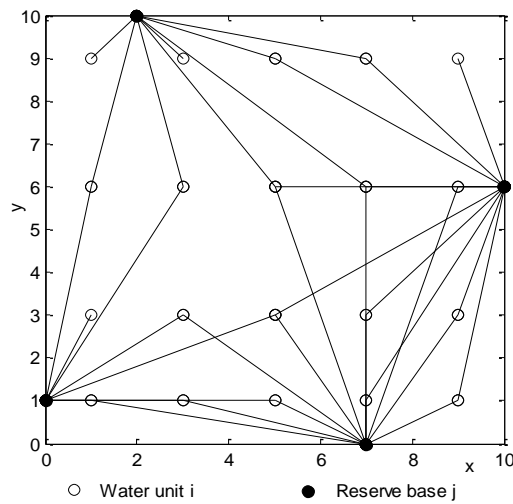


Fig 6. Location result



Build emergency supplies reserve bases at point 1, 5, 7, 9. The reserve stocks of emergency supplies are 357, 511, 475, 407. The total cost is 3485. The specific results are shown in Table 5 and Table 6.

Table 5. Location result

NO.	Coordinates	Attraction	Fixed construction cost	Unit reserve cost	Type of vessel	Number of vessels	Reserve stock
1	(0,1)	5	80	0.8	big	3	357
2	(0,9)	5	90	0.85	-	-	-
3	(3,0)	6	100	0.9	-	-	-
4	(5,0)	6	110	0.95	-	-	-
5	(7,0)	6	120	0.8	big	5	511
6	(10,2)	7	120	0.85	-	-	-
7	(10,6)	7	110	0.85	big	4	475
8	(10,8)	7	100	0.9	-	-	-
9	(2,10)	6	90	0.95	big	4	407
10	(8,10)	6	80	0.95	-	-	-

Table 6. Coverage result of water units

Water unit	1	2	3	4	5	6	7	8	9	10
Importance	4	3	7	9	3	2	4	4	6	3
Coverage Times	2	2	2	2	2	1	2	3	2	2
Reliability	>0.9999	>0.9999	>0.9999	>0.9999	>0.9999	0.9999	>0.9999	>0.9999	>0.9999	>0.9999
Water unit	11	12	13	14	15	16	17	18	19	20
Importance	2	3	4	8	1	1	3	5	7	2
Coverage times	2	2	3	3	2	1	1	2	2	2
Reliability	>0.9999	>0.9999	>0.9999	>0.9999	>0.9999	0.9999	0.9999	>0.9999	>0.9999	0.9999

Remark: the water units with the importance greater than 5 are bold

We use the traditional genetic algorithm to compare with our hybrid heuristic algorithm. The length of the chromosome is 20. The crossover probability is 0.9. The mutation probability is 0.1. The results are shown in table 7.

Table 7. Results of the genetic algorithm with different parameters

Population	Number of iteration	Location result	Reserve stock	Type of salvage vessels	Number of salvage vessels	Total cost	Computing time
100	200	(2,3,6,7,8,9,10)	(218,489,293,252,148,205,145)	(big,big,big,small,small,big,small)	(2,5,3,4,3,2,2)	4150	9.96
100	500	(1,2,5,7,10)	(307,328,492,375,248)	(small,big,small,small,small)	(4,3,7,5,4)	3828	22.05
200	200	(2,4,5,7,8)	(414,433,373,311,219)	(small,big,big,big,big)	(6,5,4,3,2)	3933	20.44
200	500	(2,4,5,8,10)	(365,463,445,240,237)	(small,big,small,big,big)	(5,4,7,2,2)	3784	48.40
200	1000	(3,6,7,9)	(593,332,426,400)	(big,big,small,big)	(5,3,6,4)	3657	90.70
500	1000	(1,5,7,9)	(357,511,475,407)	(big,big,small,big)	(3,5,6,4)	3565	273.53

We find that the feasible solution space of the problem is very large, so the traditional genetic algorithm cannot find the optimal solution easily. The algorithm result of the traditional genetic algorithm is proportional with the population size and the number of iterations. When the population is 500 and the number of iterations is 1000, the result is similar to the result of the hybrid heuristic algorithm, as bolded in table 7. But the computing time is 36 times bigger. We can find out that the hybrid heuristic algorithm is more efficient than the traditional genetic algorithm.

6. Conclusions

This paper integrates the location of emergency supplies reserve bases and the configuration of salvage vessels. We establish an optimization model. In view of the model, we design a mixed heuristic algorithm and a traditional genetic algorithm. The example analysis results show that the hybrid algorithm is more efficient. The final results can achieve the stated objectives, and provide a reference for the configuration decision of emergency resource. So the study of this paper is practical.

References

- Toregas, C.R. Swain, R. ReVelle, C.S. Bergman L. (1971), The location of emergency service facilities, *Operations Research* 19 (6): 1363–1373.
- Church, R.L. Reville, C.S. (1974), The maximal covering location problem, *Papers of the Regional Science Association*, 32 (1):101-118.
- Schilling, D.A. Elzinga, D.J. Cohon, J. Church, R.L. ReVelle, C.S. (1979), The TEAM/FLEET models for simultaneous facility and equipment siting, *Transportation Science* 13(2): 163–175.
- Daskin, M.S. Stern, E.H. (1981), A hierarchical objective set covering model for emergency medical service vehicle deployment, *Transportation Science* 15(2): 137–152.
- Gendreau, M. Laporte, G. Semet, F. (1997), Solving an ambulance Location Model by Tabu search. *Location Science* 5(2): 75–88.
- Araz, C. Selim, H. Ozkarahan, I.(2007), A fuzzy multi-objective covering-based vehicle location model for emergency services, *Computers & Operations Research* 34: 705–726.
- Segall, R.S. (2000), Some quantitative methods for determining capacities and locations of military emergency medical facilities, *Applied Mathematical Modelling* 24: 365-389.
- Canbolat, M.S. Massow, M.V. (2011), Locating emergency facilities with random demand for risk minimization, *Expert Systems with Applications* 38: 10099–10106.
- Geroliminis, N. Karlaftis, M.G. Skabardonis, A. (2009), A spatial queuing model for the emergency vehicle districting and location problem, *Transportation Research Part B* 43: 798–811.
- Curry, G.L. Skeith, R.W.(1969), A dynamic programming algorithm for facility location and allocation, *American Institute of Industrial Engineers Transactions* 1: 133-138.
- Wesolowsky, G.O. Truscott, W.G.(1975), The multiperiod location-allocation problem with relocation of facilities, *Management Science* 22(1): 57-65.
- Marianov, V. Serra, D. (2002), Location-allocation of multiple-server service centers with constrained queues or waiting times, *Annals of Operations Research* 111: 35-50.
- Sha, Y. Huang, J. (2012), The Multi-period Location-allocation Problem of Engineering Emergency Blood Supply Systems, *Systems Engineering Procedia* 5: 21-28.
- Hector T.D., Maria E.M., Sunarin C., Laura A.M. (2013), Joint location and dispatching decisions for Emergency Medical Services, *Computers & Industrial Engineering* 64: 917-928.

Competitive Strategies in Bilateral Oligopoly — The Case of Coastal Coal Transport Market in China

Jing Lu, Xiaolin Jiang and Jing Li

Transportation Management College, Dalian Maritime University, Dalian, 116026, China.

Abstract

This paper analyzes the market structure of coastal coal transport market in China and finds its bilateral oligopoly characters. Different from the pricing mechanism in perfectly competitive market, contracts of affreightment which state the traffic volume and freight rate are negotiated by ship owners and cargo owners periodically. By analyzing the factors affecting the oligarchs' bargaining power, a game theoretical model which considers the effect of imperfect information, outside options, vertical integration and horizontal alliance is established. On the basis of empirical analysis of China coastal coal transport market, competitive strategies for oligarchs in the downstream and upstream market are proposed respectively.

Keywords: Bilateral oligopoly; Imperfect information; Outside options; Vertical integration; Horizontal alliance.

1. Introduction

The complexity of bilateral oligopoly market has drawn attention of numerous researchers, which generated voluminous literature addressing these questions in recent years. Alex Dickson and Roger Hartley(2007) compared the Cournot game and the market share game with many buyers and found the difference of the equilibrium of the two models. Kenneth Hendricks and R. Preston McAfee(2010) analyzed the intermediate good market with oligopolistic numbers of firms on both sides in the case of electricity market in the United State and compared the impacts of horizontal and vertical merger. George Symeonidis (2010) analyzed the effects of downstream merger in a differentiated oligopoly and found that mergers between downstream might rise consumer surplus and overall welfare, on the other hand, Robin A. Naylor (2002) has proven that industry profits would increase with the number of firms if input prices were determined by bargaining in bilateral oligopoly by considering the product market and labor market simultaneously. Stephane Caprice(2005) showed that an input supplier's profit can increase with the number of downstream firms in the context of the upstream firm compete with an alternative inferior supplier. John R. Schroeter, Azzeddine M. Azzam and Mingxia Zhang(2000) introduced an approach to measure market power in bilateral oligopoly and applied it to the US wholesale market for beef. Lorenzo Clemenit(2012) analyzed the social welfare of different foreclosure strategies and found both the size of the integrated firms and the size of the independent firms would affect the post-merger markups. Jean-Philippe Gervais and Stephen Devadoss(2006) estimated the bargaining strengths of Canadian chicken producers and processors and developed a dynamic price adjustment mechanism using a bilateral monopoly framework. Jonas Björnerstedt and Johan Stennek(2007) studied the efficiency of the intermediate goods markets based on Rubinstein–Ståhl negotiations and demonstrated the efficiency of bilateral oligopoly market. Lommerud et al(2005) examined the effect of downstream merger to the input prices and found it could be more profitable to take part in the merger than to be an outsider. By analyzing the competition patterns of international iron ore trade, Tang Qi(2009) found factors that affect the pricing power of iron ore and introduced a complicated bargaining model to simulate the bargaining process. Ye Yang(2010) studied the pricing mechanism of intermediate product from the perspective of supplying chain and made a case test with data from SAIC Group and Baosteel Group. Ren Xiaobin and Zong Beihua(2009) applied multi-person cooperative game theory to analyze the coalition within China coastal dry bulk Shipping enterprises and drew the conclusion that coastal bulk carrier could benefit from joining the cooperative transport capacity pool. In this paper, a bargaining model considering the effect of information availability, outside options, vertical integration and horizontal alliance is built to study China coastal coal transport market.

The article is organized as follows. Section 2 describes the basic questions we are discussing. In Section 3, a basic bargaining model considering the information availability is established and solved. Section 3 further considers the effect of outside options, vertical integration and horizontal alliance to the equilibrium separately. In Section 5 numerical examples are conducted and strategies for shippers and consigners are suggested. Section 6 concludes with possible extensions.

2. Problem Description

The recent decade has witnessed great changes in China coastal coal transport market, as we noticed, more and more shippers established their own ship company to meet their transport demand, like Guangdong Yudean Group and Shenhua Group. Simultaneously the market share of professional shipping company declined a lot, for instance, the market share of the biggest coastal shipping company has dropped from 50% in 2003 to 21% in 2013. According to the Clarkson Research Service limited, despite the declining market share, China coastal coal transport market is still a bilateral oligopoly market with the HHI4 of the shipping companies to be 47% and HHI12 to be 69% in 2013. On the other side, the shippers appears to be more concentrated, according to Statistical Yearbook of China Coal Industry, the HHI4 of the coal shippers is 54%, the HHI12 even reaches up to 86%. Like other bilateral oligopoly market, the competition environment is quite complicated in China coastal coal transport market. Competition make take place in the following form: shipper-carrier competition and cooperation, carrier-carrier competition and cooperation, shipper-shipper competition and cooperation. The corresponding strategies for gamers can be concluded as follows:

Table 1. Strategies for gamers in China coastal coal transport market

Strategies for shippers	Strategies for carriers
Horizontal alliance (quite difficult)	Horizontal alliance (capacity pool etc.)
Backward integration (built ship company in the form of sole proprietorship or joint venture etc.)	Forward integration (quite difficult)
Long-term cooperation (COA)	Long-term cooperation (COA)
Competition	Competition

Eliminating the strategies which are very difficult to carry out, we analyzed the following feasible strategies in the market:

- COA contracts are negotiated and signed periodically (usually annually) by shippers and carriers.
- A joint venture is built by a shipper and a carrier while COA contract is signed between them.
- Carriers take horizontal alliance strategy in the form of “capacity pool”, COA contract is negotiated between the “pool” and independent shippers.
- Both parties take competitive strategy, all the carriers put ships in the spot market, all the shippers charter ships in the spot marker ,no COA contract is signed.

3. Basic Model — Bargining Games with Incomplete Information

3.1 The hypothesis

a. There are one oligopolistic shipper D and one oligopolistic carrier S in the game, A COA contract stating the freight rate and freight volume is negotiated each year by the way of bargaining.

b. The profit of shipper D is $\pi_D(p, q) = R(q) - pq$, while the profit of carrier S is $\pi_S(p, q) = pq - C(q)$, $C(0) = F$, p and q stand for freight rate and freight volume separately, F stands for the lay-up cost of ships belonged to S.

c. In the bargaining process, D and S quote in turn, the negotiation stops when one player accepts the quotation of the other player, otherwise the negotiation continues. The overall profit of D and S will depreciate over time, δ stands for the depreciation rate of the negotiation, δ is a function of the tolerance to stockout, market share, patience and negotiation time.

d. The market information is incomplete, and gamers cannot know the expected price of the counterparty exactly. we assume that ω_D and ω_S are the expected freight rate of D and S separately, and both of them obey uniform distribution on interval $[\alpha, \beta]$, $\alpha \approx \frac{C(q^e)}{q^e}$, $\beta \approx \frac{R(q^e)}{q^e}$.

e. Both D and S can learn from the bargaining process and adjust their estimation of the expected freight rate of the counterparty, for instance, if S quotes at p_s^1 , then D can tell that ω_S obeys uniform distribution on interval $[\alpha, p_s^1]$.

f. The bargaining process cannot go on indefinitely, when the depreciation rate goes below a certain threshold, the gamers will accept any quotations on the interval of their expected prices. If there is no agreement is reached ultimately, the profits for both gamers are zero.

3.2 The model

Stage 1: calculating the terminal time of the bargaining process

Assuming ε_D and ε_S are the thresholds of δ_D and δ_S separately, and $\varepsilon_D \in (0,1)$, $\varepsilon_S \in (0,1)$, the negotiation will continue only if

$$\delta_D^t \geq \varepsilon_D, \delta_S^t \geq \varepsilon_S \quad (1)$$

s.t.

$$\delta_D^t = e^{-r_D t_D}, \delta_S^t = e^{-r_S t_S} \quad t_D = 1, 2, 3, \dots, t_S = 1, 2, 3, \dots \quad (2)$$

$$r_D = \left(\frac{\frac{1}{\mu_D}}{\frac{1}{\mu_D} + \frac{1}{\mu_S}} \right)^{\theta_D}, r_S = \left(\frac{\frac{1}{\mu_S}}{\frac{1}{\mu_D} + \frac{1}{\mu_S}} \right)^{\theta_S} \quad (3)$$

Where δ_D^t and δ_S^t are the depreciation rate of shipper D and carrier S separately, $\delta_D^t \in (0,1)$, $\delta_S^t \in (0,1)$, μ_D and μ_S stand for the market shares of D and S, $0 < \mu_D < 1$, $0 < \mu_S < 1$; θ_D and θ_S represent the tolerance to stockout of D and S. while r_D and r_S stand for the pressure for D and S to conclude the negotiation separately, t_D and t_S stand for the round of the negotiation.

Solving the above inequations, we get

$$t_D \leq -\frac{\ln \varepsilon_D}{r_D} \quad \text{or} \quad t_S \leq -\frac{\ln \varepsilon_S}{r_S} \quad (4)$$

Let

$$t = \text{int} \left[\min \left(\frac{\ln \varepsilon_D}{r_D}, \frac{\ln \varepsilon_S}{r_S} \right) \right] \quad (5)$$

Then the bargaining process will end at the t^{th} round. If $t = \text{int} \left(\frac{\ln \varepsilon_D}{r_D} \right)$, shipper D will end the

bargaining by accepting any quotation on the interval of its expected price, otherwise carrier S will accept the quotation.

Stage 2: Bargaining in the t^{th} round

Supposing $t = \text{int} \frac{\ln \varepsilon_S}{r_S}$, and shipper D quotes at p_D^t , then carrier S will accept the quotations as long as

$\delta_S^t(p_D^t - \omega_S)q \geq 0$. Simultaneously we assume S quoted at p_S^{t-1} in the $(t-1)^{th}$ round, as a rational game player, D can tell that ω_S obeys uniform distribution on interval $[\alpha, p_S^{t-1}]$. In the t^{th} round, to maximize its profit, shipper D should quote according to the following function:

$$\max_{p_D^t} \left\{ \delta_D^{t-1}(\omega_D - p_D^t)q \cdot P_{aD}^t + 0 \cdot P_{dD}^t \right\} \quad (6)$$

s.t.

$$P_{aD}^t = P\{p_D^t \geq \omega_S\} = (p_D^t - \alpha) / (p_S^{t-1} - \alpha) \quad (7)$$

$$P_{dD}^t = P\{p_D^t < \omega_S\} = (p_S^{t-1} - p_D^t) / (p_S^{t-1} - \alpha) \quad (8)$$

Solving the maximization problem above, we got:

$$p_D^t = \frac{\omega_D + \alpha}{2} \quad (9)$$

$$\pi_D^t = \delta_D^{t-1} \left(\omega_D - \frac{\omega_D + \alpha}{2} \right) q = \delta_D^{t-1} \left(\frac{\omega_D - \alpha}{2} \right) q \quad (10)$$

$$\pi_S^t = \delta_S^{t-1} \left(\frac{\omega_D + \alpha}{2} - \omega_S \right) q \quad (11)$$

Stage 3: Bargaining in the $(t-1)^{th}$ round

If the bargaining goes to the t^{th} round, shipper D can gain $\delta_D^{t-1} \left(\frac{\omega_D - \alpha}{2} \right) q$, so in the $(t-1)^{th}$ round, shipper

D will accept the quotation of carrier S only if

$$(\omega_D - p_S^{t-1})q \geq \delta_D^{t-1} \left(\frac{\omega_D - \alpha}{2} \right) q \quad (12)$$

Which can be rewritten as:

$$\omega_D \geq \frac{2p_S^{t-1} - \delta_D^{t-1}\alpha}{2 - \delta_D^{t-1}} \quad (13)$$

In the $(t-1)^{th}$ round, the quotation problem for carrier S can be turned into the following maximization problem:

$$\max_{p_S^{t-1}} \left\{ \delta_S^{t-2} (p_S^{t-1} - \omega_S) q \cdot P_{aS}^{t-1} + \delta_S^{t-1} \left(\frac{\omega_D + \alpha}{2} - \omega_S \right) q P_{dS}^{t-1} \cdot P_{aD}^t + 0 \cdot P_{dS}^{t-1} \cdot P_{dD}^t \right\} \quad (14)$$

s.t.

$$P_{as}^{t-1} = P \left\{ \omega_D \geq \frac{2p_s^{t-1} - \delta_D^1 \alpha}{2 - \delta_D^1} \right\} = \frac{1}{\beta - p_D^{t-2}} \left(\beta - \frac{2p_s^{t-1} - \delta_D^1 \alpha}{2 - \delta_D^1} \right) = \frac{2(\beta - p_s^{t-1}) - \delta_D^1 (\beta - \alpha)}{(\beta - p_D^{t-2})(2 - \delta_D^1)} \quad (15)$$

$$P_{ds}^{t-1} = 1 - P_{as}^{t-1} = \frac{2(p_s^{t-1} - p_D^{t-2}) - \delta_D^1 (\alpha - p_D^{t-2})}{(\beta - p_D^{t-2})(2 - \delta_D^1)} \quad (16)$$

Solving the first-order derivative, we got cubic equation:

$$Ax^3 + Bx^2 + Cx + D = 0 \quad (17)$$

where

$$x = p_s^{t-1} - \alpha, A = 4, B = -2\omega_s + \delta_D^1 (\beta - \alpha) - 2\beta + 4\alpha, C = 0$$

$$D = -\delta_s^1 \left(\frac{\omega_D + \alpha}{2} - \omega_s \right) (p_D^t - \alpha) (\delta_s^1 - 2) (\alpha - p_D^{t-2}).$$

4. Factors affecting the result of the bargaining game

4.1 The effect of outside options

In the above model, we assume that there are only two gamers in the coastal coal transport market and if no agreement is reached ultimately, the profit of both gamers will be zero. But in practice, there are more than two gamers in the market, if no agreement is reached between D and S, both of them can find other ways to meet transport demand or digest transport capacity, which is called *outside options* in this paper. To explain the effect of outside option, we add the following hypothesis:

a. If no agreement is reached between D and S, S could find other ways to digest his transport capacity, like putting his ships on the spot market or cooperating with other shippers, and make a maximum profit of U_s ;

b. If no agreement is reached between D and S, D could meet his transport demand by building ship company in the form of sole proprietorship or joint venture or chartering ship from the spot market and make a maximum profit of U_D ;

c. $U_s + U_D \leq \pi^e$, otherwise no COA contracts will be signed.

Considering the effect of outside option, the bargaining game turns into partition of the markup of the long-term cooperation between D and S. To simplify the problem, we suppose the profit of the gamers are determined by their bargaining powers, then we get

$$\text{Max}\{h_s(\pi_s - U_s)h_D(\pi_D - U_D)\} \quad (18)$$

$$\pi_s + \pi_D = \pi^e \quad (19)$$

$$h_s = \frac{r_D}{r_D + r_s}, h_D = \frac{r_s}{r_D + r_s} \quad (20)$$

Where h_s and h_D stand for the bargaining power of S and D, while r_s and r_D represent the pressure of S and D.

Solving the problem, we get:

$$\pi_s^e = h_s(\pi^e - U_s - U_D) + U_s \quad (21)$$

$$\pi_D^e = h_D(\pi^e - U_s - U_D) + U_D \quad (22)$$

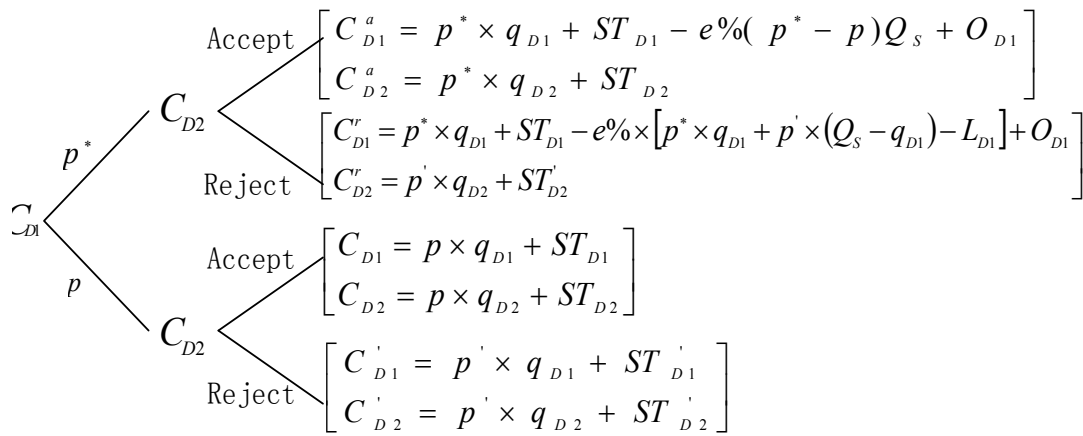
4.2 The effect of backward integration

To study the effect of the backward integration to the equilibrium freight rate, we add the following hypothesis to the model in Section 3.

- Both shipper D_1 and D_2 contracting COA with carrier S with unit freight rate of p ;
- D_1 takes backward integration strategy and acquires $e\%$ of S's share with an opportunity cost O_{D1} ;
- After the acquisition, D_1 and S raise the freight rate from p to p^* , while the freight rate in spot market is p' .

After introducing the effect of backward integration, the problem turns into a sequential game, which can be expressed in the logic tree diagram in figure1.

Fig 1. Logic Tree Diagram of sequential game



Where q_{D1} and q_{D2} are the freight volumes of D_1 and D_2 separately, ST_{D1} and ST_{D2} are the stockout cost of D_1 and D_2 when COAs are contracted, while ST'_{D1} and ST'_{D2} are the stockout cost when no COA is contracted, $e\%$ is the share that D_1 acquires from S, Q_s is the transport capacity of carrier S, O_{D1} is the opportunity cost of the merger & acquisition for D_1 , L_{D2} is the damage to S when cooperation between S and D_2 is broken.

If the acquisition between D_1 and S happens and they raise the freight rate to p^* , the transport cost of D_1 becomes

$$C_{D1}^a = p^* \times q_{D1} + ST_{D1} - e\%(p^* - p)Q_s + O_{D1} \quad (23)$$

If D_2 accepts the price rise, his cost becomes

$$C_{D2}^a = p^* \times q_{D2} + ST_{D2} \quad (24)$$

The profit of S becomes

$$\pi_s = p^* \times Q_s \quad (25)$$

If D_2 rejects the price rise, he will charter ships on the spot market with a cost of C_{D2}^r ,

$$C_{D2}^r = p' \times q_{D2} + ST_{D2}' \quad (26)$$

Accordingly, the profit of S becomes

$$\pi_s' = p^* \times q_{D1} + p' \times (Q_s - q_{D1}) - L_{D2} \quad (27)$$

Shipper D_2 would accept the markup only if $C_{D2}^a < C_{D2}^r$, solving the inequation, we get

$$p^* < p' + \frac{ST_{D2}' - ST_{D2}}{q_{D2}} \quad (28)$$

Shipper D_1 would take backward integration only if $C_{D1}^a < C_{D1}$, solving the inequation, we get

$$p^* > p + \frac{O_{D1}}{e\%Q_s - q_{D1}}, e\% > \frac{q_{D1}}{Q_s} \quad (29)$$

Carrier S would accept the acquisition only if the profit the acquisition would generate is greater than the damage it would cause, that is $\pi_s' > \pi_s$, solving it we get

$$L_{D2} < (p' - p)Q_s - (p' - p^*)q_{D1} \quad (30)$$

In conclusion, the backward integration would only happen under the following conditions:

Firstly, the coastal coal transport market is at its peak, and freight rate in the spot market is higher than that in the COA contract; Secondly, the share of S that D_1 acquires through merger & acquisition should be large enough; Finally, the profit D_1 makes should be greater than the opportunity cost of the merger & acquisition.

4.3 The effect of horizontal alliance

According the model in Section 3, the bargaining power of a gamer is determined by his outside options, tolerance of stockout, patience and market share, the gamer with higher market share would be more powerful in the bargaining. Therefore, both the shipper and carrier have the motivation to enlarge their market share, especially the carrier with weaker bargaining power. To study the effect of horizontal alliance, we add the following hypothesis.

- A “capacity pool” is built by n shippers, whose market shares are denoted by μ_i , and the bargaining takes place between the “capacity pool” and separate shipper;
- The profit of the gamer is determined by their bargaining power according to Eq.20.
- To manage the “capacity pool”, there will be extra running cost Π ;
- The “capacity pool” will be built only if

$$\sum_{i=1}^n \pi_{pool}^i - \sum_{i=1}^n \pi_{Si} \geq \Pi \quad (31)$$

Where $\pi_{pool} = \sum_{i=1}^n \pi_{pool}^i$ is the overall profits of pool members, while $\sum_{i=1}^n \pi_{Si}$ is the overall profits of pool

members before the “capacity pool” is built.

5. Numerical examples

5.1 Bargaining game with incomplete information

We applied the model built in section 3 to study the strategies for two gamers S and D who runs in the north-south route (Qinhuangdao to Guangzhou) coal transport market, the corresponding parameters for the gamers are as follows: $\mu_D = 27\%$, $\mu_S = 21\%$, $\alpha = 30$, $\beta = 160$. ω_S , ω_D , r_S and r_D will change with the market condition. When the market is rising, both ω_S and ω_D will increase, the pressure for shipper D to conclude the bargain, r_D will increase, while the pressure for S will decrease. In this paper, sensitivity analysis of parameter ω_S , ω_D , θ_S and θ_D is carried out. For the expected freight rate of D and S will change with the market condition, so we use the mean of ω_S and ω_D to reflect the market condition. The tolerance of stockout for D and S will change with the market station, so as their pressure, which will influence the bargain power. In this paper we assume the initial $\theta_S = 3$, $\theta_D = 2$, $\omega_S = 40$, $\omega_D = 80$. We solve the equivalent freights separately when θ_S changes from 3 to 9, while θ_D change from 2 to 0.2, ω_S rises from 40 to 100, ω_D rises from 80 to 100. With 61 groups of numbers, we get 61 equivalent freight rates, and correspondingly the Profits of S and D. As we can see from Fig.2, with the market upturning from 60 to 100, r_S decreases from 0.18 to 0.01, while r_D increases from 0.19 to 0.85. Supposing the bargain will terminate at the second round and S quotes in the first round, according to our model, with ω_S increasing from 40 to 100, p_S^1 will increase from 59.61 to 101.92, D will accept the quotation of S when $p_S^1 < 80$ and the agreement can be reached in the first round, otherwise, D will reject the quotation of S, the bargain will end in the second round.

As we can see from Fig.3, the actual profit of S will increase to 44.40q and drop to 29.06q with D reject the quotation of S and then increase to 32.22 with the market rising, while the profit of D will drop from 50.39q to 18.21q.

Fig 2. Market condition, pressure and profits

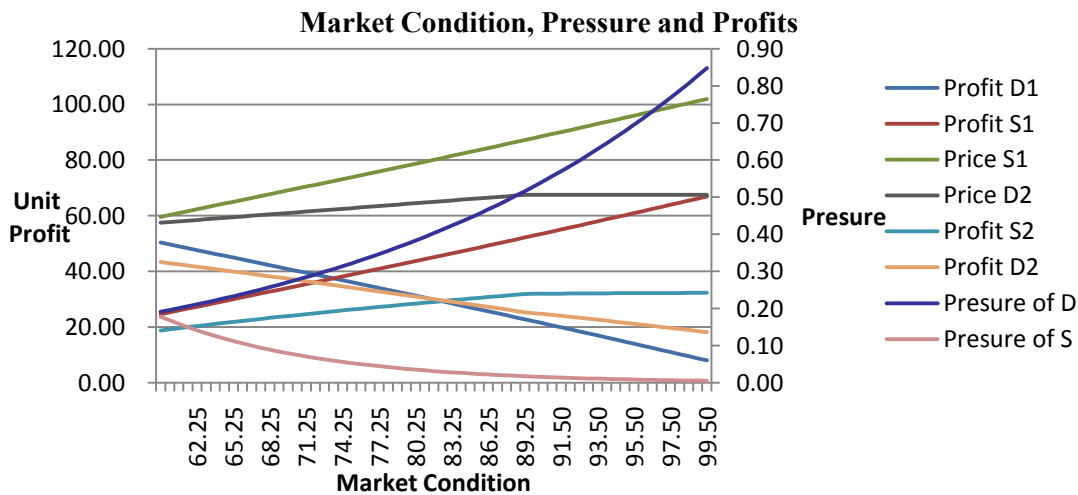
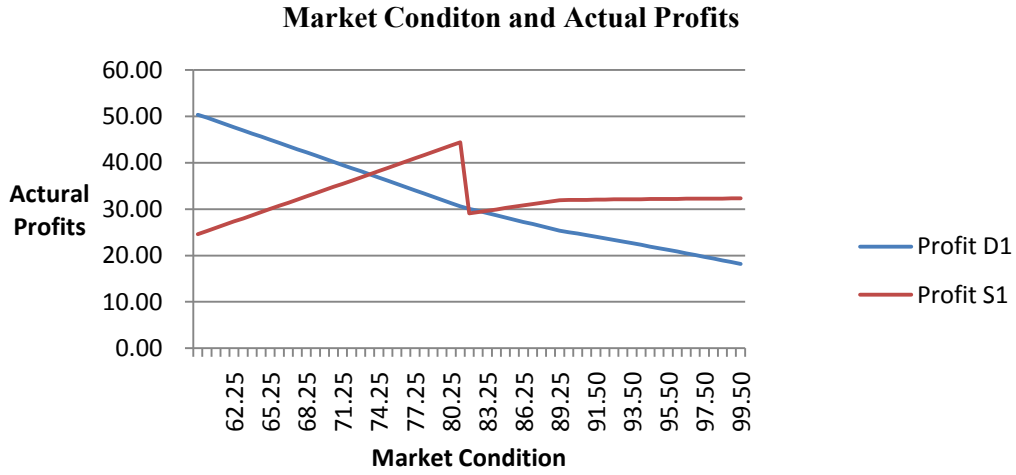


Fig 3. Market condition and actual profits



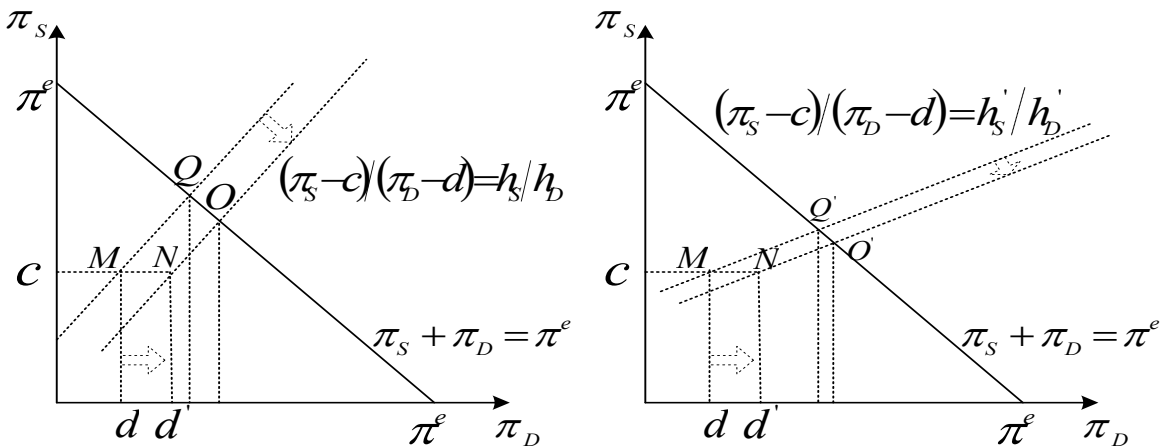
We can tell from the numerical examples that there is second-mover advantage in dynamic games with incomplete information, the gamer quotes at the second turn will get information from his counterparty through his quotation and adjust bargaining strategy accordingly.

5.2 The effect of outside option and horizontal alliance

Assuming S quotes in the first round and the COA is contracted. The maximal outside option profit for D is $U_D = 10q$, while the maximal outside option profit for S is $U_S = 20q$, according to Eqs.22-24, $h_s = 0.5182, \pi_s^e = 43.32q$ and $h_d = 0.4818, \pi_d^e = 31.68q$. Further studies show that increasing outside options profit benefits the gamer with weaker bargaining power more than the one with stronger bargaining power as shown in figure 2. The effect of the outside options explained why a mass of shipper-owned ship companies were built in recent years and how they changed the competition patterns in the coastal coal transport market.

About the backward integration, there are too many factors to be considered, we have to stop at the modeling stage for the lack of living examples and data.

Fig 4. The effect of outside option profit to the profit partition



Finally, we will study the effect of horizontal alliance. To simplify the question, we choose a game with two shippers and two carriers, which is denoted by S_1, S_2 and D_1, D_2 . The parameters of the four gamers are as follows:

$$\mu_{S_1} = 15\% , \mu_{S_2} = 5\% , \mu_{D_1} = 12\% , \mu_{D_2} = 8\% , \theta_D = 2 , \theta_S = 3$$

According to Eq.22-24, we get $h_{S_1} = 0.78, h_{D_1} = 0.22, h_{S_2} = 0.39, h_{D_2} = 0.61$, when no “capacity pool” is built, the revenues for the four gamers are: $\pi_{S_1} = h_{S_1}\pi_1^e = 0.78\pi_1^e$, $\pi_{D_1} = h_{D_1}\pi_1^e = 0.22\pi_1^e$, $\pi_{S_2} = h_{S_2}\pi_2^e = 0.39\pi_2^e$, $\pi_{D_2} = h_{D_2}\pi_2^e = 0.61\pi_2^e$ separately.

Assuming a “capacity pool” is built by S_1 and S_2 , and the additional running cost of the “pool” is $\Pi = 0.1(\pi_1^e + \pi_2^e)$, the overall revenue of the “pool” is $\pi_{pool} = \pi_{pool}^1 + \pi_{pool}^2$. According to equation 22-24, after the establishment of the “pool”, the revenue for the four gamers are as follows:

$$\pi_{pool}^1 = 0.88\pi_1^e, \pi_{D_1} = 0.12\pi_1^e, \pi_{pool}^2 = 0.96\pi_2^e, \pi_{D_2} = 0.04\pi_2^e,$$

the revenue of S_1 and S_2 increase

$\pi_{pool} - (\pi_{S_1} + \pi_{S_2}) = 0.1\pi_1^e + 0.57\pi_2^e > 0.1(\pi_1^e + \pi_2^e)$. Therefore both S_1 and S_2 have the motivation to build the “capacity pool”, especially S_2 , whose revenue rises from $0.39\pi_2^e$ to $0.96\pi_2^e$ after the horizontal alliance.

6. Conclusion

In this paper, a bargaining model considering the effect of information availability, outside option, vertical integration and horizontal alliance is built and applied to study China coastal coal transport market. Through our research, we find that there is second-mover advantage in the coastal coal transport market, the gamer quotes in the second round will benefit more from the information he gets. The bargaining between a shipper and a carrier cannot go on indefinitely, the gamer with lower market share, less tolerance to stockout and high pressure tends to end the game earlier. Therefore, both the shippers and the carriers would like to hide their own private information and to dig the private information of their counterparty.

Outside option profit would affect the partition of the markup of the cooperation, the gamer with higher outside option would gain more in the bargaining. The weaker the gamer is, his motivation to increase outside option profit is stronger because the increase of outside option profit would benefit the weak gamer more which explained why a mass of shipper-owned ship companies were built in recent years and how they changed the competition patterns in the coastal coal transport market.

A shipper will take backward integration strategies, like building his own ship company or vertical merger, to control his coal transport cost when the freight rate is too high or the transport reliability is too low. Compared with building a sole proprietorship, merger & acquisition is more risk controllable. To guarantee the profitability of the vertical integration, the merged gamers have to rise freight rate in the COA. The freight rise would never happen unless the share the shipper acquired is large enough. However, freight rising is quite a dilemma for the merged carrier because he might lose other collaborator.

The bargaining power of a gamer depends on his market share largely. Both the shippers and the carriers have motivation to enlarge their market shares. For carriers, horizontal alliances often take place in the form of “capacity pool”. The “pool” can only survive when the profit it makes for the pool members is more than the extra running cost it generates. Carriers with relative lower market share have stronger incentive to join a “capacity pool” because they will benefit more from the pool.

This paper studies how the effect of information availability, outside option profit, backward integration and horizontal alliance will affect the freight equilibrium in the coastal coal transport market and analyzes strategies for both sides in the market. However, the competition environment in coastal coal transport market is much more complicated and there are more factors need to be considered in practice. Accordingly the

optional strategies for the carriers and shippers are more abundant, sometimes mixed strategies can be taken which makes the problem even more sophisticated. However, the sophisticated market environment would provide us with more possibility for future studies.

References

- Alex Dickson, Roger Hartley (2013), Bilateral oligopoly and quantity competition, *Econ Theory* 52: 979–1004.
- George Symeonidis (2010), Downstream merger and welfare in a bilateral oligopoly, *International Journal of Industrial Organization* 28 : 230–243.
- John R. Schroeter, Azzeddine M. Azzam (2000), Measuring market power in bilateral oligopoly: The wholesale market for beef, *Southern Economic Journal* 66(3): 526-547.
- Jean Philippe Gervai, Stephen Devadoss (2006), Estimating bargaining strengths of Canadian chicken producers and processors-Using a bilateral monopoly framework, *Agribusiness* 22: 159-173.
- Jonas Björnerstedt, Johan Stennek(2007), Bilateral oligopoly-The efficiency of intermediate goods markets, *International Journal of Industrial Organization* 25: 884-907.
- Kenneth Hendricks, R. Preston McAfee (2010), A theory of bilateral oligopoly, *Economic Inquiry* 38: 391-414.
- Kjell Erik Lommerud, Odd Rune Straume, Lars Sorgard(2005), Downstream merger with upstream market power, *European Economic Review* 49: 717-743.
- Lorenzo Clemenit(2012), Vertical integration and foreclosure strategies in bilateral oligopoly, *European Association for Research in Industrial Economic*, 2012.
- Robin A.Naylor(2002), Industry profits and competition under bilateral oligopoly, *Economics Letters* 77: 169–175.
- Ren Xiaobin, Zong Beihua (2006)), The application of multi-person cooperative game theory in China coastal shipping enterprise coalition, *Shipbuilding of China* 47(2): 89-95.
- Stephane Caprice (2005), Incentive to encourage downstream competition under bilateral oligopoly, *Economics Bulletin* 9: 1-5.
- Tang Qi (2009), Economic analysis of pricing mechanism on bilateral oligopoly market, Dissertation paper, Fudan University.
- Ye Yang(2010), A study on the dual oligopolistic price competition in the supply chain, Dissertation paper, Tongji University.
- Clarkson Research Service Limited's website: www.clarksons.net.

GARCH Models Application in Volatility of Dry Bulk Freight Index

Feier Chen¹, Lei Dai¹, Shijie Chen², Hao Hu¹, Chunxia Lu¹ and Yifei Zhao³

¹School of Naval, Architecture, Ocean & Civil Engineering, Shanghai Jiao Tong University, Shanghai.

²Department of Statistics, London School of Economics and Political Science, London.

³Sino-US Global Logistics Institute, Shanghai Jiaotong University, Shanghai.

Abstract

The purpose of this paper is to investigate the volatility of dry bulk freight index during different phases, which could be helpful for the investment risk management in the shipping market. This paper applies the ARMA-GARCH model to analyze the time varying characteristics of BCI, BPI and BSI indexes, and finds out different volatility persistence effects on these three indexes. The volatility has larger impact and longer duration on Capsize ships than Panamax and Supramax ships. EGARCH model suggest that good and bad news have different effects on different types of ships. Leveraged effects exit in BSI. But for BCI, good news effects more than bad news. Then GARCH and EGARCH models are applied to estimate the parameters for forecasting. The empirical results suggest that Conditional Heteroskedasticity models catch the volatility characteristics well and forecasts of GARCH model fit the original data best.

Keywords: Volatility; GARCH; Dry Bulk Shipping; Forecast.

1. Introduction and Literature Review

The global dry bulk shipping market is the major component of international shipping and international trade (Lun et al. 2006). The world dry bulk market is a highly risky and volatile market because of the world economy and world trade are always fluctuating. Unlike the world container shipping market, the dry bulk market is highly competitive, fierce freight rate volatility has made the market hardly predictable (Stopford, 1988). The world dry bulk shipping market gained its historical boom in the 2000s, especially from 2005 to mid-2008, the Baltic Dry Index (BDI) reached its historical record at 11771 in May 2008, and nearly all the market participants could make profits during that market boom. Before that, the world dry bulk shipping market has seen a continuous growing from 2001 to 2004. However, the world dry bulk shipping market turned to shrink suddenly in late 2008 with the happening of world financial crisis. Since then, the world dry bulk shipping market has been struggling in the downturn, many investors suffered heavy loss. So, this is the very practical example of the volatility of dry bulk market. Thus, it is crucial to investigate the inherent volatile character in the dry bulk market, especially when the market experienced its great booms and recessions in the last 10 years.

The Baltic Dry Index (BDI), which represents the freight rate level in the dry bulk shipping market, could best reflect the market volatility characteristics, and has been widely investigated in shipping finance and risk management. Many previous research has been done on dry bulk shipping and ship market volatilities, mainly on dry bulk shipping freight rate volatility econometric modeling and dry bulk vessel price volatility analysis, such as Kavussanos (1996a, 1996b, 1997) etc. Few attention has been paid to the dry bulk market index (such as BDI, etc.) volatility modelling, though, especially after the world financial crisis period. In the post-2008 world financial crisis period, the world dry bulk market may have derived new volatility mechanism which really attracts our interests.

Dry bulk shipping market volatility econometric modeling has long been a hot research topic. An ARIMA (3, 1, 0) model was proposed by Cullinane (1992) for speculation by Box-Jenkins approach to time series analysis and forecasting. Veenstra and Franses (1997) studied the monthly freight rates of 3 capesize and 3 panamax routes using the augmented Dickey-Fuller test. They concluded that the specification of long-term relationships cannot improve the accuracy of short-term or long-term forecasts. Tvedt (2003) rejected the random walk hypothesis of

dry bulk freight rates in most cases using the unit root test. The findings validated that the shipping freight rates were stationary, especially when the data were transformed from US dollar to Japanese Yen, the stationarity seemed to be more obvious. Tvedt (2003) extended his work and proposed a stochastic optimal control problem with the effect of freight rates of rigidities in yard capacity, and derived an optimal investment and restructuring policies under switching costs. Kavussanos was among the earliest to investigate the volatility characteristics on dry bulk shipping markets since the 1990s, and he is the first to introduce the class of ARCH (Auto Regressive Conditional Heteroskedasticity) models into world shipping and ship market (Kavussanos 1996a). Kavussanos (1996) used the monthly data of spot and time charter freight rates from 1973 to 1992 to study the volatility effects in dry bulk market. Kavussanos (1996b) also applied ARCH models to estimate the price volatility of world tanker market. Kavussanos and Nomikos (2000) applied the GARCH (General Auto Regressive Conditional Heteroskedasticity) error structure model and a GARCH-X model to estimate the time-varying and constant hedge ratios in the BIFFEX (Baltic International Freight Futures Exchange) market. The results revealed that the GARCH specification is better than a simple GARCH model in reducing risks. Besides the volatility characteristics, Kavussanos (2001) also investigated the seasonality of dry bulk freight rate. They examined the seasonality pattern between different vessel sizes, different vessel contract durations and different market conditions by unit root tests. Moreover, Kavussanos (2004) studied the dry bulk forward market. Referring to the authors, a Vector Error Correction Model (VECM)-GARCH model was presented to investigate the lead-lag relationship in both return and volatilities between spot and futures markets. Together with that research, Kavussanos (2004) verified that how the FFA (Forward Freight Agreement) affects the spot market price volatility in two dry bulk shipping routes. The conclusions revealed that FFA trading has no detrimental effect on the spot market.

The classes of ARCH and GARCH models introduced by Engle (1982) and Bollerslev (1986) had been widely accepted since its introduction to the world financial market. The ARCH model has been proved to provide good approximations for many stock return series, which showed the classical distributions of stock returns: fat tail, spiked peaks and persistence in variance structure. Chen and Wang (2004) applied EGARCH (Exponential General Auto Regressive Conditional Heteroskedasticity) model (Nelson, 1991) to explore the leverage effect in the global bulk shipping market. They claimed that the asymmetric impact between past innovations and current volatility were internal nature in the international bulk shipping market. Lu et al. (2008) conducted an analysis on the world dry bulk freight rate market from with EGARCH model, and concluded that the asymmetric characters are distinct for different vessel sizes and different market conditions. Chen (2011) modeled relationships between economic and technical variables of dry bulk ships, by using modern time series approaches. Xu et al. (2008) studies the relationship between the time-varying volatility of dry bulk freight rates and the change of the supply of fleet trading in dry bulk markets. Amir H. A. (2013) investigates the price volatility and trading volume relationship in the forward freight agreement (FFA) market for dry bulk ships over the period 2007–2011.

However, till now, the market condition and world macro-economy condition have greatly changed. It is critical to investigate the current volatility rule in world dry bulk market. A thorough study need to be done to address the general volatility characteristics of dry bulk shipping freight rates in the past fluctuating years.

The rest of the paper is organized as follows. Section 2 presents the methodology and data. Section 3 shows the empirical results. Discussions and conclusions are remarked in the last section.

2. Methodology

2.1 Data description

To model the dry bulk freight rate volatility, we divide the world dry bulk shipping market into 3 sub-markets: supramax, capesize and panamax sub-market. Different sized vessels are used for different world shipping routes and different cargo trades. Thus, different vessel sizes have different volatility effects and internal rules, and may show different risk characters, while these are all the key issues we try to investigate. We choose BCI, BPI and BSI to analyze the volatility mechanisms in the 3 sub-markets.

The sample data of BCI, BPI and BSI cover the period from 2005/7/4 to 2013/11/21 with 2098 observations. The properties of these data are shown in Figure 1 and Table 1. The raw data are processed by log first order difference.

$$r_t = \ln P_t - \ln P_{t-1} = p_t - p_{t-1} \quad (1)$$

In Equation (1), P_t and P_{t-1} are the freight rate index at time t and $t-1$, while p_t and p_{t-1} are the log freight rate index at time t and $t-1$, r_t is the volatility (or daily return). The volatilities of the 3 sector time series are denoted as V_BSI , V_BCI and V_BPI .

Fig 1. Freight rate indexes from 2005/07/04 to 2013/11/21

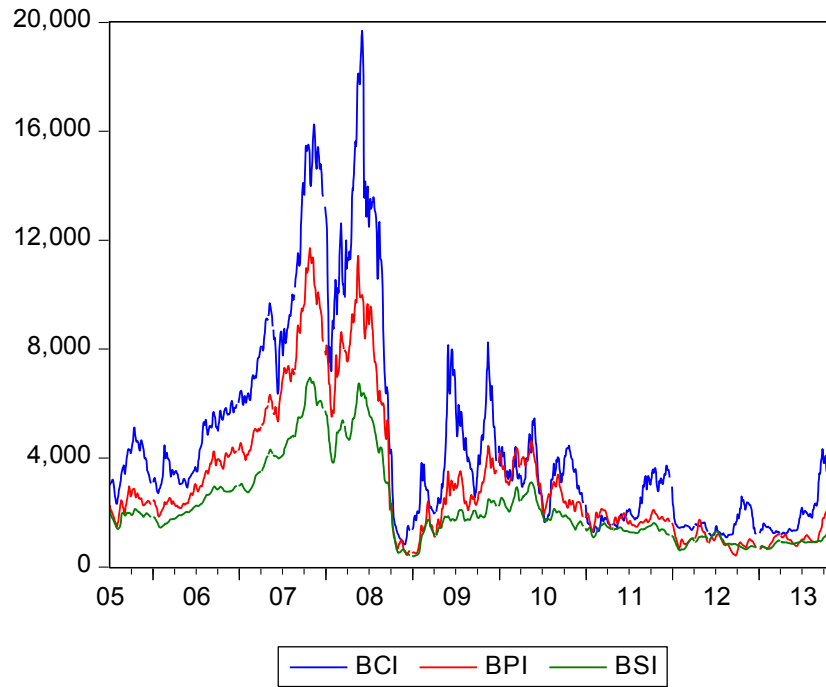


Table 1. Statistical properties for freight indexes

	Mean	Median	Max.	Min.	S. Dev.	Skewness	Kurtosis	J-B	Prob.
BCI	4611.054	3389.500	19687.00	830.0000	3770.023	1.631841	5.131181	1340.831	0
BPI	3161.606	2319.500	11713.00	418.0000	2523.341	1.455902	4.391765	763.3934	0
BSI	2218.068	1762.500	6956.000	389.0000	1509.319	1.365074	4.093910	763.3934	0

Fig 2. Volatility of BCI, BPI and BSI

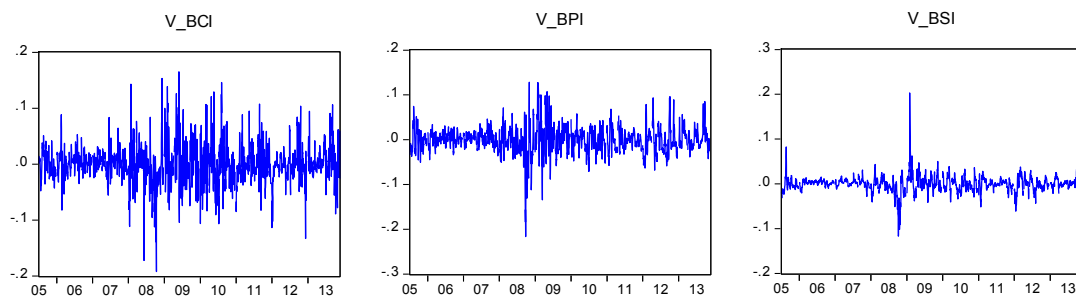


Table 2. Descriptive statistics of dry bulk freight rate volatility

Return	Mean	Median	Max.	Min.	S. Dev.	Skewness	Kurtosis	J-B	Prob.
BCI	-0.000094	-0.00085	0.16502	-0.19215	0.0323	0.0999	6.617	1147	0
BPI	-0.000229	0	0.136576	-0.11953	0.0223	-0.0199	6.979	1382	0
BSI	-0.000198	0.000662	0.202794	-0.11663	0.0166	0.478	22.514	33369	0

Table 3. ADF test results

	V BCI	V BPI	V BSI
ADF	-21.74086	-17.77183	-11.1517
1%	-3.433272	-3.433278	-3.433275
5%	-2.862717	-2.86272	-2.862718
10%	-2.567443	-2.567444	-2.567443
conclusion	Stationary	Stationary	Stationary

Table 4. Auto Correlation test results

	V BCI		V BPI		V BSI	
	LBQ	Prob.	LBQ	Prob.	LBQ	Prob.
Q(1)	1080	0	1359.2	0	1676.2	0
Q(5)	1520	0	2627	0	5326.8	0
Q(10)	1658.7	0	3058.1	0	6445.1	0
Q(20)	1769.1	0	3375.3	0	6771.8	0

The statistics of all the freight rates and freight rate volatility are listed in above tables. As can be seen from Table 2, the freight rates are very volatile in the past years. Those statistics show that all the freight rate volatilities in 3 sub-markets are stationary. And all the freight rate volatilities in 3 sectors show auto-regressive effects, so the application of the class of ARCH models is feasible.

2.2 GARCH, EGARCH model

GARCH models have been successfully modeling conditional volatility in various financial markets. Here in this paper, we will apply the GARCH (1, 1) model to analyze the indexes' volatilities to explore the dynamic nature of dry bulk shipping market. The GARCH (1, 1) model is specified as follows:

$$r_t = b_0 + b_1 r_{t-1} + b_2 r_{t-2} + \dots + b_m r_{t-m} + \varepsilon \quad (2)$$

$$\varepsilon_t = \sqrt{h_t} v_t, \quad v_t \sim N(0,1) \quad (3)$$

$$h_t = \omega + \alpha \varepsilon_{t-1}^2 + \beta h_{t-1} \quad (4)$$

where r_t is the index volatility (rate of return), b_0 is a constant. α is the coefficient of ARCH term, reflects the magnitude effect. β is the coefficient of GARCH term, measures the volatility persistence in the same market. The persistence of volatility variance is measured by the sum of α and β , the more the sum approaches 1, the greater the persistence of market shocks to freight rate volatility is. If $(\alpha + \beta) > 1$, the GARCH process is non-stationary, and the shocks will not decrease, but have the tendency to increase instead.

However, the GARCH model does have limitations such as unable to capture the asymmetric effect of positive or negative returns on volatility (Lu et al., 2008). Usually, the asymmetric effect occurs when an unanticipated price decrease induced a greater volatility than an unexpected increase of price in a similar magnitude. To overcome the limitation of GARCH model, Nelson (1991) proposed a modified GARCH model-EGARCH model, which could ensure the variance remains positive for all t periods with probability 1. Based on Equation (4), we get the modified EGARCH (1, 1) model as follows:

$$\log h_t = \omega + \varphi v_{t-1} + \alpha(|v_{t-1}| - E|v_{t-1}|) + \beta \log h_{t-1} \quad (5)$$

here the coefficient β measures persistence of variance, the closer β approaches 1, the greater is the persistence of shocks to volatility. Coefficients φ and α reflect that how the unexpected returns determine future variance. α indicates a magnitude effect, for $\alpha > 0$, the innovation in $\log h_t$ is positive (negative) when the magnitude of v_{t-1} is larger (smaller) than its expected value. φ is a sign effect coefficient. If $\varphi = 0$, it means that there's no asymmetric volatility effect; if $\varphi > 0$, and is statistically significant, this confirms the existence of asymmetric volatility, and indicates that the volatility of positive innovations is larger than that of the same magnitude of negative innovations; otherwise, when $\varphi < 0$, and statistically significant, the volatility

of negative innovations are larger than the counterpart. The negative φ represents the presence of leverage effect in the freight rate volatility.

3. Empirical Results and Discussion

To gain a clear understanding of the dry bulk freight rate volatility properties, we first applied the traditional GARCH (1, 1) model to investigate the persistence characters of the residual variance. The detailed statistics are listed in Table 5. Here, in this GARCH model, α is the ARCH term parameter that can reflect the intensity of outside shocks on freight rate market volatilities, a higher value of α means that a more intense response to changes happens in the market. β is the GARCH term that reflects the character of the memory of own volatility. If $0 < \beta < 1$, the bigger value of β indicates a slowly-decreasing and longer-lasting volatility effect. Else $\beta > 1$, the volatility will be more fluctuating by the influence of past volatilities within its own fluctuation system.

Table 5. GARCH (1, 1) model estimates of freight rate volatility

	V_BCI	V_BPI	V_BSI
b_1	1.010420*	1.107906*	1.059042*
b_2	-0.314975*	-0.316321*	-0.176567*
ω	2.32E-05*	1.46E-05*	5.24E-07*
α	0.370913*	0.388716*	0.281940*
β	0.663293*	0.595150*	0.780305*
$\alpha + \beta$	1.034206	0.983866	1.062245

Notes: * denotes significant at 1% level

As shown in Table 5, the values of α are 0.370913, 0.388716 and 0.281940 for V_BCI, V_BPI and V_BSI respectively. All the 3 estimated parameters are significant at 1% level. Those results indicate that the panamax sector is more likely to be influenced by outside shocks and response to outside shocks more intensely, with the V_BPI α value the biggest one. This is maybe that panamax sized vessels are more flexible than capesize and supramax vessels. The β values are 0.663293, 0.595150 and 0.780305 for V_BCI, V_BPI and V_BSI respectively. Panamax sized vessel has the smallest β value, this means that the volatility memory in panamax sector is not as long as for the other counterparts. Besides, the values of $(\alpha + \beta)$ are bigger than 1 in capesize and supramax sectors, while are less than 1 in panamax sector. These results show that for the capesize and supramax sectors, the outside shocks will not decrease but have the tendency to strengthen in the future, while for the panamax sized vessels, the outside shocks tend to decrease with a slow pace as $(\alpha + \beta)$ is very near 1.

GARCH (1, 1) is good for investigating basic volatility properties, but not enough for further volatility effects testing, such as leverage effects. Thus, we continue to apply EGARCH (1, 1) model to test the freight rate indexes. The coefficient estimations are listed in Table 6. The coefficient α will reflect that how the volatilities determine future variance, and all the α values for 3 vessel types are significant at 1% level. This means that the influences of past period shocks on current freight rate volatilities are detected. The coefficient β , which measures the persistence of shocks to volatility, are all significant at 1% level for 3 types, and the β values for BCI and BSI are very close to 1, indicating that there are greater persistence of shocks to volatility in capesize and supramax sectors. The β value for BPI is the smallest among the 3, means that the persistence of shocks is not as long as the other 2 types.

Table 6. EGARCH (1, 1) model estimates of freight rate volatility

	V_BCI	V_BPI	V_BSI
b_1	1.017900*	1.138617*	1.089363*
b_2	-0.314957*	-0.342967*	-0.208709*
ω	-1.155548*	-1.365850*	-0.541159*
α	0.530927*	0.510848*	0.409797*
φ	0.005102	0.005474	-0.005958
β	0.901522*	0.888562*	0.975494*

Notes: * denotes significant at 1% level

The φ values for BCI and BPI are positive while the BSI value is negative. And the φ values of the 3 sub-markets are not statistically significant. For capesize and panamax sized vessels, the positive φ means that the volatility of return shocks is asymmetric and the volatility of positive innovations is larger than negative innovations. To the BSI, the negative φ indicates that the volatility of return shock is asymmetric, while the volatility of negative innovations is larger than that of the same magnitude of positive innovations.

All these results may be explained due to the unique characters of each vessel type. Capesize and panamax vessels are mainly used to transport iron ore and coal, they are less flexible than supramax vessels, for which, the iron ore and coal are the basic resource of economic development, so even the world economy slows down, the demand for the resource will not decrease significantly. So, the positive information in the capesize and panamax market takes the great role: volatility of positive innovations is larger than negative innovations. While for the supramax market, the market condition is just the opposite, so the volatility of negative past innovations is larger than the negatives.

Besides, we also examined the variance forecasting accuracy of GARCH and EGARCH model. The results are shown in Figure 3-5.

Fig 3. BCI forecasting by GARCH model

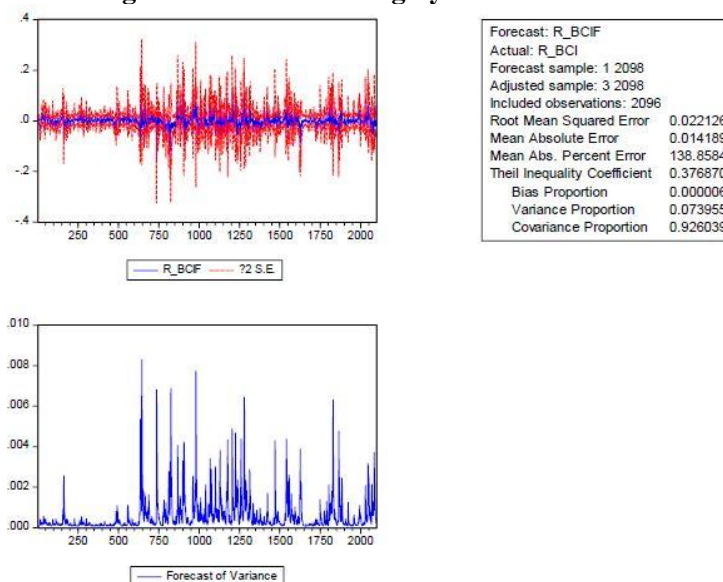


Fig 4. BPI forecasting by GARCH model

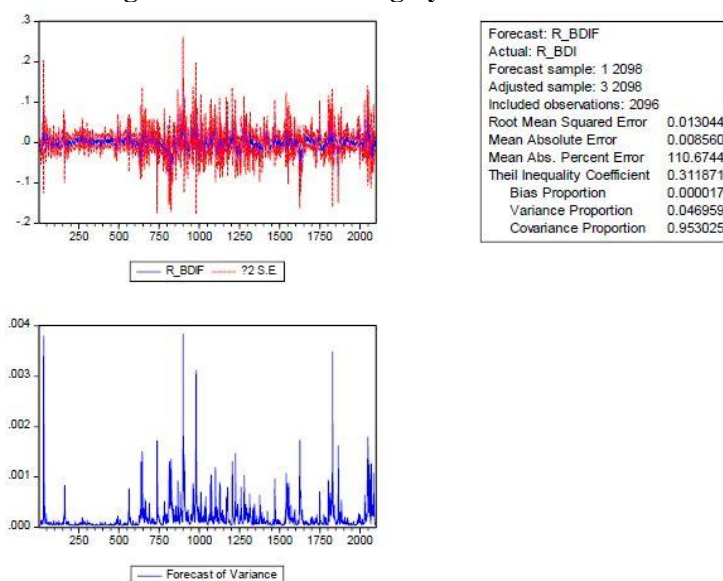
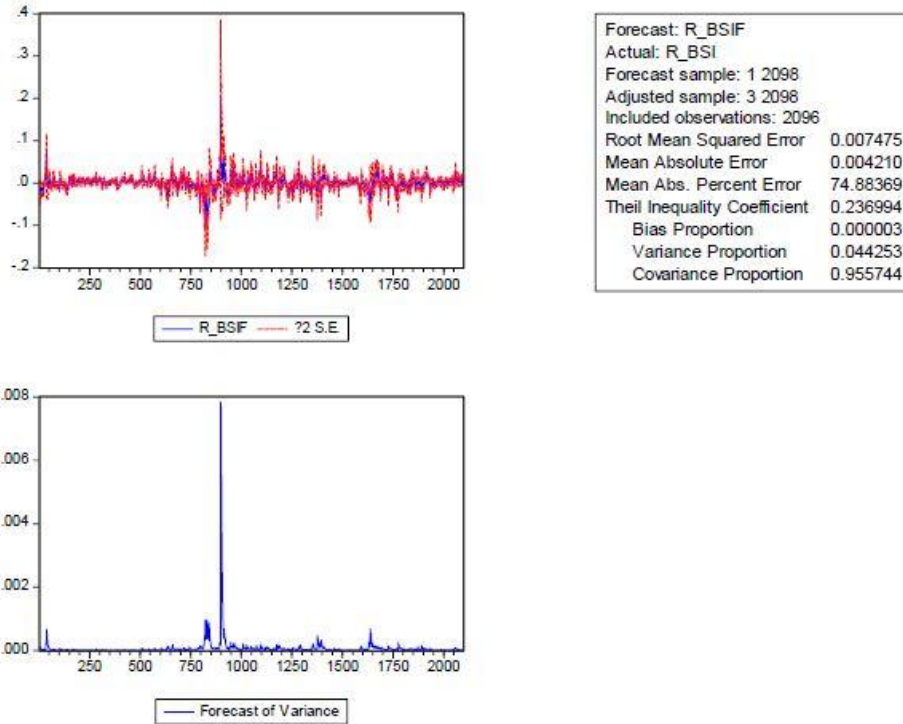


Fig 5. BSI forecasting by GARCH model



As can be seen from Figure 3-5, we use the Akaike info criterion (AIC) value and Schwarz criterion (SC) value as the selective criterion. The model with the smaller AIC and SC values is the better model on forecasting volatility variances. Our findings showed that the GARCH model outperforms EGARCH model on the variance forecasting work.

4. Conclusion

We did a comprehensive econometric research on the dry bulk freight rate market to investigate the volatility characters within this market. Firstly, similar findings are found that the 3 sub-markets, namely capesize shipping market, panamax shipping market and supramax shipping market are all very volatile, especially during the 2008 world financial crisis, the fluctuation was much more intense than other periods. With the ADF tests, the freight rates are all first order stationary, that is, the freight rate volatilities in 3 sectors are stationary. Those findings are consistent with previous literature. Secondly, we applied the EGARCH model to test the leverage effect in the world dry bulk shipping market. The empirical studies showed that in the capesize and panamax sectors, the positive market information or shocks have greater market effect than the negative market shocks, that is, in those 2 sub-markets, there exist positive leverage effects. While in the supramax sector, there exists the negative leverage market effect, the volatility of negative shocks is larger than the volatility caused by positive market shocks. Moreover, we also found that in forecasting the variance of freight rate volatility, the GARCH model is better for EGARCH model.

In this paper, we did a relatively thorough investigation upon the world dry bulk shipping market, our findings to some extent provided some useful tips for shipping firms and ship owners. However, future research still needs to be done to gain more accurate conclusions.

Acknowledgement

This work is sponsored by “Shanghai Jiao Tong University, State Key Laboratory of Ocean Engineering”, (Project No. GKZD010056) and MOE (Ministry of Education in China) Project of Humanities and Social Sciences (Project No.12YJCGJW001).

References

- Amir, H. A., (2013), Trading volume and volatility in the shipping forward freight market, *Transportation Research Part E: Logistics and Transportation Review* 49(1): 250-265.
- Bollerslev, T., (1986), Generalized autoregressive conditional heteroscedasticity, *Journal of Econometrics* 31: 307–327.
- Chen, S., (2011), *Modelling and Forecasting in the Dry Bulk Shipping Market*, ISBN: 9789085704218.
- Chen, Y. S. and Wang, S. T., (2004), The empirical evidence of the leverage effect on volatility in international bulk shipping market, *Maritime Policy & Management* 32(2): 109–124.
- Cullinane, K., (1992), A short-term adoptive forecasting model for BIFFEX speculation: a Box–Jenkins approach, *Maritime Policy & Management* 119(2): 91–114.
- Engle, R. F., (1982), Autoregressive conditional heteroscedasticity with estimates of variance of United Kingdom inflation, *Econometrica* 50(4): 987–1006.
- Xu, J.J., Yip, T.L., Marlow, P. B., (2011), The dynamics between freight volatility and fleet size growth in dry bulk shipping markets, *Transportation Research Part E: Logistics and Transportation Review* 47 (6): 983-991.
- Lun, Y.H.V., Lai, K.H., Cheng, T.C.E. (2006) , *Shipping and Transport Logistics*, McGraw Hill.
- Kavussanos, M.G. (1996a), Comparisons of freightmarket volatility in the dry-cargo ship sector. Spot vs time-charter and smaller vs larger vessels, *Journal of Transport Economics and Policy* XXX1, 67- 82.
- Kavussanos, M. G., (1996b), Price risk modelling of different size vessels in the tanker industry using Autoregressive Conditional Heteroskedastic (ARCH) models, *The Logistics and Transportation Review* 32 (2): 161-176.
- Kavussanos, M. G., (1996), Comparisons of volatility in the dry-cargo ship sector: spot versus time charters, and small versus larger vessels, *Journal of Transport Economics and Policy* January, 67–82.
- Kavussanos, M. G., (1997), The dynamics of time-varying volatilities in different size second-hand ship prices of the dry-cargo sector, *Applied Economics* 29(4): 433-443.
- Kavussanos, M. G., Nomikos, N. K., (2000), Constant vs. time-varying hedge ratios and hedging efficiency in the BIFFEX market, *Transportation Research Part E* 36, 229–248.
- Kavussanos, M. G., Amir, H. A., (2001), Seasonality patterns in dry bulk shipping spot and time charter freight rates, *Transportation Research Part E* 37, 443-467.
- Kavussanos, M. G., Visvikis, I. D., (2004), Market interactions in returns and volatilities between spot and forward shipping freight markets, *Journal of Banking and Finance* 28: 2015-2049.
- Lu, J., Marlow, P. B., Wang, H., (2008), An analysis of freight rate volatility in dry bulk shipping markets, *Maritime Policy & Management* 35(3): 237-251
- Nelson, D., (1991), Conditional heteroscedasticity in asset returns: a new approach, *Econometrica*, 59: 347–370.
- Stopford, M., (1988), *Maritime Economics*, Unwin Hyman, London.
- Tvedt, J., (2003), A new perspective on price dynamics of the dry bulk market, *Maritime Policy and Management* 30(3): 221–230.
- Tvedt, J., (2003), Shipping market models and the specification of freight rate processes, *Maritime Economics and Logistics* 5: 327–346.
- Veenstra, A., Franses, P. H., (1997), A co-integration approach to forecasting freight rates in the dry bulk shipping sector, *Transportation Research Part A* 31(6): 447-458.

Combining Multi-Stage DEA and Fuzzy AHP to Evaluate the Efficiency of Major Global Liner Carriers

Shih-Liang Chao

Department of Shipping and Transportation Management, National Taiwan Ocean University, Keelung, Taiwan, ROC.

Abstract

Measuring operational efficiency is an important issue in the liner shipping industry. This study applies the typical concept of a multi-stage data envelopment analysis (DEA) model to decompose the production process of a liner shipping carrier into three stages. However, due to the fact that conventional solution procedures cannot guarantee the uniqueness of solutions, in this study, a new algorithm is devised to overcome this problem. The proposed algorithm is composed of two steps. In the first step, a questionnaire survey is conducted that ranks the priority of all stages by applying the fuzzy analytical hierarchical process (AHP). The second step then solves the efficiency score for each stage one by one according to their priority. The results of our empirical test show that the proposed algorithm can not only determine a unique solution for the efficiency scores, but can also present the relative importance of each stage of the production process.

Keywords: liner shipping, fuzzy AHP, data envelopment analysis (DEA).

1. Introduction

Liner shipping is the most efficient and economical way to move cargo globally due to the fact that standard containers can be exchanged among vehicles such as vessels, trucks and trains conveniently. It's worth noting that the liner shipping market is dominated by only a few carriers because it's costly to run such a business. That is, a considerable number of vessels, containers and substantial fuel are necessary inputs for a carrier to build a sailing network with a fixed schedule. Most leading carriers even own their own dedicated terminals at many major ports. The huge investment not only prevents newcomers from entering this market, but also makes the existing carriers value their operational performance. Therefore, measuring operational efficiency has become an important issue in the liner shipping industry. Some models have been proposed or applied for efficiency evaluation, in which the data envelopment analysis (DEA) has been widely used because it can take multiple input and output data items into account. In addition to the basic models, many extended models based on DEA have been proposed to deal with various cases, in which the so-called multi-stage DEA model has been devised to investigate the efficiency of the production process related to decision making units (DMUs). While applying such a model, the production process for a DMU must be decomposed into several stages with corresponding inputs and outputs, respectively. Afterwards, the optimal solution can be found by solving an integrated linear programming (LP) problem. However, this method cannot guarantee the uniqueness of the solutions obtained because the total efficiency score is the product of the efficiency scores of all stages.

This study aims to overcome this problem by devising a new algorithm determining the priority of the stages before solving the efficiency values. Namely, we propose to conduct a questionnaire survey designed to collect expertise about the relative importance of the stages first and then determine the priority of the stages by applying a fuzzy analytical hierarchical process (AHP) that can deal with such multi-criteria decision making (MCDM) problems. Subsequently, the efficiency score for each stage is then determined one at a time by solving its corresponding LP problem fixing the total efficiency score and all efficiency scores of the stages that are more important than the current one. In this study, a three-stage DEA model is established and tested empirically to evaluate the efficiency of major global liner carriers. The results indicate that the proposed algorithm can deal with the weakness of multi-stage DEA models effectively. The remainder of this paper is organized as follows: Section two reviews related literature mainly focusing on DEA models and evaluations of shipping carriers. The methodology and algorithm proposed by this study are described in Section three.

Section four presents the results of the empirical study. The conclusions and implications for future research are summarized in the last section.

2. Literature Review

Although there have been lots of studies investigating efficiency evaluation, few of them have focused on issues about liner carriers. Early studies tended to evaluate carriers according to their financial performance without taking the input items into account (Grammenos and Marcoulis, 1996; Lim, 1996; Evangelista and Morvilo, 1996). Such a concept cannot provide an insight into the evaluation because it puts undue emphasis on the output. Therefore, methodologies that can take both input and output (I/O) into account, such as DEA, have been applied widely in recent research and have become the dominant method currently in use for the purpose of efficiency evaluation. For example, Førsund (1992) made a comparison between parametric and non-parametric measures by evaluating Norwegian ferry companies in order to provide a yardstick by which the government could review subsidies. In total, 23 ferry companies were evaluated empirically with four input variables: wage, maintenance and repair, fuel and capital. The only output variable considered was the product of the total length run in 1988 multiplied by the capacity of the ferry company under consideration measured in ferry cars. The efficiency distributions were found to be quite similar for the two methods except for scale efficiency. Herrero (2005) applied four methods to measure the efficiency of Spanish main trawl fleets operating in Moroccan waters. All four methods considered I/O variables simultaneously, in which the distance functions approach and DEA were used to include multi-output variables. The empirical study found multi- or single-output features to be the determinant related to producing differences in efficiency estimates.

Panayides et al. (2011) also applied a DEA model to measure major international shipping companies. An empirical study was conducted with three inputs: total assets, number of employees and capital expenditures, and one output: sales. The results showed that the operational efficiency of liner carriers is higher than that of dry bulk and tanker carriers. Focusing on the liner shipping industry, Lun and Marlow (2011) used a DEA-CCR model to evaluate the efficiency of major global carriers in 2008. The model considered two inputs: capacity and operating cost, and profit and revenue were used as the outputs. Gutierrez et al. (2013) conducted an analysis of the efficiency of major international liner carriers. The proposal model considered labour, number of ships and fleet capacity as inputs and container throughput handled and turnover as outputs. The simulation and bias-corrected procedure proposed by Simar and Wilson (2000) was applied to correct the efficiency score set. Although the two efficiency score sets were different significantly at the one percent level, the ranks for the DMUs were the same. In addition, the efficiency scores of alliance members and independent carriers were tested to examine the effect of joining strategy alliances.

In terms of the DEA model, in addition to measuring efficiency scores based on the original inputs and final outputs, some extended models have been proposed to further examine the efficiency of the DMU production process. For example, Sexton and Lewis (2003) evaluated the efficiency of baseball teams in major league baseball (MLB). The model decomposed the production process into two stages. The efficiency score for each stage and the total production process were solved individually to provide an insight into the evaluation.

Similarly, Bichou (2011) developed a two-stage supply chain DEA model to measure the efficiency of a container-terminal system and its sub-systems. Although the efficiency scores of each stage were solved in an integrated model, the total efficiency score was not considered. In other words, the proposed model focused on examining the efficiency of each stage instead of the total efficiency. To provide comprehensive information, Kao and Hwang (2008) proposed a two-stage DEA model which was similar to that proposed by Bichou (2011). The main difference is that Kao and Hwang (2008) took the total efficiency into account by limiting its score within zero and 1 with a constraint and maximizing it in the objective function. Assume that a production process uses m inputs to produce q intermediate products, which are used to produce s final products. Let X_{ik} denote the i th initial input of DMU _{k} ; Z_{pk} denotes the p th intermediate product of DMU _{k} , and Y_{rk} denotes the r th final output of DMU _{k} . The two-stage model proposed by Kao and Hwang (2008) to evaluate the efficiency of n DMUs can be expressed by model [MAIN] with Eqs. 1-5.

$$[\text{MAIN}] \quad E_k^T = \text{Max} \sum_{r=1}^s u_r Y_{rk} \quad (1)$$

$$\text{s.t. } \sum_{i=1}^m v_i X_{ik} = 1 \quad (2)$$

$$\sum_{r=1}^s u_r Y_{rj} - \sum_{i=1}^m v_i X_{ij} \leq 0 \quad j=1, 2, \dots, n \quad (3)$$

$$\sum_{p=1}^q w_p Z_{pj} - \sum_{i=1}^m v_i X_{ij} \leq 0 \quad j=1, 2, \dots, n \quad (4)$$

$$\sum_{r=1}^s u_r Y_{rj} - \sum_{p=1}^q w_p Z_{pj} \leq 0 \quad j=1, 2, \dots, n \quad (5)$$

$$u_r, v_i, w_p \geq \varepsilon, \quad r=1, 2, \dots, s; i=1, 2, \dots, m; p=1, 2, \dots, q$$

Once an LP problem is solved by applying Eqs. 1-5, the maximal total efficiency score of DMU_k, which is defined as E_k^T in Eq. 6, can be obtained by Eq. 1 because the denominator in Eq. 6 is limited to 1 by Eq. 2. The advantage of such a model is that it not only keeps the original idea of the DEA model by maximizing the total efficiency (E_k^T), but also examines the product process by calculating the efficiency scores for each stage simultaneously. However, except for the total efficiency, the model may have multiple solutions for the efficiency score for each stage. For example, let E_k^1 and E_k^2 denote the efficiency scores for the first and second stage of DMU_k; it's easy to prove $E_k^T = E_k^1 \times E_k^2$ because Eq. 6 is the product of Eqs. 7 and 8. In other words, once a solution is found, the uniqueness of E_k^1 and E_k^2 may not be guaranteed although the E_k^T is maximized by Eq. 1. To deal with this problem, in this study, a new algorithm integrating fuzzy AHP and multi-stage DEA is devised. AHP as proposed by Satty (1980) is a method applied commonly to decompose a complicated problem into a hierarchical structure in order to determine the relative importance of the elements in the structure. Our proposed algorithm applies the idea of AHP to compare the relative importance of each stage in a multi-stage model. Meanwhile, the fuzzy logic proposed by Chang (1996) is included while determining the relative importance because such a complementary logic can prevent the result from being disturbed by extreme values.

$$E_k^T = \sum_{r=1}^s u_r^* Y_{rk} / \sum_{i=1}^m v_i^* X_{ik} \quad (6)$$

$$E_k^1 = \sum_{p=1}^q w_p^* Z_{pk} / \sum_{i=1}^m v_i^* X_{ik} \quad (7)$$

$$E_k^2 = \sum_{r=1}^s u_r^* Y_{rk} / \sum_{p=1}^q w_p^* Z_{pk} \quad (8)$$

3. Methodology

The methodology and algorithm proposed in this study are mainly comprised of a multi-stage DEA model and the fuzzy AHP used commonly for dealing with an MCDM problem. Figure 1 illustrates the algorithm which is detailed as follows:

- (1) *Establishing a basic multi-stage DEA model*: Instead of measuring the efficiency based on the original inputs and final outputs, a multi-stage DEA model decomposes the production process of a DMU into several stages based on the characteristics of an industry. Each stage has its corresponding inputs and outputs, respectively. In this study, we decompose the production process of a global liner carrier into three stages. The corresponding efficiencies are defined with Table 1, in which the first stage, called *fleet efficiency*, reflects the direct performance related to deploying a vessel fleet. The I/O variables used for measuring this efficiency are vessel capacity, operating expenses and calling ports. For a global liner carrier, more calling ports make it easier to meet shipper demands for moving containers between port pairs. The second efficiency in the model, which is called *loading efficiency*, measures the performance from the perspective of marketing and sales. Namely, calling ports can be deemed as inputs for a liner

carrier because they can generate space utility for shippers. Lifting of containers is the amount of container movement among calling ports by a liner carrier. Liner carriers always do their best to increase the lifting of laden containers in order to yield profit and reduce the losses resulting from unutilized vessel space. Therefore, the number of calling ports and the amount of container lifting are used as input and output, respectively, to measure loading efficiency. The third efficiency defined in Table 1 is *marketing efficiency*. In the liner shipping market, the freight for moving a container depends on many determinants, including distance, commodity, transit time, quantity of containers and if there is a contract or not. A liner carrier prefers to secure shipments with high freight loads to maximize the revenue yield from the lifting. Accordingly, the business efficiency is measured by container lifting and revenue. Lastly, the total efficiency is defined with the original input and the final output just as the one found in a typical DEA model.

Table 1. Stage definition and the corresponding variables

Variables \ Stages	Fleet efficiency		Loading efficiency		Marketing efficiency		Total efficiency	
	input	output	input	output	input	output	input	output
Owned feet capacity	V						V	
Chartered feet capacity	V						V	
Operating Expenses	V						V	
Main calling ports		V	V					
Side calling ports		V	V					
Container lifting (TEU)				V	V			
Revenue (USD)						V		V

- (2) *Ranking the priority of each stage*: To overcome the problem of uncertain uniqueness of the solution in a typical multi-stage DEA model, we propose to rank the priority of the stages before solving the efficiency scores. Namely, this study conducts a questionnaire survey to collect expertise in order to determine the relative importance of all stages. The questionnaire is designed in a typical form, a standard AHP that compares the importance of the stages in pairs. Afterwards, the fuzzy logic proposed by Chang (1996) is applied to solve the weight of each stage. The priority of each stage is then determined accordingly.
- (3) *Solving the efficiency scores iteratively*: Instead of solving the total efficiency and efficiency scores of all stages simultaneously, in this study, the efficiency scores are solved iteratively according to their priority. For a production composed of g stages, let E_k^i and V_k^{i*} denote the efficiency and the optimal score of the i th stage of DMU _{k} . Firstly, model [MAIN] is applied to formulate an LP problem to find the maximal score of E_k^T , which is denoted as V_k^* . Secondly, Eq. 9 is inserted into model [MAIN] to fix E_k^T and replace the objective function with Eq. 10 ($i=1$), and then the LP problem is solved again to find V_k^{1*} . Thirdly, one more constraint (Eq. 11) is added to fix E_k^1 , and the objective function is replaced with Eq. 10 again to solve the V_k^{i*} of the next important stage. This solving procedure continues iteratively until $V_k^{(g-1)*}$ is obtained. The V_k^{g*} can be simply obtained by applying Eq. 12 due to the fact that V_k^* is the product of all V_k^{i*} , which is defined in model [MAIN].

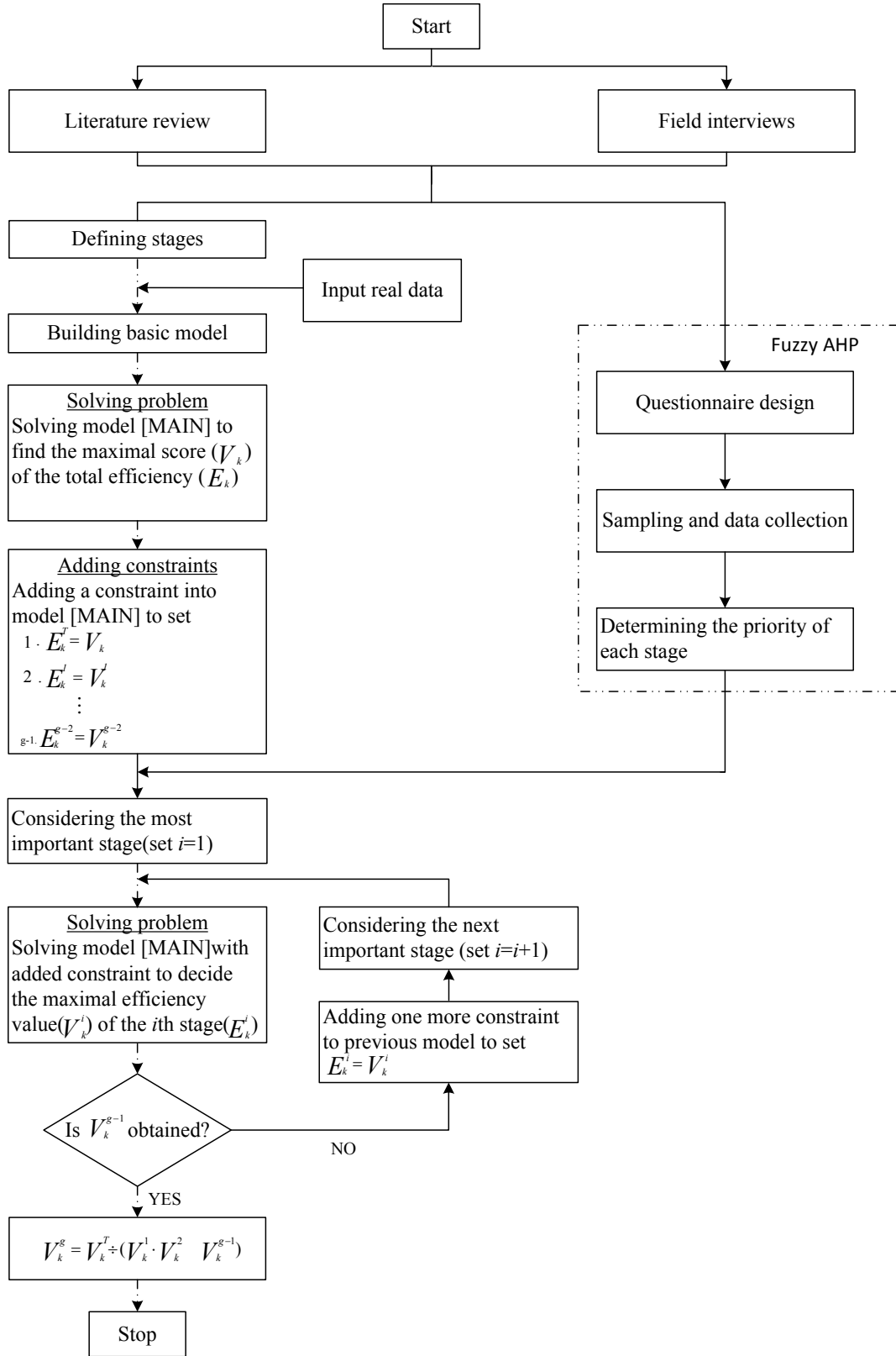
$$E_k^T = V_k^* \quad (9)$$

$$\text{Max } E_k^i \quad (10)$$

$$E_k^i = V_k^{i*} \quad i=1, 2, \dots, g-1 \quad (11)$$

$$E_k^g = V_k^* / (V_k^{1*} \cdot V_k^{2*} \dots V_k^{(g-1)*}) \quad (12)$$

Fig 1. Illustration of the proposed algorithm



4. Results

To verify our proposed algorithm, the efficiency evaluation problem of major global liner carriers (listed in the Appendix) was tested empirically in this section. The first step was to determine the priority of each stage.

Firstly, the production process of a liner carrier was decomposed into three stages with corresponding I/O variables, which are defined in Table 1. Secondly, a simple questionnaire was designed in the format of a traditional AHP to ask the respondents to compare the priorities of the stages in pairs. Experts composed of practitioners and researchers were invited to answer the questionnaires from February 1 through 7, 2014. In total, 15 questionnaires were issued, and nine were returned, accounting for a return rate of 60%. Before calculating the priorities, it was necessary to test the consistency index (C.I.) of each returned sample. A sample is deemed valid if and only if its C.I. value is less than 0.1 (Satty, 1980). Five valid samples were found in our empirical study due to the fact that only three elements were compared in the questionnaire. Thirdly, all valid samples were integrated into a fuzzy positive reciprocal matrix (FPRM), as shown in Table 2. Afterwards, the priorities of the three stages: 0, 0.39 and 0.61, were solved by applying the fuzzy logic proposed by Chang (1996). The results showed marketing efficiency to be the top priority among all stages. Loading efficiency took the second place, and fleet efficiency was of the least importance.

Table 2. The fuzzy positive reciprocal matrix of stage priority

	Fleet efficiency	Loading efficiency	Marketing efficiency
Fleet efficiency	(1, 1, 1)	(0.14, 0.20, 0.25)	(0.13, 0.15, 0.20)
Loading efficiency	(4, 5.11, 7)	(1, 1, 1)	(0.14, 0.34, 1)
Marketing efficiency	(5, 6.72, 8)	(1, 2.92, 7)	(1, 1, 1)

The next step was to solve the score for each DMU in each stage. The proposed algorithm first solved the problem based on model [MAIN] to find the maximal score of the total efficiency, and then fixed it by adding a constraint (Eq. 9) to model [MAIN] to form a new problem. Afterwards, according to the priorities of the three stages, the scores for each DMU in each stage were obtained one by one. The results obtained from the proposed model are summarized in Table 3. In terms of the total efficiency, HJ took the first place, with a score of 0.424. The next best was MSK (0.315), which is the largest liner carrier in the world. The scores of CSAV, HPL and MOL were 0.29, 0.28 and 0.28, respectively, which kept these three DMUs in a leading position. On the other hand, EMC was ranked last due to its score being only 0.15. In addition to the above analysis regarding total efficiency, the efficiency of the production process could also be examined, which is the critical value contributed by a multi-stage DEA model. Taking HJ as an example, although it was ranked the best DMU, none of its scores in any stage were the best. It fell behind K-Line and MOL in terms of fleet efficiency. Its score for loading efficiency was also lower than that of MSK, COSCO and HMM. Meanwhile, HJ didn't take the first place for marketing efficiency because its score was lower than CSAV's. In other words, rather than focusing on only one or two stages, a balanced development in the production process could significantly bring up the total efficiency of a liner carrier. Another obvious example was ZIM, which had a low score for total efficiency. Although its scores for fleet and marketing efficiency were both excellent, a poor loading efficiency score pulled down its whole performance markedly. This analysis provides useful information enabling managers to pay attention to weaknesses so they can take measures to improve the bottlenecks in the production process. In the case of ZIM, its total efficiency could be improved effectively by increasing its loading efficiency.

5. Conclusions

Efficiency measuring is an important issue in the liner shipping industry due to the high investment costs and the significant inseparability and perishability related to production. Although many methods and models have been proposed to measure efficiency, only a few studies have focused on measuring or examining the efficiency of liner carriers. In addition to measuring efficiency based on the initial inputs and final outputs, which has been applied widely by many studies, this study establishes a three-stage model to decompose total efficiency in order to further examine the causes of inefficiency during liner carrier production processes. Taking advantage of fuzzy AHP, which can determine the relative weights of several criteria efficiently and objectively, in this study, an algorithm which ranks the priority of all stages first is devised, which then solves the efficiency of each stage iteratively. The main advantage of the proposed algorithm is twofold. First, the efficiency score for each stage solved by the proposed algorithm is unique. This is the main contribution to the literature because it prevents a multi-stage DEA problem from obtaining solutions. Second, the relative importance of each stage is identified. This additional information further yields an insight into the production

process of a liner carrier. The value of an analysis of multi-stage DEA is thus increased by measuring both the efficiency and importance of each stage. While solving the efficiency scores, the proposed algorithm takes only the priority of the stages into account instead of considering their actual weights. Although this concept can guarantee the uniqueness of each solution, the degree of relative importance is ignored. Therefore, developing an algorithm that can reflect the importance of stages while determining their efficiency scores is an issue worthy of further study. In addition, in terms of DEA analysis, few global liner carriers are suitable to become DMUs because some carriers do not reveal their critical data directly. These limited DMUs obstruct the model from considering many I/O variables simultaneously. For this reason, applying multi-stage DEA models is an alternative that helps overcome this problem. Lastly, variables such as the number of containers (separated by 20 or 40-foot), number of services (separated by main or side services) and container movements (separated by service or contain types) are all of importance and meaningful with regard to representing the production processes of liner carriers. It's worth expending the effort required to collect such data in order to include them in related multi-stage DEA models for future study.

Table 3. Efficiency scores obtained by the proposed algorithm

DMU	Fleet efficiency	Loading efficiency	Marketing efficiency	Total efficiency
MSK	0.396	1.000	0.795	0.315
COSCO	0.535	0.674	0.469	0.169
HPL	0.883	0.401	0.791	0.280
EMC	0.953	0.502	0.281	0.135
APL	0.693	0.471	0.727	0.237
HJ	0.953	0.547	0.812	0.424
CSCL	0.666	1.000	0.281	0.191
OOCL	0.614	0.395	0.619	0.150
CSAV	0.598	0.483	1.000	0.290
MOL	0.995	0.388	0.727	0.280
NYK	0.906	0.385	0.745	0.259
K-Line	1.000	0.316	0.724	0.241
YML	0.917	0.488	0.571	0.256
HMM	0.529	0.587	0.756	0.235
ZIM	0.911	0.263	0.804	0.193
Average	0.774	0.528	0.674	0.244

Acknowledgements

The author would like to thank the National Science Council of the Republic of China, Taiwan, for financially supporting this research under Contract No. NSC 102-2410-H-019-028. The deepest appreciation is extended to Mr. Neo Lan and Mr. Wei-Fang Hsieh for their assistance in data collection and analysis.

References

- Bichou, K. (2011), A two-stage supply chain DEA model for measuring container-terminal efficiency, *International Journal of Shipping and Transport Logistics* 3(1): 6-26.
- Chang, D.Y. (1996), Applications of the extent analysis method on fuzzy AHP, *European Journal of Operational Research* 95 (3): 649–655.
- Ester Gutiérrez, Sebastián Lozano and Salvador Furió, (2014), Evaluating efficiency of international container shipping lines: A bootstrap DEA approach, *Maritime Economics & Logistics* 16(1): 55-71
- Evangelista, P. and A. Morvillo, (1998), The Role of Training in Developing Entrepreneurship: The Case of Shipping in Italy, *Maritime Policy and Management* 125(1): 81-96.
- Førsund, F.R. (1992), A comparison of parametric and non-parametric efficiency measures: The case of Norwegian ferries, *Journal of Productivity Analysis* 3(1-2): 25-43.

- Grammenos, C. T H, and S. N. Marcoulis, (1996), A Cross-section Analysis of Stock Returns: The Case of Shipping Firms, *Maritime Policy and Management* 23(1): 67-80.
- Herrero, I. (2005), Different approaches to efficiency analysis: An application to the Spanish Trawl fleet operating in Moroccan waters, *European Journal of Operational Research* 167(1): 257-271.
- Kao, C. and Hwang, S. N. (2008), Efficiency decomposition in two-stage data envelopment analysis: An application to non-life insurance companies in Taiwan, *European Journal of Operational Research* 185(1): 418-429.
- Lim, S. M. (1996), Round-the-world Service: The Rise of Evergreen and the Fall of U.S. Lines, *Maritime Policy and Management* 23(2): 119-44.
- Lun, Y.H.V. and Marlow, P. (2011), The impact of capacity on firm performance: A study of the liner shipping industry, *International Journal of Shipping and Transport Logistics* 3(1): 57-71.
- Panayides, P.M., Lambertides, N. and Savva, C.S. (2011), The relative efficiency of shipping companies, *Transportation Research Part E* 47(5): 681-694.
- Saaty, T.L. (1980), *The Analytic Hierarchy Process*, McGraw-Hill: New York.
- Sexton, T.R. and H.F. Lewis, (2003), Two-Stage DEA: An Application to Major League Baseball, *Journal of Productivity Analysis* 19: 227-249.
- Simar, L. and Wilson, P.W. (2000), Statistical inference in nonparametric frontier models: The state of the art, *Journal of Productivity Analysis* 13(1): 49-78.

Appendix

Table A. Major global liner carriers and their abbreviations

Global global liner carrier	Abbreviation
Compañía Sud Americana de Vapores	CSAV
COSCO Container Line.	COSCO
China Shipping Container Line	CSCL
Evergreen Marine Corporation	EMC
Hanjin Shipping	HJ
Hapag-Lloyd	HPL
Hyundai Merchant Marine Co., Ltd.	HMM
Kawasaki Kisen Kaisha Ltd.	K-Line
Maersk Line Ltd.	MSK
Malaysia International Shipping Corporation Berhad	MISC
Mitsui O.S.K. Line	MOL
Neptune Orient Lines Ltd.	NOL
Nippon Yusen Kabushiki Kaisha	NYK
Orient Overseas Container Line	OOCL
Wan Hai Lines	WHL
Yang Ming Line	YML
ZIM Integrated Shipping Ltd.	ZIM

Optimizing the Performance of Urban Consolidation Centers

Xiaolei Wang^{1*} and Lei Guo²

¹ Sino-US Global Logistics Institute, Shanghai Jiao Tong University, Shanghai, 200030, P. R. China.

Tel: +86-18680683726. Email: xlwangiris0420@gmail.com.

² Sino-US Global Logistics Institute, Shanghai Jiao Tong University, Shanghai, 200030, P. R. China.

Email: guolayne@gmail.com.

**Corresponding author*

Abstract

To mitigate the negative impact of congestion, emission and safety problems caused by frequent freight transportation in urban areas without hurting the area's economic vitality, hundreds of urban consolidation centers (UCCs) that provide common service for last-mile delivery were built around the world. But most of them cannot survive without government subsidy. This paper firstly proposes a Stackelberg lead-follower game model to examine the profitability of a UCC. The consignees play as the followers who independently choose between private delivery and common delivery to minimize their total logistics cost. And with a correct prediction of consignees' reactions, the UCC operator determines the best combination of service quality and charge rate to maximize its profit. The UCC and consignees' decision problems are formulated into a bi-level optimization problem with nonlinear objectives and constraints, and solution techniques are provided.

Keywords: Urban consolidation centre; Stackelberg game; Optimization, Freight transportation.

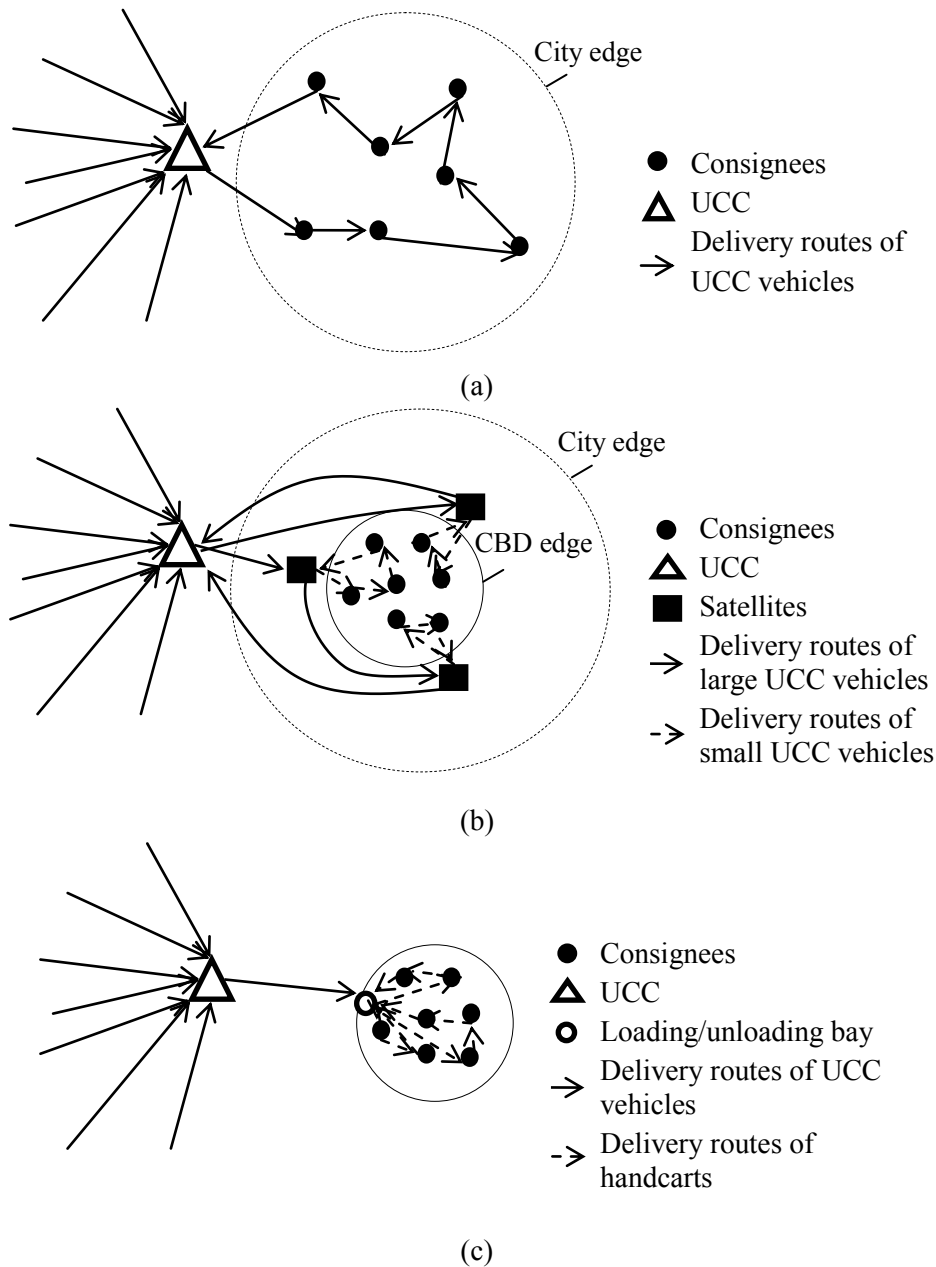
1. Introduction

Freight traffic is always a disturbing factor for citizens. They compete with passenger cars for limited road space and cause serious congestion, pollution, safety and noise problems, hence reduce living qualities in urban area and impede city images. More and more world's large cities have been aware of this problem, and try to encounter their challenges by implementing city logistics policies. In 2000, the European Commission (DG Transport and Energy) funded the European Co-ordination Action called "BEST Urban Freight Solutions" (BESTUFS) to identify, describe and disseminate best practices, success criteria and bottlenecks of urban freight transport solutions. As described in their report BESTUFS (2007), 'the most effective sustainability freight transport policy measures are likely to be those that meet economic, environmental and social needs simultaneously; and so minimize trade-offs between objectives to reduce associated losses and costs.' In 2008, 17 partners from 10 countries got together to work on sustainable urban goods logistics achieved by regional and local policies, and produced SUGAR (2011) that identified 44 best practices of city logistics around the world, including night deliveries in Barcelona (Spain), low emission zone in London (UK), congestion charging in Stockholm (Sweden), etc. The measures adopted in the 44 best examples can be classified into five catalogs: 1) traffic and parking regulations, access regulations; 2) intelligent transportation systems; 3) planning strategies; 4) consultation processes and labeling schemes and 5) consolidation schemes. Among the most popular city logistics measures are urban consolidation centers (UCC).

A UCC (in many cases UCC is also called city distribution center (CCC), urban distribution center (CDC) or city consolidation center (CCC)) is a logistics facility situated in relatively close proximity to the geographical area that it serves (be that a city center, an entire town or a specific site such as a shopping center), to which many logistics companies deliver goods destined for the area, from which consolidated deliveries are carried out within that area, in which a range of other value added logistics and retail services can be provided (BESTUFS, 2007). According to the different characteristics of geographical areas they serve, UCCs can work in the following three ways as shown in Figure 1. In the first way in Figure 1(a), a UCC conducts only

one level of consolidation-distribution activities, distribution routes starting at a UCC and delivering the freights directly to the consignees. This single-tiered system applies to small and median size cities, and most UCC projects initially undertaken in Europe and Japan were based on such single-tiered systems. For large cities, because of the higher density and longer traveling distance, more complex systems as the two-tiered system in Figure 1(b) are proposed (Crainic, 2009). In a two-tiered system, freights are first consolidated at a UCC located at the edge of the city, and loaded into rather large vehicles, which brings them to a smaller UCC-like facility in the neighborhood of the city center. Loads are then transshipped to smaller vehicles which then deliver them to the final consignees. The third way in Figure 1(c) applies to a much smaller service area (e.g. a highly dense commercial area, a shopping mall or an airport) with limited accessibility. The freights are firstly consolidated at a UCC before the congestion sector and then transported to a loading/unloading bay located inside the serving area, and then either be picked up by consignees themselves at the loading/unloading bay or delivered from the unloading bay to consignees by handcarts.

Fig 1. Delivery Types of UCCs



No matter which organization and operation way is adopted by a UCC, the fundamental idea is the same: serving the target area with fewer vehicles that are better loaded and thus to reduce the total number of freight

vehicle trips. Significant reduction of 70-80% CO₂ emission and 60-80% delivery vehicle movements are observed in successful UCC projects (e.g. in London and Bristol in UK, Yokohama in Japan) (SUGAR, 2011). Other potential benefits may include higher reliability of delivery time, 24hr freights receiving at UCCs, better inventory control and economic delivery for retailers, especially for those small ones. Usually, to boost utilization of UCCs, accompany policy measures, e.g. tolls, time-windows- and access regulations, and subsidies will be provided.

According to Browne et al. (2007), there are/were at least 114 UCC projects initiated. Most UCCs are initiated one decade ago with financial support, but few of them survived when the government could no longer subsidize them. To figure out the key factors that determine the viability of a UCC, a series of case studies have been conducted (e.g. Browne et al. (2007), Duin et al. (2010), Allen et al. (2012)), and they offered directional guidance to the future development of UCCs. As they both suggested, there are 4 key factors that determines the success of a UCC: 1) the imposing organization is able to control or strongly influence all the players; 2) the awareness and understanding of UCC is widespread among both public and private sectors; 3) the UCC is operated efficiently with speedy and secure delivery; 4) financial support is provided by the government at the trial stage. However, until now, no existing studies provided quantitatively method to evaluate the viability of UCCs.

In this paper, a Stackelberg leader-follower game is formulated to investigate the survivability of UCCs. The UCC operator plays as the leader to determining its optimal land occupation, fleet size and service qualities (i.e. delivery frequency, operation time and damage rate) that maximize its own profit. And the consignees play as the followers to determine their best utilization rates of the UCC that minimize their generalized logistics costs (including transportation cost, holding cost and damage cost) provided any UCC service quality. To avoid the complex vehicle routing problem with time windows (VRP-TW) from making the problem unsolvable, this paper focuses on the third UCC operation way as in Figure 1(c), and the final handcart delivery is treated as minor.

The rest of this paper is organized as follows. Section 2 presents a comprehensive literature review of UCC and tradable credits in transportation area is presented. Section 3 provides a preliminary story to establish the problem. An busy airport is taken as an example to represent the service area in this paper. In Section 4, the decision problems of the UCC operator and consignees are described by a Stackelberg leader-follower game and formulated into a bi-level optimization problem. Numerical examples are presented to illustrate the function of the game-theoretic model in predicting the survivability of UCCs. In case a UCC cannot be self-financing even under the optimal operation strategies, tradable shipping credit schemes are proposed in Section 5.

2. Literature Review

The discussion of UCC in research area can be dated back to Cadotte and Robicheaux (1979), that firstly introduced the cooperative behavior of business organizations to achieve the economies of consolidated shipments. But then no seminal work is followed until the recent decades. Existing works on UCC can be divided into two streams. One main stream is qualitative analysis based on empirical studies. They reviews existing (or past) UCCs, conducts ex-post evaluations and concludes experiences and lessons from successful and failing examples. For example, Allen et al. (2012) reviewed 114 UCCs in 17 countries, Browne et al. (2007) discussed cost and benefits of all participants, and Marinov et al. (2010) emphasized the fundamental function of the BESTUFS report (Allen et al., 2007), and pointed out missing knowledge to the current state of the art. Literatures mention or contain qualitative discussion of UCCs are various. The readers can refer to Browne et al. (2005) and Taniguchi et al. (2012) for a comprehensive review.

On the other hand, another stream of work, quantitative investigations, is quite rare. This leads to a limited guidance to UCC projects at an operational level. To the authors' knowledge, modeling and simulation of UCC operations are limited to the following papers. In 2000, Taniguchi et al. (2000) firstly presented a methodology for evaluating city logistics initiatives using a dynamic traffic simulation with optimal routing and scheduling, and tested on an example road network with three city logistics schemes including cooperative freight transport system. Crainic et al. (2009) addressed the very difficult short-term scheduling

and routing problem of operations and management of resources within a general two-tiered city logistics system. Crainic et al. (2010) conducted experiments to analyze the impact on the total distribution cost of several parameters including customer distribution, satellites-location rules, depot location, number of satellites, etc. However, in both Taniguchi (2000) and Crainic et al. (2009, 2010), fixed freight transportation demand is assumed, so the objective of UCCs is only to minimize total transportation cost. So they did not answer another important question: how should the UCCs optimize their service quality and charge rates to attract demand? Realizing the importance of the cost and benefits of different stakeholders involved for the demand hence survivability of a UCC project, Duin et al. (2012) developed a dynamic model to simulate the operation condition of a UCC based on multi-agent modeling and vehicle routing. Although the freight demand of UCC in Duin et al. (2012) is treated as elastic, the decision of using UCC is made by freight carriers who care about transportation costs only, rather than consignees who calculate generalized logistics costs. To achieve financial viability of UCCs, Duin et al. (2012) considered imposition of different delivery schemes and toll rates. But because of its focus on the first UCC type in Figure 1(a), difficult VRP-TW problem is involved, so they only tested some policy parameters using the proposed simulation tool rather than formulating the problem into a bi-level optimization problem then solving it.

3. Preliminaries

Consider a busy and dense commercial area with a considerable number of retailers located inside. At this time stage, we ignore the detailed transportation network and assume that the commercial area can be accessed through a single corridor. Originally, every retailer replenishes their inventory through private delivery service. As a result, the freight vehicles have constituted a significant part of traffic flow that makes the corridor congested always during the day time and then contributes to a large proportion of traffic emission in this area. To alleviate the corridor congestion and air pollution thus improve the area image, the government authorized a logistics company to build and operate a UCC to provide common delivery services to consignees (i.e., retailers) in the commercial area. The UCC will be constructed near the starting point of the corridor, such that all freights to the commercial area may be consolidated at the UCC first, transported to the unloading point inside the commercial area by clean electronic vehicles following a fixed frequency, and then delivered to their consignees by handcarts or mini electronic vehicles.

Let I indicate the set of consignees located inside the commercial area, and $D_i, i \in I$ be their fixed monthly demand. The logistics related cost of consignees includes transportation cost, holding cost (rent cost plus inventory cost) and damage cost. For consignee $i \in I$, the rent cost and delay cost per unit per month are indicated by c_{ir} and c_{id} respectively. With a UCC, the consignees can either keep hiring dedicated carriers for private delivery, or use the UCC for common delivery. If a consignee $i \in I$ adopts private delivery with shipment size F_i^P , then for each delivery it pays the dedicated carrier a fixed transportation cost c_{if}^P and variable transportation cost $c_{iv}^P F_i^P$, and incurs a loss $\theta_i^P F_i^P l_i$ from possible damage in the delivery process, where θ_i^P is the damage rate of private delivery and l_i is the loss per unit damage for consignee $i \in I$. If common delivery is adopted with shipment size F_i^C , the consignee $i \in I$ still has to pay the dedicated carrier who transports freights from its supplier to the UCC, but with a lower fixed cost c_{if}^C and variable cost $c_{iv}^C F_i^C$. Meanwhile, it pays p^{UCC} per unit to the UCC operator for the last mile delivery, and incurs an additional damage loss $\phi_i \theta^C F_i^C l_i$ caused by additional operations at the UCC. Here θ^C is the average damage rate caused by common delivery, and ϕ_i is the scale factor for consignee $i \in I$'s freights, depending on the freight characteristics (for example, ϕ_i is higher if consignee $i \in I$'s freight is glasswork rather than clothing), so $\phi_i \theta^C$ indicates the damage rate of consignee $i \in I$'s freights caused by UCC operation. The common delivery interval t^{UCC} (hour), unit operating time t^o (hour) at the UCC and destination, and the average damage rate θ^C represent the service quality of the UCC. Consignees compare the service quality and monetary charge rates of common and private deliveries to make their delivery mode choices.

With correct predictions of consignees' reactions to different combinations of service quality and charge rate, the UCC operator (or the common delivery provider) determines its vehicle fleet size n^{UCC} , delivery interval t^{UCC} , unit operating time t^o , damage rate θ^C and unit charge rate p^{UCC} to maximize its own profit. At this time stage, only delivery service is considered for the UCC, although other value-added services, e.g., inventory, accounting, finance, can be provided at a UCC.

To ease reading, the notation of parameters and variables is listed in the following table.

Table 1. Parameters and variables

Parameters
I : the set of consignees located inside the commercial area D_i : fixed monthly demand of consignee $i \in I$ c_{if}^P : fixed transportation cost per shipment paid by consignee $i \in I$ to its dedicated carrier for private delivery c_{if}^C : fixed transportation cost per shipment paid by consignee $i \in I$ to its dedicated carrier for carrying the freights from its supplier to the UCC for common delivery c_{iv}^P : variable transportation cost per unit paid by consignee $i \in I$ to its dedicated carrier for private delivery c_{iv}^C : variable transportation cost per unit paid by consignee $i \in I$ to its dedicated carrier for carrying the freights from its supplier to the UCC for common delivery c_{ir} : rent cost per unit per month of consignee $i \in I$ c_{id} : inventory cost per unit per month of consignee $i \in I$ t_i^P : lead time (hour) of private delivery of consignee $i \in I$ t_i^C : lead time (hour) of common delivery for consignee $i \in I$ V : the set of vehicle types v_i : vehicle type utilized by dedicated carrier of consignee $i \in I$ V^C : capacity of the vehicle utilized for common delivery V_i : capacity of the vehicle utilized by dedicated carrier of consignee $i \in I$ $t(x)$: travel time function of the corridor, differentiable and increasing with traffic flow x on the corridor θ_i^P : damage rate of consignee $i \in I$'s freights by private delivery ϕ_i : scale factor of common damage rate of consignee $i \in I$'s freights l_i : damage loss per unit for consignee $i \in I$ w_f : fuel cost per vehicle per trip of the UCC w_l : each driver's salary cost per month x_b : passenger trips per hour on the corridor
Decision variables of consignees
D_i^P : monthly demand of consignee $i \in I$ for private delivery D_i^C : monthly demand of consignee $i \in I$ for common delivery F_i^P : shipment size of consignee $i \in I$ for private delivery F_i^C : shipment size of consignee $i \in I$ for common delivery
Decision variables of the UCC operator

t^{UCC} : headway (hour) of common delivery
p^{UCC} :monetary charge per unit load
t^o : average operating time (hour) per unit load at UCC and destination
θ^C :average damage rate caused by additional operation at the UCC
n^{UCC} : number of vehicles of the UCC
Other variables
x : traffic flow on the corridor from the UCC to the airport

4. The Stackelberg Leader-follower Game

Assuming no extra policies are implemented to encourage UCC utilization, the UCC operator's decision problem is formulated as a leader-follower game. The UCC operator plays as the leader to maximize its own profit through an optimal combination of service quality and charge rate. The consignees, i.e., the followers, response to the service quality and charge rate and then rationally choose the delivery mode that minimizes their logistics related cost.

4.1 The follower problem

We start from the followers' delivery mode choice. Suppose a consignee $i \in I$ determines to deliver D_i^P freights by private delivery, then the related total cost is given by

$$C_i^P(F_i^P, D_i^P) = \frac{D_i^P}{F_i^P} c_{if}^P + D_i^P c_{iv}^P + D_i^P c_{id} \left(\frac{t_i^P}{30 \times 24} + \frac{F_i^P}{2D_i} \right) + c_{ir} D_i^P \frac{F_i^P}{D_i} + l_i \theta_i^P D_i^P \quad (1)$$

where the first and second terms in Eq. (1) are total transportation cost, the third term is inventory cost, the forth term is rent cost, and the last tem is damage loss. Here t_i^P is the lead time of private delivery of consignee $i \in I$. Apparently, t_i^P includes the transportation time on the corridor $t(x)$, which is a function of its traffic flow x . But the influence of x to t_i^P is usually insignificant, so t_i^P is assumed a constant here to avoid making the problem unnecessarily complex. For given D_i^P , the optimal shipment size F_i^{P*} solves the following optimization problem:

$$\min_{F_i^P} C_i^P(F_i^P, D_i^P) \quad \text{s.t. } 0 \leq F_i^P \leq m_i D_i \quad (2)$$

As the objective function is convex with respect to F_i^P , it is easy to obtain the optimal shipment size F_i^{P*} under given D_i^P :

$$F_i^{P*} = \sqrt{\frac{2D_i c_{if}^P}{c_{id} + 2c_{ir}}} \quad (3)$$

On the other hand, if the consignee determines to deliver D_i^C freights by common delivery, then the related total cost is given by

$$C_i^C(F_i^C, D_i^C) = \frac{D_i^C}{F_i^C} c_{if}^C + D_i^C c_{iv}^C + D_i^C p^{UCC} + D_i^C c_{id} \left(\frac{t_i^C}{30 \times 24} + \frac{F_i^C}{2D_i} \right) + c_{ir} D_i^C \frac{F_i^C}{D_i} + l_i (\theta_i^P + \varphi_i \theta^C) D_i^C \quad (4)$$

where the first and second terms describe the total transportation cost from the supplier to the UCC, the third term provides the monetary pay to the UCC for the last mile delivery, the fourth term is total inventory cost, the fifth term is rent cost, and the last term is total damage loss. Here, t_i^C indicates the lead time of common delivery of consignee $i \in I$. Compared with t_i^P , t_i^C contains additional waiting time at the UCC, and operating time at both the UCC and the destination, so

$$t_i^C = t_i^P + \frac{t^{UCC}}{2} + t^o \quad (5)$$

Here the average waiting time at the UCC is approximated by half of the time interval of common delivery, $t^{UCC}/2$. Similar to Eq. (3), minimizing $C_i^C(F_i^C, D_i^C)$ in Eq. (4) under given D_i^C yields the optimal shipment size F_i^{C*}

$$F_i^{C*} = \sqrt{\frac{2D_i c_{if}^C}{c_{id} + 2c_{ir}}} \quad (6)$$

Clearly, both F_i^{C*} and F_i^{P*} are relevant with neither D_i^C and D_i^P nor the UCC's service quality. What altering consignees' shipment size are the different charge rates offered by dedicated carriers. Let β_i indicate the value of unit travel time saving for consignee $i \in I$'s dedicated carrier, then it is reasonable to predict a rate difference of c_{if}^P and c_{if}^C that equals

$$c_{if}^P - c_{if}^C = \beta_i \tilde{t}_i + \tau \quad (7)$$

where \tilde{t}_i is the original round trip travel time from the UCC location to the consignee $i \in I$, which includes the original round travel time on the corridor and delivery time inside the commercial area, and τ is the extra fee required if a freight vehicle enters the service area, e.g., the parking fee at the destination unloading bay, the road toll on the corridor, and the permit cost of entering the service area. Apparently, if transporting freights to the UCC instead of to the consignees can save the dedicated carrier a lot of transportation cost, they would offer a noticeably lower charge rate c_{if}^C to encourage consignees' utilization of UCC. It is claimed in previous studies that the existence of UCC will significantly reduce consignees' shipment size (e.g. Cranic et al 2009). As we can see here, this happens when the VOT of dedicated carrier is high, the last-mile delivery is time consuming, the parking fee inside the service area is high and/or the government imposed other regulating policies to discourage entrance of freight vehicles. .

Replacing F_i^C and F_i^P in Eqs. (1) and (4) with F_i^{C*} and F_i^{P*} , summarizing Eqs. (1) and (4), and assuming the same variable transportation cost offered by dedicated carriers, i.e. $c_{iv}^C = c_{iv}^P$ we obtain the following consignee $i \in I$'s decision problem (i.e., the lower-level problem):

$$\begin{aligned} \min_{D_i^P, D_i^C} TC_i(D_i^P, D_i^C) = & D_i^C \left[\frac{c_{if}^C}{F_i^{C*}} + \frac{F_i^{C*}(c_{id} + 2c_{ir})}{2D_i} + l_i \phi_i \theta^C + p^{UCC} + \frac{c_{id}}{30 \times 24} \left(t^o + \frac{t^{UCC}}{2} \right) \right] \\ & + D_i^P \left(\frac{c_{if}^P}{F_i^{P*}} + \frac{(c_{id} + 2c_{ir}) F_i^{P*}}{2D_i} \right) + \left(\frac{c_{id} t_i^P}{30 \times 24} + l_i \theta_i^P + c_{iv}^C \right) D_i \end{aligned} \quad (8)$$

$$\text{s.t. } D_i^C + D_i^P = D_i, \quad D_i^P \geq 0, D_i^C \geq 0 \quad (9)$$

The above problem is simply a linear problem (LP), and its optimal solution satisfies:

$$D_i^{C*} \in \begin{cases} D_i, & \text{if } q_i^C - q_i^P < 0 \\ [0, D_i], & \text{if } q_i^C - q_i^P = 0 \\ 0, & \text{if } q_i^C - q_i^P > 0 \end{cases} \quad \text{and} \quad D_i^{P*} = D_i - D_i^{C*} \quad (10)$$

with q_i^C and q_i^P being the average costs of common delivery and private delivery, and defined respectively by

$$q_i^C = l_i \phi_i \theta^C + p^{UCC} + \frac{c_{id}}{30 \times 24} \left(t^o + \frac{t^{UCC}}{2} \right) + 2 \sqrt{\frac{(c_{id} + 2c_{ir})c_{if}^C}{2D_i}} \quad (11)$$

$$q_i^P = 2 \sqrt{\frac{(c_{id} + 2c_{ir})c_{if}^P}{2D_i}} \quad (12)$$

Clearly, (D_i^{C*}, D_i^{P*}) is unique if $q_i^C - q_i^P \neq 0$. But if $q_i^C - q_i^P = 0$, (D_i^{C*}, D_i^{P*}) is generally not unique. In this case, we assume the consignee tends to not change their initial private delivery mode, which is so called the pessimistic formulation of Stackelberg problem.

4.2 The leader's decision problem

For the UCC operator, knowing consignees' reactions, it first has to guarantee two things: 1) all freights can be delivered with the current frequency, that is $\sum_{i \in I} D_i^C \leq 30 \times 18 V^C / t^{UCC}$, where V^C is the vehicle capacity of the type utilized for common delivery; 2) the fleet size is large enough to realize the promised delivery time interval, that is, $n^{UCC} \geq (2t(x) + t^o) / t^{UCC}$. Here $2t(x) + t^o$ constitutes the round trip travel time which is made up by two parts – travel time on the corridor and operating time at the UCC and destination.

The total cost of building and running the UCC consists of plenty of terms, e.g., land cost, real estate cost, vehicle cost, fuel cost, salary cost, insurance cost and other operation cost including machine cost and software cost. We generally divide them into four categories: the one that is proportional to the total number of freights handled (e.g., land cost, real estate cost, insurance cost etc.), the one that is proportional to the total number of vehicles (vehicle cost, drivers' salary cost etc.), the one that is proportional to the total number of round trips (e.g. fuel cost), and the one that is proportional to the service quality. Let α , β and w_f indicate the unit cost per freight handled, per vehicle and per round trip, and $g(t^o, \theta^C)$ be the additional operating cost related to service quality, then the total cost of UCC can be written into

$$TC^{UCC} = \alpha \sum_{i \in I} D_i^C + \beta n^{UCC} + w_f \frac{30 \times 18}{t^{UCC}} + g(t^o, \theta^C) \quad (13)$$

For simplicity, we assume $g(t^o, \theta^C)$ follows the following linear form:

$$g(t^o, \theta^C) = U - at^o - b\theta^C \quad (14)$$

where U is a constant indicating the required investment for fastest operating time and lowest damage rate, a and b are coefficient factors for t^o and θ^C , and $g(t^o, \theta^C) \geq 0$ for any feasible t^o and θ^C . Meanwhile, the revenue of the UCC all comes from its delivery service and thus it is given by

$$R^{UCC} = p^{UCC} \sum_{i \in I} D_i^C \quad (15)$$

As a result, the UCC operator's decision problem of maximizing its own profit can be described by UCC-0:

$$\begin{aligned} \max S(n^{UCC}, t^{UCC}, t^o, \theta^C, p^{UCC}) &= R^{UCC} - TC^{UCC} \\ &= (p^{UCC} - \alpha) \sum_{i \in I} D_i^C - \beta n^{UCC} - w_f \frac{30 \times 18}{t^{UCC}} - U + at^o + b\theta^C \end{aligned} \quad (16)$$

s.t.

$$n^{UCC} \geq \frac{2t(x) + t^o}{t^{UCC}} \quad (17)$$

$$\sum_{i \in I} D_i^C \leq \frac{30 \times 18 V^C}{t^{UCC}} \quad (18)$$

$$x = x^b + \pi_{UCC} \frac{2t(x) + t^o}{30t^{UCC}} + \sum_{i \in I} \frac{\pi_i (D_i - D_i^C)}{30F_i^{P*}} \quad (19)$$

$$\underline{t}^o \leq t^o \leq \bar{t}^o, \underline{\theta} \leq \theta^C \leq \bar{\theta}^C, t^{UCC} \geq 0, p^{UCC} \geq 0 \quad (20)$$

$$n^{UCC} = \{1, 2, \dots, \bar{n}^{UCC}\} \quad (21)$$

and (D_i^C, D_i^P) solves LP (8)-(9) **Error! Reference source not found.** for any $i \in I$.

Note that a UCC has to own at least one vehicle to provide delivery service, so n^{UCC} is restricted to be a positive integer here, and \bar{n}^{UCC} is its upper bound. If the objective value of UCC-0 turns out to be negative, the planner may give up the UCC construction plan and in this case $n^{UCC} = 0$. In Constraint (19) π_{UCC} and $\pi_i, i \in I$ are passenger car units (PCUs) of UCC vehicle and consignee $i \in I$'s private delivery vehicles respectively. Constraint (19) indicates the composition of total daily traffic flow x on the corridor: the fixed passenger trip, the daily common delivery trip and the total daily private delivery trip. Constraint (20) provides the upper and lower bounds of different variables.

It is worth pointing out that at this time stage, we did not consider the detailed match problem of the consignees' ordering schedule and the UCC's delivery schedule. It is possible that the desired frequency of consignee $i \in I$, D_i^C / F_i^C , is higher than the monthly frequency of common delivery, $30 \times 18 / t^{UCC}$. However, it is reasonable to assume that the service frequency of a viable UCC is enough to meet most consignees' requirements. Taking the Heathrow airport retail consolidation center as an example, it delivers more than 5000 times per year, that is, more than 15 times per day, which should be enough to meet a single consignee's requirement (Allen et al., 2007).

4.3 Solution techniques

There is only one integer variable n^{UCC} , so if an exact solution is desired, we can solve UCC-0 for all fixed n^{UCC} and choose the one that contributes to a maximal objective value. However, even the problem with a

fixed n^{UCC} is generally difficult to solve, because the problem UCC-0 is a bi-level optimization problem with nonlinear and non-convex constraints.

To make the problem solvable, we assume a linear travel time function, $t(x) = \zeta - \omega x$, and relax the lower level problem (8) and (9) into the following nonlinear constraints following the suggestions in Scholtes (2001):

$$(q_i^C - q_i^P + \lambda_i) D_i^C \leq \varepsilon_i, \quad i \in I \quad (22)$$

$$D_i^C \geq 0, \quad q_i^C - q_i^P + \lambda_i \geq 0, \quad i \in I \quad (23)$$

$$(D_i - D_i^C) \lambda_i \leq \varepsilon_i, \quad i \in I \quad (24)$$

$$D_i - D_i^C \geq 0, \lambda_i \geq 0, \quad i \in I \quad (25)$$

where ε_i is a positive constant, and by gradually reducing ε_i to 0, Eqs. (22)-(25) become identical to the KKT conditions of LP (8) and (9). Meanwhile, we introduce two new variables y_1 and y_2 defined by

$$y_1 = \frac{2t(x) + t^o}{t^{UCC}} \quad (26)$$

and

$$y_2 = \frac{30 \times 18V^C}{t^{UCC}} \quad (27)$$

Then the problem UCC-0 under given $n^{UCC} = \tilde{n}^{UCC}$ and ε_i can be written into

$$\max \tilde{S}(\tilde{n}^{UCC}, y_1, y_2, \theta^C, p^{UCC}, D_i^C) = (p^{UCC} - \alpha) \sum_{i \in I} D_i^C - \beta \tilde{n}^{UCC} - \frac{w_f}{V^C} y_2 - U + at^o + b\theta^C \quad (28)$$

$$\text{s.t.} \quad \tilde{n}^{UCC} \geq y_1 \quad (29)$$

$$\sum_{i \in I} D_i^C \leq y_2 \quad (30)$$

$$y_1 t^{UCC} = 2 \left[\zeta - \omega \left(x^b + \pi_{UCC} y_1 + \sum_{i \in I} \frac{\pi_i (D_i - D_i^C)}{30F_i^{P*}} \right) \right] + t^o \quad (31)$$

$$y_2 t^{UCC} = 30 \times 18V^C \quad (32)$$

$$x = x^b + \pi_{UCC} y_1 + \sum_{i \in I} \frac{\pi_i (D_i - D_i^C)}{30F_i^{P*}} \quad (33)$$

$$30 \times 18V^C (2y_1 + 1) \geq 2t(x) y_2 \quad (34)$$

$$y_1 > 0, y_2 > 0, p^{UCC} > 0, 1 \geq \theta^C \geq 0 \quad (35)$$

and Eqs. (22)-(25) **Error! Reference source not found.**

The above optimization problem is a quadratic problem with quadratic constraints that can be solved by QCP solvers. Note that all existing QCP solvers are not guaranteed to produce a globally optimal solution, we may stop at a locally optimal solution.

5. Conclusion

In the recent decades, hundreds of urban consolidation centers (UCCs) have been built around the world to provide common service for last-mile delivery, but almost all of them were closed when government cannot continue to provide subsidy. This paper makes the first attempt to investigate the capability of UCCs to make profit. A Stackelberg lead-follower model is proposed to optimize the performance of UCCs. The consignees

play as the independent followers who choose between private delivery and common delivery to minimize their total logistics cost., and the UCC operator plays as the leader to determine the best combination of service quality (i.e., delivery frequency, operation time and damage rate) and charge rate that maximize its profit, with a correct prediction of consignees' mode choices. The UCC and consignees' decision problems are formulated into a bi-level optimization problem with nonlinear objectives and constraints, therefore is generally very difficult to solve. Under some mild assumptions, we provide solution techniques to transform the problem into a QCP that can handled by QCP solvers.

References

- Allen J., Thorne G. Browne, M. (2007), Good practice guide on urban freight transport. BESTUFS consortium, European Commission, Accessed on 2014-01-14: http://www.eltis.org/docs/tools/English_BESTUFS_Guide.pdf
- Allen J., Browne M., Woodburn A., Leonardi J. (2012), The role of urban consolidation centres in sustainable freight transport, *Transport Reviews* 32(4): 473-490.
- Browne, M., Sweet, M., Woodburn, A., Allen, J. (2005), Urban freight consolidation centres final report. Transport Studies Group, University of Westminster for the Department for Transport.
- Browne M., Woodburn A., Allen J. (2007), Evaluating the potential for urban consolidation centres. *European Transport, Trasporti Europei* (35): 46-63.
- Crainic T. G., Ricciardi N., Storchi G. (2009), Models for evaluating and planning city logistics systems, *Transportation science* 43(4): 432-454.
- Crainic T. G., Perboli G., Mancini S., Tadei R. (2010), Two-echelon vehicle routing problem: a satellite location analysis, *Procedia-Social and Behavioral Sciences* 2(3): 5944-5955.
- Cadotte, E. R., Robicheaux, R. A. (1979), Institutional Issues in Urban Freight Consolidation. *International Journal of Physical Distribution & Logistics Management* 9(4): 158-168.
- LET – Aria Technologies – Systems Consult (2006), Mise en place d'une methodologie pour un bilan environnemental physique du transport de marchandises en ville, consommation, emissions, qualite de l'air. Co-edition ADEME, CERTU, Lyon.
- Marinov M., Zunder T., Islam D.M.Z. (2008), Urban freight consolidation concepts: is there something missing?, *Transport Problems* 5(2): 5-12.
- van Duin, J. H. R., Quak H., Muñuzuri J. (2010), New challenges for urban consolidation centres: A case study in the Hague, *Procedia-Social and Behavioral Sciences* 2(3): 6177-6188.
- van Duin J. R., van Kolck A., Anand N., Tavasszy L., Taniguchi E. (2012), Towards an agent-based modelling approach for the evaluation of dynamic usage of urban distribution centres, *Procedia-Social and Behavioral Sciences* 39: 333-348.
- Scholtes, S. (2001), Convergence properties of a regularization scheme for mathematical programs with complementarity constraints, *SIAM Journal on Optimization* 11(4): 918-936.
- SUGAR (2011), City logistics best practices: a handbook for authorities, Accessed on 2014-01-24: <http://www.sugarlogistics.eu/pliki/handbook.pdf>.
- Taniguchi, E., Van Der Heijden, R. E. (2000), An evaluation methodology for city logistics, *Transport Reviews* 20(1): 65-90.
- Taniguchi, E., Thompson, R. G., Yamada, T. (2012), Emerging techniques for enhancing the practical application of city logistics models, *Procedia-Social and Behavioral Sciences* 39: 3-18.

ⁱ Here and in the following, we always assume the LTL assumption holds, that is, the shipment size of any consignee is less than truckload (LTL).

ⁱⁱ We assume 30 days per month, and 18 working hours every day.

Northeast Asian Transport Corridors: Potential and Development under the Greater Tumen Initiative

Varvara Krechetova

Programme Officer (Transport), Greater Tumen Initiative's Secretariat/United Nations Development Program, Beijing, China.

Abstract

The paper provides a descriptive view on development of transport in the core Northeast Asia (NEA) - Greater Tumen Region (GTR) - under Greater Tumen Initiative (GTI). It describes the lacunae in the NEA main trade routes in GTR and elaborates on the potential of the region for logistics and outlines efforts that involved countries make at domestic level to materialize the benefits of region's economic position. Paper introduces NEA transport corridors as defined within GTI and shows how international cooperation at regional level contributes to their development. The article summarises the impediments along the corridors both infrastructural and regulatory, provides traffic forecasts for the corridors.

Keywords: Northeast Asia; Greater Tumen Initiative; Transport corridors.

1. Northeast Asia

Northeast Asia (NEA) is economically powerful region that includes Northeast China, Japan, Mongolia, states of Korean Peninsula and Russian Far East. Together, the countries that belong to NEA possess significant economic power: in 2012 they produced about 24% of the World's GDP (based on World Bank, 2013). Their share in the World population is about 22% (based on World Bank, 2013).

As a region, NEA has particularly prominent limitrophe-like borders:

- Two of the countries that constitute the region belong to it by only part of their territories: China (Dongbei or Northeastern provinces and part of Inner Mongolia) and Russia (Far East).
- Three of the countries are stretched between different regions: China – between East, Central, Southeast and Northeast Asia; Mongolia – Northeast and Central Asia; Russia – between Northeast Asia, Eastern Europe, it borders Central Asia.

These features of NEA in combination with complicated historical path, that lead to apparent absence of strong regional cooperation movements in the region till very recently, make the region miss quite a number of opportunities. Among them, missed opportunities in transport are the most obvious. The whole rail and road network within the core of NEA does not provide intermodal international services it is geographically bounded to provide and partially it is simply absent.

2. Greater Tumen Initiative

Greater Tumen Initiative (GTI) is a member-driven intergovernmental cooperation platform in Northeast Asia, supported by United Nations Development Programme. By far it is the only comprehensive cooperation mechanism at central governments level in the region.

Member-countries of GTI are China, Mongolia, Republic of Korea (ROK) and Russia. Democratic People's Republic of Korea (DPRK) was a member prior to 2009. The organization focuses on the region that includes China's Northeastern provinces (Heilongjiang, Jilin, Liaoning) and Inner Mongolia autonomous region, eastern aimags of Mongolia (Dornod, Khentii, Sukhbaatar), east coast of ROK, Primorsky territory of Russia (see Figure 1). The region is called the Greater Tumen Region (GTR).

The region lies in the land core of the NEA and missed opportunities, mentioned above, are particularly pronounced in this area. Geographical position of GTR allows fast and short land connection between Japan/ROK and Europe suggesting that Pacific ports of Russia and DPRK might join the list of World leading ports by capturing noticeable share of current sea flow between NEA and Europe (see also section 5). If actively used, the transport routes in the region would lure assembly manufacturing from Japan/ROK that would be also attracted by cheaper labour forces. None of this happens at the moment. Size of GTR economy confirms high concentration of missed opportunities in the core of NEA: GTR contributes less than 2% to the World's GDP or about 8% of NEA GDP. GTR population is about 2% of the World's or 9.7% of NEA's population (based on World Bank, 2013, 1, 2; GTI, 2014). GTR area constitutes approximately 15% of NEA area if taken as defined in 1 which gives ~2 times less dense economic production than on average in NEA.

Transport is one of the priorities for cooperation (others are trade and investments, tourism, energy and environment). Cohesive and efficient regional transport network with minimum delays at border is the goal for joint actions in the sector. This work direction of GTI is the focus of the paper.

Another direction is facilitation and promotion of regional joint ventures in logistics that are intermodal (sea-land) routes based on ferries in the East Sea/Sea of Japan. Historically, there were a number of such companies; operating now are DBS Cruise Ferry: Sakaiminato (Japan) – Donghae (ROK) – Vladivostok (Russia); Stena Daea Line: Sokcho (ROK) – Zarubino (Russia) – Vladivostok (Russia). Being intra-regional by nature, these lines cannot benefit from diverting to other ports, therefore they bear the full costs of inefficient cross-border regime and lack of infrastructure.

3. Trade Flows in NEA

3.1. Trade flows in NEA

Countries of NEA are important players in the world trade: in 2012, China, Mongolia, Japan, ROK and Russia combined generated 21% of World's export value, 19% of import (WTO, 2013). In 2010-2012, China, Japan and ROK were within top ten world's exporters and importers (WTO, 2012-2013).

3.2. Trade between GTI member-countries

Most of NEA trade and respectively transport volumes goes beyond the region: in 2010, intra-NEA trade accounted to 13% of total NEA trade or about 7 billion USD (GTI, 2013).

The biggest NEA trade exchange in value term is between China and Japan, more than 340 billion USD in 2011; China – ROK is the second important in NEA with over 220 billion USD; ROK – Japan trade amounts to over 105 billion USD (WTO, 2012). NEA trade with Russia is much smaller in value: trade turnover with China, main trade partner for Russia in NEA, is around 80 USD billion, Russia's trade turnovers with Japan and ROK are below 30 USD billion each (FSSS, 2013). Total foreign trade turnover of Mongolia in 2011 reached 11.4 billion USD (NSO, 2012).

Despite their central position to NEA, the share of GTR provinces in these flows is not big. For instance, estimates for 2011 on the base of WTO and regional statistical sources give for Jilin province about 0.9% to China – Russia and Japan – Russia flows, 0.3% to China – ROK flow; for Heilongjiang province about 0.3% to China – Japan and China – ROK flows. Heilongjiang province's trade volume with Russia is remarkable with outstanding 23% of the overall China – Russia trade turnover. In 2011 Primorsky territory contributed about 5% to Russia – China trade volume, 6% to Russia – ROK trade volume and about 2% to Russia – Japan trade.

Fig 1. Greater Tumen Region and its transport corridors



Source: GTI (2013, 3)

The figures reflect the underdevelopment in the GTR both in terms of transport infrastructure and overall economic structure that are interlinked: each is cause and consequence of the other.

4. Transport in NEA

4.1. Transport network in NEA

To serve the respective trade flows, the region hosts ports from World's top 50 (Table 1).

Table 1. World's Leading Ports in NEA (2011)

	Total Freight Volume		Container Traffic	
	Thousand tons	Rank in AAPA ranking	Thousand TEU	Rank in AAPA ranking
Tianjin (China)	459,941	3	11,588	11
Qinhuangdao (China)	284,600	8	n/a	n/a
Busan (ROK)	281,513	9	16,164	5
Dalian (China)	211,065	14	6,400	19
Nagoya (Japan)	186,305	18	2,472	46
Ulsan (ROK)	163,181	20	327	n/a
Incheon (ROK)	151,462	21	1,925	65
Chiba (Japan)	149,661	22	n/a	n/a
Kwangyang (ROK)	102,844	35	2,062	59
Kitakyushu (Japan)	99,979	36	512	n/a
Osaka (Japan)	88,095	40	2,173	56
Kobe (Japan)	87,017	42	2,725	41
Tokyo (Japan)	83,358	45	4,416	25
Pohang (ROK)	56,182	68	n/a	n/a

Source: American Association of Port Authorities (AAPA), World Port Ranking 2011; Ulsan Port Authority; Statistics of Port of Kitakyushu 2012.

The region also boasts major Asian and Asia – Europe railway corridors: Trans-Siberian Railway (TSR), Trans-Mongolian railway (Naushki – Ulaanbaatar – Zamyn Uud – Tianjin), Lianyungang – Alashankou – Druzhba – Europe (Trans-China railway).

Important road corridors stretch along these railways, China and ROK developed comprehensive and cohesive domestic road networks. Mongolia is still on the way to widen and improvement of its road network.

4.2. *Transport in the Greater Tumen Region*

Transport infrastructure of the Greater Tumen Region is secondary in relation to the main railway and road corridors and serves mostly regional transport flows. Apart from China's Bohai Bay ports, key GTR sea ports are smaller than main NEA ports listed above. The ports are connected to Trans-Siberian Railway or to the East and Northeast China railway system.

Table 2: Main GTR Ports (2011)

Port	Turnover, thousand tons	Container Turnover, thousand TEU
Dalian (China)	211,065	6,400
Dandong (China)	76,370	710
Yingkou (China)	260,850	4,030
Posiet (Russia)	4,022	-
Trinity Bay port (Zarubino) (Russia)	117	-
Vladivostok (Russia)	11,873	600
Vostochny (Russia)	38,516	339
Nakhodka (Russia)	14,961	2

Source: NBSC, 2014; World Shipping Council, 2014; SINA Corporation, 2012; GTI, 2013, 1.

In Northeast China, the railways connect main provincial cities (Shenyang, Changchun, and Harbin) to ports in Bohai Bay, Trans-Siberian Railway via Manzhouli and to Vladivostok area ports in Russia. Roads follow the same corridors and supplement them in areas that are not served by railways.

The most important to GTR trade is the railway connection TSR – Zabaykalsk (Russia) – Manzhouli (China) – Harbin – Suifenhe – Grodekovo (Russia) – Vladivostok/Vostochny/Nakhodka. Currently, it is the busiest route in GTR (Table 3). Meanwhile, potentially most interesting route for freight forwarders, that yet exists only partially, is the railway connection Mongolia – China's Arxan – Ulanhot – Changchun – Hunchun – Russia's Makhalino – Zarubino. Presently, the railway track is laid at Arxan – Zarubino section; Jilin province and Primorsky territory, Russian Railway actively work on operationalization of Hunchun to Zarubino part. However, the route is showcase of impediments that threaten freight and passenger flows in GTR: at a short distance of 63 km a cargo/passenger should cross borders twice: first, China – Russia, then exit from Russia at Zarubino – facing all the cross-border delays that might unpredictably arise.

In Mongolia, Eastern part lacks both railways and roads. Railway system that is currently under expansion is mainly presented by Trans-Mongolia railway, connection Choibalsan to Borzya (Russia) and further to TSR. Mongolian part of the route from Mongolia to Hunchun and Zarubino described above exists only in form of plans.

4.3. *NEA Transport Corridors*

The first attempt to formalise international transportation corridors in NEA to make NEA governments to recognise potential of inner-NEA transport network and facilitate strategic planning and investment was made by the specially created Transportation Subcommittee of the Northeast Asia Economic Conference Organizing Committee. The subcommittee identified nine such corridors using the materials of the participating countries and ERINA institute researches (ERINA, 2002), we depict the corridors in Figure 1:

- BAM Railway: Vanino – Taishet – SBL.
- Siberian Land Bridge (SBL): ports in Primorsky Territory, Russia – Europe/Central Asia.

- Suifenhe Transport Corridor: ports in Primorsky Territory, Russia – Grodekovo – Suifenhe -- Harbin – Manzhouli – Zabaykalsk – SBL.
- Tumen River Transport Corridor: ports in Tumen River Area (Zarubino/Posiet/Rajin) – Changchun – East Mongolia – SLB.
- Dalian Transport Corridor: Dalian – Shenyang – Harbin – Harbin – Heihe – Blagoveshchensk – SLB.
- Tianjin – Mongolia Transport Corridor: Tianjin – Beijing – Ulaanbaatar – SLB.
- China Land Bridge (CLB) Corridor: Lianyungang Port – Kazakhstan – Europe.
- Korean Peninsula West Corridor: Busan – Seoul – Pyongyang – Sinuiju – Shenyang – Harbin – SLB.
- Korean Peninsula East Corridor: Busan – Rajin – Tumangang – Khasan – SLB.

For transport cooperation in GTR, GTI member countries chose six of the above corridors to concentrate their efforts on. Some amendments were made to the alignment of the Tumen Transport Corridor (1a,1b in Fig 1):

- 1) Tumen Corridor: Zarubino/Posiet/Rajin ports – Tumen/Hunchun – Changchun – Arxan – East Mongolia – Trans-Mongolia Railway or TSR, this corridor has a branch Baruun Urt – Khuut – Bichigt – Chifeng – Jinzhou;
- 2) Suifenhe corridor: ports in the Primorsky Territory (Vostochny, Nakhodka, Vladivostok) – Grodekovo – Suifenhe – Harbin – Manzhouli – Zabaykalsk – TSR;
- 3) Siberian Land Bridge: TSR;
- 4) Dalian corridor: Dalian – Shenyang – Harbin – Heihe – Blagoveshchensk – TSR;
- 5) Korean West corridor: Busan – Seoul – Pyongyang – Sinuiju – Shenyang – Harbin;
- 6) Korean East corridor: Busan – Rajin – Tumangang – Khasan – TSR.

5. Potential of GTR transport routes and traffic forecasts for the trans-GTR corridors

Potential opportunities for the transport routes in the core NEA that is Greater Tumen Region are provided by the blooming NEA trade. GTR ports (Vladivostok, Vostochny, Nakhodka, Zarubino, Rajin) might, under certain conditions such as modernization of facilities, streamlined custom procedures, improved rolling stock management and more flexible tariff policy of Russian Railways on TSR, etc., attract significant share of freight that presently is shipped by sea directly from Japan to Europe, ROK to Europe (see GTI 2013 1, 2). While operating sustainably, these routes might as well generate traffic from Mongolian mineral bases and local GTR manufacturing and tourism business.

In other words, the most obvious benefits provided by the regional railways and ports are:

- shortening the way from Japan/ROK to Europe (from about 30 days by sea to about 2 weeks or less by intermodal sea/railway route);
- a short way for Mongolia's mineral resources to markets in Japan, ROK, China;
- possibility to establish factories for Japan/ROK companies both within GTR and beyond relying on TSR and Zarubino – Hunchun corridor as a quick way to supply parts for assembly. Hyundai Motors and KIA that used TSR before 2009 to deliver parts to their production lines in Taganrog and Izhevsk in Russia are examples of the latter.

Unfortunately, the limited data available for GTR provinces in all 4 countries makes analysis for such potential benefits extremely difficult if not impossible. Additional complications are the facts like 7 years' suspension of operations of Hunchun (China) – Makhilino (Russia) railway that makes prognosis of traffic via this railway quite challenging. The railway resumed operations in late 2013 and the impact on Zarubino and other Primorsky territory ports will be clear in coming years.

Some efforts to analyse potential of ports in GTR were made in the survey of the experts' prospects on the Zarubino port potential turnover in 2010 by GTI. The survey, participated by transport actors and experts from NEA and working with NEA, suggested that by 2020, the port might have 2.5 million TEU and 11-17 million ton of general cargos (GTI, 2010).

GTI Integrated Transport Infrastructure and Cross-Border Facilitation Study for the Trans-GTR Transport Corridors provides the following traffic forecasts for the main BCPs and ports in GTR (Table 3).

Table 3. GTR Freight Flows at BCPs and Ports

BCP/Port	(in thousand tons)					
	2010			2020		
	Road/port	Rail	Total	Road/port	Rail	Total
Nomrog (Mongolia)/Arxan (China)	0	0	0	10	15,200	15,210
Kraskino/Gvodezvo (Russia)/Hunchun (China)	93	0	93	360	2,415	2,775
Quanhe (China)/ Wonjong (DPRK)	200	0	200	360		360
Zarubino Port (Russia)	337		337	3,165		3,165
Zabaykalsk (Russia)/Manzhouli (China)	403	21,358	21,761	710	30,740	31,450
Pogranichny (Russia)/Suifenhe (China)	514	6,956	7,470	732	8,780	9,512
Solovievsk (Russia)/Ereentsav (Mongolia)	1	37	38	4	565	569
Blagoveshchensk (Russia)/Heihe (China)	178		178	419		419
Khasan (Russia)/Tumangang (DPRK)		131	131		5,400	5,400

Source: GTI Integrated Transport Infrastructure and Cross-Border Facilitation Study for the trans-GTR Transport Corridors. Regional Summary Report. 2013. P.19. Originally prepared by Dr. J-F.Gautrin, adapted for this paper.

The possibility to reach or exceed this forecast depends fully on the level of efforts by member countries to both create infrastructure and facilitate cross-border procedures in the region. The more advance on this way, the more traffic might be attracted and generated. The barriers to be removed along the way are listed below.

6. Impediments for transport flows in GTR

Problems in realization of potential transportation benefits of geographic position of GTR are, classically, both in infrastructure and cross-border regulations.

1. There are obvious lacunae in transport network: “empty” Eastern Mongolia in terms of railways and poor quality of roads, absence of connection Heihe (China) – Blagoveshchensk (Russia) (freight cannot travel TSR – Dalian via this route), etc.
2. Ports and BCPs lack of capacity with Zarubino port, Kraskino BCP (Russia) as most prominent examples.
3. TSR suffers from congestion, ROK – DPRK railway connections are closed.
4. The region also lacks dry ports, logistics terminals, bridges and roads at other locations.
5. Cross-border regulations are inefficient and thus lead to miniscule or non-existent transit via GTR’s network. There are no comprehensive transit agreements on bilateral or multilateral levels. Treatment of transit by customs adds to the pressure on transit. Foreign trucks are restricted to travel in non-origin countries.
6. BCPs are not modernised and not fully equipped for electronic control, there no attempts for joint custom control or implementing other custom facilitation measures, even if countries actually are using single window or electronic declaration systems in general: most of GTR BCPs are just remotely located.

7. Domestic Development Policies in GTR and GTI Strategies

7.1. Development Policies in GTR Initiated Domestically

GTI member countries well understand the discrepancy between the size of the trade in NEA and underdevelopment of the areas in NEA core as well as the possibilities that are provided by core’s geographical position. They designed a number of domestic policies to tackle existing issues. Geographical scope of these policies does not fully match GTR area because NEA’s limitrophe-like borders dictate each country to choose different regions to cover with a policy.

In 2003, China adopted *Strategy of Revitalization of the Old Industrial Bases of the Northeast* up to 2020. The Strategy covers provinces Heilongjiang, Jilin, Liaoning, townships Hulun Buir, Tongliao, Chifeng, and Xing’an and Xilin Gol Leagues of Inner Mongolia Autonomous Region. The Strategy aims at improvement of

industrial structure of the Northeast; speeding up development of advanced strategic industries such as manufacturing, new construction materials industry, energy efficiency and environment protection sectors, new energy sources, cars on new energy sources; speeding up development of logistics, financial and business services, high-tech; development of agriculture. The Strategy also promotes closer cooperation of the 4 provinces as well as strengthening cooperation with Russia (Revitalise, 2014).

To give further stimulus to the development in the core NEA and China's Northeast, in 2009, China approved establishment of the *Chang-Ji-Tu Pilot Zone for Development and Opening*. The zone is part of the *Development and Cooperation Plan for China's Tumen River Area (2009 – 2020)*. The zone is designed to be pilot zone for bilateral and multilateral cooperation in NEA in manufacturing and new industries, high-tech, tourism (promotion of Changbaishan/Baekdusan travel), logistics, trade (Development, 2009).

In 1996, Russia adopted federal special-purpose program *Economic and Social Development of Far East and Baikal regions*. Initially set up to 2013, it was updated and extended up to 2018. The Program covers Primorsky, Khabarovsk, Zabaykalsky, Kamchatsky Territories, Republics of Buryatia, Sakha, Jewish autonomous oblast, Amursky, Irkutsky, Magadan, Sakhalin oblasts, Chukotsky autonomous prefecture. The Program aims at development of transport, energy and engineer infrastructure to speed up development in the regions, improve investment climate and population well-being. The program specially mentions development of transport transit potential of the area (Federal, 2014).

To strengthen governmental capacity in development work on the Far East, in 2012, Ministry of the Far East Development was established and headquartered in Khabarovsk. The ministry is tasked with implementation and management of the existing development programs in the Russian Far East.

In 2010, Mongolia endorsed *State Policy on Railway Transportation* that sets the direction towards expansion of the railway system in the country to ensure sustainable access to world markets, transit and export of mineral resources. The Strategy includes construction of industrial complex in Sainshand for processing raw minerals; construction of railway connections to China, west from existing Trans-Mongolian railway: Dalanzadgad –Tavan Tolgoi – Tsagaan Suvraga – Zuunbaya, Tavan Tolgoi – Gashuun Sukhait, Nariin Sukhait – Shivee Khuren; construction of railway connection to China, east from existing Trans-Mongolian railway: Khuut – Tamsagbulag- Numrug, Khuut – Bichigt, Khuut – Choibalsan. At the last stage a line from Russian border to China's border at the west of the country is planned. The railways gauge according the strategy is wide 1520 mm (State Hural, 2010).

7.2. GTI Strategic Action Plan and Regional Transport Strategy

Having identified their objectives in the GTR at domestic level, GTI member countries determine to reach good partnership for common prosperity in the region at multilateral one. The vision is reflected in the GTI Strategic Action Plan (SAP) 2012-2015 (originally 2006-2015, amended in 2012). To implement this vision they set the following strategic cooperation areas for their multilateral efforts: transport, trade and investments, tourism, energy and environment (GTI, 2012).

Transport infrastructure and transport facilitation are deemed as precondition to the overall economic development of the region as reflected by the SAP. While the SAP sets development of the regional transport corridors to reduce logistics costs and promote seamless flows of goods and people, GTI further adopted separate Regional Transport Strategy (GTI, 2013, 3), focusing on the above defined six corridors (see 4.3).

For these six corridors as well as GTR transport network as a whole, the strategy identifies five policy directions (GTI, 2013, 3):

- 1) Connectivity – increase connectivity between GTI member countries to ensure win-win situation for all;
- 2) Support to transport infrastructure improvements – creation of efficient transport and trade facilitation infrastructure;
- 3) Software support to transport corridor functioning – creation of effective cross-border regulations and procedures, if needed covered by bilateral or multilateral agreements;

- 4) Management of transport corridors – it is advised in addition to the body that manages and determine overall work for development of the all corridors in GTR, to set multi-country and multi-sector bodies to work on development of sub-corridors as well as a body to monitor the corridors performance.
- 5) Private sector involvement – maximisation of involvement of private sector in planning, financing, operation and monitoring of the transport corridor's infrastructure.

The Strategy is supplemented by Action Plan that includes investment program for infrastructure and recommendations for the corridors management and regulations' improvements. The minimal estimates of the investment need for infrastructure development is 3.5 billion USD (GTI, 2013, 3).

The ways to finance infrastructure improvements, especially of cross-border nature, are still investigated by GTI member countries. One of the finance vehicles was established in 2012-2013 when 4 EXIM and Development Banks - one from each member country (the Export-Import Bank of China, the Development Bank of Mongolia, the Export-Import Bank of Korea, Vnesheconombank, Russia) - entered into MOU to create NEA EXIM Banks Association. The Association is now discussing pilot cooperation projects within GTR and transport is the key sector to start with.

8. Conclusions

NEA is an important actor in the World's trade and logistics, however, the core of the region lags behind in terms of economic development, transport and trade. Presently, there is one comprehensive regional cooperation mechanism in NEA, that aims at overcoming the situation, - Greater Tumen Initiative. GTI focus area is exactly the core of NEA: China's Northeast, east of Mongolia, east of ROK, Primorsky Territory of Russia.

GTR area is particularly promising in terms of logistics as it provides shortcut between Asia and Europe via land railway connection and short route for Mongolian mineral resources to markets in China, ROK and Japan.

Recognising the benefits of the geographical position of the area and its potential for logistic, industrial, tourism development, GTI member countries adopt a number of domestic and regional policies to develop transport infrastructure in the region and facilitate cross-border movement, for instance GTI Regional Transport Strategy and Action Plan with at least 3.5 billion of planned investments and ambitious goals in transport facilitation. While implemented, these measures can lead to multifold growth of freight traffic along the main transport corridors in NEA that cross its core.

Remarks

(The views expressed in this paper are those of the author and do not necessarily reflect the views and policies of the Greater Tumen Initiative (GTI) or members of its Consultative Commission and Transport Board or the governments they represent.)

Acknowledgements

Author would like to thank the team that produced the six reports for Integrated Transport Infrastructure & Cross-border Facilitation Study for the Trans-GTR Transport Corridors that was referenced in the paper: Mr. Hirofumi Arai, Ms. Meizhen Gao, Dr. Jean-François Gautrin, Dr. Gotov Dugerjav, Dr. Mikhail Kholosha, Dr. Hee-Seung Na.

References

- American Association of Port Authorities, World Port Ranking, (2011), [online], available: <http://aapa.files.cms-plus.com/PDFs/WORLD%20PORT%20RANKINGS%202011.pdf> , last accessed in January 2014.
- DBS Cruise Ferry, (2014), [online], available: <http://www.dbsferry.com>; last accessed in January 2014.

Development and Cooperation Plan for China's Tumen River Area – To Make Chang-Ji-Tu a Pilot Zone for Development and Opening, (2009), [online], available: <http://www.cjtzlss.com/news/7/17.html>, last accessed March 2014.

ERINA, (2002), Vision for the Northeast Asia Transportation Corridors, Northeast Asia Economic Conference Organizing Committee, Transportation Subcommittee, ERINA booklet.

Federal special-purpose program “Economic and Social Development of Far East and Baikal regions” as amended in December, (2013), [online], available: <http://minvostokrazvitia.ru/upload/iblock/c31/fcp480update.pdf>, last accessed March 2014.

FSSS (Federal State Statistics Service of Russia), (2013), Russian Statistical Yearbook 2013: Moscow 623.

GTI (2010), Survey on Zarubino Port's Cargo Turnover Outlook, [online], available: <http://www.tumenprogramme.org/?info-642-1.html>; last accessed March 2014.

GTI (2012), Strategic Action Plan 2012- 2015, www.tumenprogramme.org/?info-549-1.html; last accessed March 2014.

GTI (2013), Integrated Transport Infrastructure & Cross-border Facilitation Study for the Trans-GTR Transport Corridors: Individual Country Report – Russia, [online], available: <http://www.tumenprogramme.org/UploadFiles/pdf/GTI%20corridors%20Study%20Russia%20final%20report%20small.pdf>, last accessed March 2014.

GTI (2013), Integrated Transport Infrastructure and Cross-Border Facilitation Study for the trans-GTR Transport Corridors, Regional Summary Report, www.tumenprogramme.org/UploadFiles/pdf/summary%20report_combined.pdf, last accessed March 2014.

GTI, (2013), GTI Regional Transport Strategy and Action Plan, [online], available: www.tumenprogramme.org/?info-13-115.html, last accessed March 2014.

GTI, (2014), GTI Member Countries and Greater Tumen Region at a Glance, [online], available: <http://www.tumenprogramme.org/?list-1528.html>, last accessed in February 2014.

National Bureau of Statistics of China (NBSC), (2014), [online], available: <http://data.stats.gov.cn/workspace/index?m=hgnd>, last accessed March 2014.

National Statistical Office of Mongolia (NSO), (2012), Monthly bulletin of statistics, December 2012: Ulaanbaatar : 92.

Revitalize Northeast, (2014), [online], available: <http://www.chinaneast.gov.cn>, last accessed March 2014.

SINA Corporation, (2012), Dandong port advances towards a 100 million ton port, [online], available: <http://ln.sina.com.cn/city/csgz/2012-02-17/482.html>, last accessed March 2014.

State Great Hural (Parliament) of Mongolia, (2010), State Great Hural (Parliament) of Mongolia Resolution No. 32: Endorsement of State Policy on Railway Transportation. 24 June, 2010.

Port of Kitakyushu, (2012), Statistics of Port of Kitakyushu 2012, [online], available: www.kitaqport.or.jp/eng/business/statistics2012.pdf, last accessed March 2014.

Stena Daea Line, [online], available: <http://stenadaea.com>; last accessed in January 2014.

Ulsan Port Authority, [online], available: http://www.upa.or.kr/cms/CmsAction.do?cmd=CmsView&menu_key=306&menu_id=323&HOME_SEQ=305&next=/01/305/306/315/319/40.jsp, last accessed in March 2014.

World Bank, (2013), World Bank GDP ranking 2013, [online], available: <http://data.worldbank.org/data-catalog/GDP-ranking-table>, last accessed in February 2014.

World Bank, (2013), World Bank Population (Total) 2013, [online], available: <http://data.worldbank.org/indicator/SP.POP.TOTL>, last accessed in February 2014.

World Shipping Council, (2014), Top 50 World Container Ports. [online], available: <http://www.worldshipping.org/about-the-industry/global-trade/top-50-world-container-ports>; last accessed March 2014.

WTO, (2013), International Trade Statistics 2013, [online], available: http://www.wto.org/english/res_e/statis_e/its2013_e/its13_toc_e.htm, last accessed in January 2014.

WTO, (2014), International trade statistics 2012, [online], available: http://www.wto.org/english/res_e/statis_e/its2012_e/its12_appendix_e.htm, last accessed March 2014.

Production Strategy with Green Technology Input under Cap and Trade Policy

Zhenyu Luo^{1*}, ChangSong Ma², Jialu Pan³ and Yun Cao⁴

¹Logistics Research Institute, Tian Fu College of Southwestern University of Finance and Economics, MianYang, Sichuan, 621000, China. Email: fancy_one@hotmail.com.

²School of Management and Economics, University of Electronic Science and Technology of China, ChengDu, SiChuan, 610054, China. Email: uestc-vip@163.com.

³Logistics Research Institute, Tian Fu College of Southwestern University of Finance and Economics, MianYang, Sichuan, 621000, China. Email: pan678910@hotmail.com.

⁴English Teaching and Research Department, Tian Fu College of Southwestern University of Finance and Economics, ChengDu, SiChuan, 610000, China. Email: 14aspirin@sina.com.

**Corresponding author*

Abstract

With the cap and trade policy, this paper aims to make a study of production strategy from the perspective of the manufacturer. It will enable enterprise to make a maximum profit and reduce the carbon emissions capacity at the same time through constructing the production model including green technology input. The following conclusion can be drawn: (1) Under cap and trade policy, the manufacture's optimal production quantity is lower than the case without carbon emission constraint. The expected profit of manufacture mainly depends on the initial carbon emission allowance required by government. (2) The manufacture could improve the production quantity and expected profit through green technology input under cap and trade policy.

Keywords: Cap-and-trade Green technology input Production strategy.

1. Introduction

We can't deny the truth that global warming brought severe challenge for the survival and development of human beings. The IPCC fourth assessment of data since 1970 has shown that it is likely that anthropogenic (human made) warming has had a discernible influence on many physical and biological systems. Transforming the way of social production and living has become a strategic means which could cope with weather safety problem. Cap and trade policy was established by the Clean Development Mechanism (CDM) after Kyoto Protocol. It makes carbon emissions rights be regarded as a scarce resource and aims to play the initiative on reducing global greenhouse carbon emission by building the mechanism of market selection.

Since 1950's, academic circles has made a widely and deeply research on production strategy and has obtained abundant achievements. The main target of manufacture is to achieve the certain customer service level at the lowest total cost, however, ignoring the carbon emission in their operations activities. In practice, a great number of governments have implemented cap and trade policy to reduce carbon emission. The manufactures must face the necessary restriction in production and management. Thus, more and more technological innovation has been invented and adopted for some production firms in order to reduce the adverse effect on producing pollution to the environment. Therefore, this paper aims at making a study of optimal production policies, which enables enterprise to make maximum profit, at the meantime to reduce the carbon emissions from the perspective of the manufacturer.

2. Literature Review

More and more technological innovation has been invented and adopted in the United States and European Union in order to reduce the adverse effect on the environment. We first now review major literature on green technology. Brawn and Wield (1994) at the earliest put forward the concept of green technology when the

environmental pollution appears, and they thought that green technology is an external method, which could reduce ecological environment pollution. Yu (2007) pointed out that the implementation of green technology could significantly improve the industrial performance, at the same time substantially increase the productivity. Along with the continued global warming, the green technology has become an important part in operation of corporate. The focus of this issue is known to be expanding beyond macroscopic field. He (2007) agreed that carbon emission allowance has become an important enterprise resource, and the function of green technology should be in conformity with reality. Through the introduction of CR&D cost function in cap and trade case, he optimized the green technology input strategy. Du (2009) discussed how to establish an enterprise production model from the point of pollution governance after analyzing the characteristics of governance cost, and showed the effectiveness of the green technology input. Li (2012) established manufacturer's green technology input strategy model under the technical uncertainty condition and obtained the best timing and value function of green technology input.

Now we review the literature about production strategy research under cap and trade policy. Carbon emissions related issues have been attracting scholars' attention since the middle of 1990s. Song (2011) considered the classical single-period problem. He got a conclusion that the firm's optimal quantity and expected profit under cap and trade policy is always higher than that with carbon emissions constraint. Laffont and Tirole (1996) studied the earliest production strategy in the cap and trade situation. The conclusion that carbon trading mechanism can effectively reduce the pollution considering two-stage production model is obtained. Dobos (2007) researched the influence of carbon emission allowance trading by the Arrow-Karlin model. Hong (2012) studied the production planning model for suppliers to determine their emission allowances and emission trading strategies. Chaabane (2012) considered a sustainable supply chain model under the emission trading scheme in the aluminum production industry. They demonstrated that emission trading scheme should be enhanced and sustainability of a supply chain can be achieved in a cost-effective manner with the presence of efficient carbon management strategies. The cap-and-trade policy has been claimed to be useful in controlling air emission. Many researchers have attempted in investigating the effectiveness of the policy, as well as examining the application of such policy to supply chain networks. Benjaafa is one of the earliest scholars focusing on enterprise operation strategy under carbon emission reduction policy. Benjaafa (2012) took carbon emission constraint factor into supply chain system and studied how the carbon emission constraint is considered to the operational decision making model. Benjaafar, Li and Daskin (2013) on the basis of the Benjaafar (2012) designed effective production planning and inventory management strategy for corporate. The conclusion that green technology is appropriate to increase the profits is obtained.

3. Problem Description and Assumption

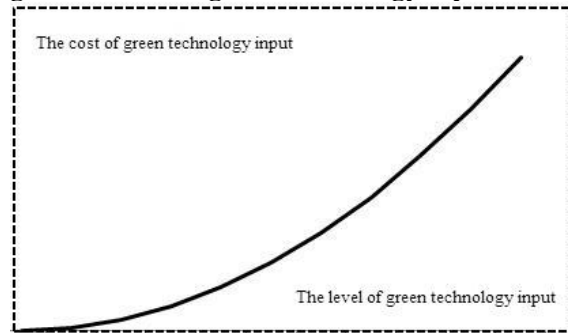
There exists a monopolistic manufacturer which offers a number of products to customers in a market. The customer market demand is random. Under cap and trade policy, the government set a mandatory standard K and the firm could trade carbon emission allowance in the market. Firm's carbon emissions capacity in production activities cannot exceed the mandatory standard K made by government. There is a salvage value per unit of unsold product when the sales cycle ends. In addition, a list of major notations used in this paper is given as follow:

- $f(\cdot)$ —probability density function of random demand
- $F(\cdot)$ —distribution function of random demand
- Q —product output
- p —unit retail selling price of product
- c —unit cost of production of each
- v —unit salvage value to keep a unit of product till the end of the period
- r —unit opportunity loss if there is a shortage of a unit of product
- K —government's initial carbon emission allowances
- k —unit carbon emission of product
- T —green technology input level, $0 \leq T \leq 1$
- E —carbon trading volume in the production process
- ω —unit price of carbon emission trading with outside market

In this paper, the parameters must satisfy certain conditions for the model to make sense, so we assume:

- (1) $p \geq c > v > 0$, This condition states there is a positive profit for each product if a unit of item is sold to consumer market. On the other hand, the salvage value is less than the produce cost. There is a loss if an item is unsold. The condition gives sufficient positive incentive to produce along with a negative penalty if over-stocked.
- (2) $r = p - c$, this condition represents the unit underage cost equals the profit of each unit.
- (3) In this paper, the firm might obtain emission allowance through input of green technology. The characteristic of green technology cost $C(T)$ was increasing rapidly with the level of the green technology T because of marginal diminishing effect. $C(T)$ is continuously differentiable and they satisfy $C'(T) > 0$, $C''(T) > 0$.

Fig 1. The green technology input function



4. Modeling

In this section, we separately study the optimal expected profit and production quantity in cap and trade situation, green technology input situation and constraint situation. Comparison and analysis in the three situations are obtained.

4.1 CASE 1: The Production Strategy of Non-constrained

There is a random demand in customers market. Using the above notations and assumptions, we derive the manufacturer's expected profit without carbon emission constraint as follow:

$$\pi^n(Q) = (p - v) \int_0^Q xf(x) dx - (c - v) \int_0^Q Qf(x)dx + (p + r - c) \int_Q^\infty Qf(x) dx - r \quad (1)$$

We obtain the derivatives of function $\pi(Q)$ with respect Q :

$$\frac{d\pi^n(Q)}{dQ} = (v - p - r)F(Q) + p + r - c \quad (2)$$

Let $\frac{d\pi^n(Q)}{dQ}$ equal to zero, we get, $Q^* = F^{-1}\left(\frac{p+r-c}{p+r-v}\right)$

4.2 CASE 2: The Production Strategy under Cap and Trade Situation

In this situation, firm's carbon emissions capacity in production activities cannot exceed the mandatory standard K made by government. But, the firm could trade carbon emission allowance on the market. Define E as the carbon emission trading quantity in the external market. When $E > 0$, it implies that manufacture will buy carbon emission allowance from the external markets. When $E = 0$, it implies that manufacture will neither buy nor sell any carbon emission allowance in the external markets. When $E < 0$, it implies that manufacture will sell the carbon emission allowance it can't use up in the external market. Then, we could get the expected profit function under cap and trade policy as:

$$\pi^a(Q) = \pi(Q) - \omega E \quad (3)$$

$$s.t \quad kQ = K + E \quad (4)$$

$kQ = K + E$ represents that carbon emission of enterprises must be equal to the initial carbon emission allowance required by government and exchange quantity in external market.

Define $\theta(Q) = \frac{1}{k} \frac{d\pi(Q)}{dQ}$ as the manufacture's profit gained from unit carbon emission.

Proposition 1: There exists an optimal product policies for product and satisfy $(Q_1^*) =$.

Proof: From the equation (4), $E = kQ - K$ is obtained. Then, the expected profit of the manufacture is:

$$\begin{aligned} \pi^a(Q) = & (p - v) \int_0^Q xf(x) dx - (c - v) \int_0^Q Qf(x)dx + (p + r - c) \int_Q^{\infty} Qf(x) dx - r \int_Q^{\infty} xf(x) dx \\ & - \omega(kQ - K) \end{aligned}$$

We obtain the derivatives of function $\pi^a(Q)$ with respect Q : $\frac{d\pi^a(Q)}{dQ} = (v - p - r)F(Q) + p + r - c - \omega k$

We have the following second-order derivatives, $\frac{d^2\pi^a(Q)}{dQ^2} = (v - p - r)f(Q) < 0$. Therefore, $\pi^a(Q)$ is a concave function of Q . Let $\frac{d\pi^a(Q)}{dQ}$ equal to zero, we get $(v - p - r)F(Q) + p + r - c - \omega k = 0$, therefore, $\theta(Q_1^*) = \omega$ can be obtained. This completes the proof.

Proposition 2 indicates that there exists an optimal production strategy under cap and trade policy. The equilibrium condition $\theta(Q_1^*) = \omega$ states that the unit marginal carbon emission profit must equal to unit price of carbon emission trading. On the other hand, if $\theta(Q_1^*) > \omega$, the marginal profit of producing one more unit of product is higher than the cost in purchasing one unit of carbon emission allowances. The manufacture will buy carbon emission allowance to produce more product. If $\theta(Q_1^*) < \omega$, the unit price of one unit of allowance is larger than the marginal profit of producing one more unit of product. The manufacture will sell carbon emission allowances to the outside market. Therefore, the manufacture achieves the equilibrium solution when $\theta(Q_1^*) = \omega$.

Denote the maximum expected profit of the manufacture under cap and trade policy as:

$$\pi^a(Q_1^*) = \pi^n(Q_1^*) - w(kQ_1^* - K) \quad (5)$$

Proposition 2: $Q_1^* \leq Q^*$

Proof: We obtain the derivatives of function $\theta(Q)$ with respect Q :

$$\frac{d\theta(Q)}{dQ} = \frac{1}{k}(v - p - r)F_1(Q_1) + p + r - c < v - c - \omega k < 0$$

So, $\theta(Q)$ decreases in Q . From proposition 1 and equation (2), we get $\theta(Q^*) = 0$ and $\theta(Q_2) = \omega$. Hence, $Q^* > Q_1^*$. This completes the proof.

The proposition 2 means that with cap and trade policy, the manufacture's optimal production quantities is lower than the case without carbon emission constraint.

In order to discuss the impact on the expected profit under carbon cap and trade policy, we get the following propositions:

Proposition 3: When $K^* = kQ_1^* + \frac{1}{\omega}[\pi^n(Q^*) - \pi^n(Q_1^*)]$,

- (1) If $K > K^*$, then $\pi^a(Q_1^*) > \pi^n(Q^*)$
- (2) If $K = K^*$, then $\pi^a(Q_1^*) = \pi^n(Q^*)$
- (3) If $K < K^*$, then $\pi^n(Q^*) > \pi^a(Q_1^*)$

Proof: If $K \leq kQ_1^*$, we get $\pi^a(Q_1^*) = \pi^n(Q_1^*) - w(kQ_1^* - K) \leq \pi^n(Q_1^*) < \pi^n(Q^*)$ from equation (5). So, $\pi^a(Q_1^*) < \pi^n(Q^*)$. If $K \geq kQ^*$, $\pi^a(Q_1^*) > \pi^n(Q^*) - w(kQ^* - K) > \pi^n(Q^*)$ is obtained. So, $\pi^a(Q_1^*) > \pi^n(Q^*)$. Therefore, there must exist a $K^* \in (kQ_1^*, kQ^*)$ and satisfies $\pi^a(Q_1^*) = \pi^n(Q^*)$ according to intermediate value theorem. In this situation, $K^* = kQ_1^* + \frac{1}{\omega} [\pi^n(Q^*) - \pi^n(Q_2^*)]$.

Because $\pi^a(Q)$ is increasing on K . So, (1) if $K > K^*$, then $\pi^a(Q_1^*) > \pi^n(Q^*)$; (2) If $K = K^*$, then $\pi^a(Q_1^*) = \pi^n(Q^*)$; (3) If $K < K^*$, $\pi^a(Q_1^*) < \pi^n(Q^*)$. This completes the proof.

Proposition 3 shows that the manufacture could increase its expected profit by purchasing or selling the carbon emission trading allowance in market. The other hand, the expected profit of manufacture mainly depends on the initial carbon emission allowance required by government.

4.3 CASE 3: Considering Green Technology The Production Strategy under Cap and Trade Policy

Under cap and trade policy, more and more technological innovation has been invented and adopted for reducing the adverse effect on producing pollution to the environment. Therefore,

Denote T as the level of green technology input. The expected profit of enterprise is:

$$\pi^b(Q, T) = (p - v) \int_0^Q xf(x) dx - (c + c(T) - v) \int_0^Q Qf(x) dx + [p + r - c - c(T)] \int_Q Qf(x) dx - r \int_Q xf(x) dx - \omega E \quad (6)$$

$$s.t \quad (1 - T) kQ = K + E \quad (7)$$

Constraint condition means that the total carbon emission with green technology input must be equal to the initial carbon emission allowance required by government and carbon emission trading quantity. The following propositions are obtained.

Proposition 4: There exists an unique optimal production policy maximizing manufacturer's expected profit and satisfy $\theta(Q_2^*) = (1 - T)\omega$.

Proof: We get $E = (k - T)Q - K$ from equation (7) and the expected profit of manufacturer in this case is:

$$\begin{aligned} \pi^b(Q, T) &= (p - v) \int_0^Q xf(x) dx - (c + c(T) - v) \int_0^Q Qf(x) dx + [p + r - c - c(T)] \int_Q Qf(x) dx \\ &\quad - r \int_Q xf(x) dx - \omega[(1 - T)kQ - K] \end{aligned}$$

Using Leibniz's rule for differentiating integrals, we obtain:

$$\frac{\partial \pi^b(Q, T)}{\partial Q} = (v - p - r)F(Q) + p + r - c - c(T) - \omega k(1 - T)$$

$$\frac{\partial \pi^b(Q, T)}{\partial T} = -c(T) - \omega kQ$$

$$\frac{\partial^2 \pi^b(Q, T)}{\partial Q^2} = (v - p - r)f(Q) < 0$$

$$\frac{\partial^2 \pi^b(Q, T)}{\partial T^2} = -c'(T) < 0$$

$$\frac{\partial^2 \pi^b(Q, T)}{\partial Q \partial T} = -c'(T) - \omega k < 0$$

$$\frac{\partial^2 \pi^b(Q, T)}{\partial T \partial Q} = -\omega k < 0$$

We can show that

$$\begin{vmatrix} \frac{\partial^2 \pi^b(Q, T)}{\partial Q^2} & \frac{\partial^2 \pi^c(Q, T)}{\partial Q \partial T} \\ \frac{\partial^2 \pi^b(Q, T)}{\partial T \partial Q} & \frac{\partial^2 \pi^b(Q, T)}{\partial T^2} \end{vmatrix} > 0$$

Let $\frac{\partial \pi^b(Q, T)}{\partial Q}$ equals zero, $(v - p - r)F(Q) + p + r - c - c(T) - \omega k(1 - T) = 0$ is obtained. Hence, $\theta(Q_2^*) = (1 - T)\omega$. This completes the proof.

Proposition 4 indicates that the marginal profit of producing one more unit of product is higher than the cost $(1 - T)\omega$, the manufacture will buy carbon emission allowances from the outside market to gain more profit. On the other hand, the unit price of one unit of allowance is less than $(1 - T)\omega$, the manufacture will sell carbon emission allowances to the outside market. Therefore, only when $(1 - T)\omega$, the manufacture will not produce one more unit of product and the manufacture's decision achieves the equilibrium solution.

Below we discuss the effect of green technology on the manufacture's production decision, and the following proposition is obtained.

Proposition 5: $Q_1^* \leq Q_2^* < Q^*$

Proof: Because $\theta(Q)$ decreases on Q . From proposition 4 and equation (2), we get $\theta(Q^*) = 0, \theta(Q_2^*) = \omega, \theta(Q_3^*) = (1 - T)\omega$. Therefore, $Q_1^* \leq Q_2^* < Q^*$. This completes the proof.

Proposition 5 indicates that the optimal quantity with green technology under cap and trade policy could not exceed that without carbon emission constraint. But, It means manufacturer could increase the quantity through input of green technology.

Considering green technology input, the manufacture's maximum profit under cap and trade policy is,

$$\pi^b(Q_2^*, T) = \pi^n(Q_2^*) - \omega[(1 - T)kQ_2^* - K] - c(T) \quad (8)$$

To discuss the impact on green technology input to manufacture's expected profit, we get the following propositions:

Proposition 6: $\pi^b(Q_2^*) \geq \pi^a(Q_1^*)$.

Proof: We get $\pi^b(Q_2^*, T) - \pi^a(Q_1^*) = \pi^n(Q_2^*) - \pi^n(Q_1^*) - c(T) - \omega k[Q_1^* - (1 - T)Q_2^*]$ from equation (8)–equation(5). If $T = 0, \pi^b(Q_2^*, 0) - \pi^a(Q_1^*) = \pi^n(Q_2^*) - \pi^n(Q_1^*) - c(T) - \omega k[Q_1^* - (1 - T)Q_2^*] = 0$.

- (1) When $\pi^n(Q_2^*) - \pi^n(Q_1^*) - c(T) > \omega k[Q_1^* - (1 - T)Q_2^*]$, $\pi^b(Q_2^*, T) > \pi^a(Q_1^*) = \pi^c(Q_2^*, 0)$ is obtained. In this case, green technology input could improve manufacturer's expected profit under cap and trade policy.
- (2) When $\pi^n(Q_2^*) - \pi^n(Q_1^*) - c(T) = \omega k[Q_1^* - (1 - T)Q_2^*]$, $\pi^b(Q_2^*, T) = \pi^a(Q_1^*) = \pi^b(Q_2^*, 0)$ is obtained. In this case, green technology input could not improve manufacturer's expected profit under cap and trade policy. Hence, Manufacturer should give green technology up rationally.
- (3) When $\pi^n(Q_2^*) - \pi^n(Q_1^*) - c(T) < \omega k[Q_1^* - (1 - T)Q_2^*]$, $\pi^b(Q_2^*, T) < \pi^a(Q_1^*) = \pi^b(Q_2^*, 0)$ is obtained. In this case, green technology input will decrease manufacturer's expected profit under cap and trade policy. Manufacturer should give green technology up rationally. Hence, $\pi^b(Q_2^*, T) = \pi^a(Q_1^*)$. Therefore, $\pi^b(Q_2^*) \geq \pi^a(Q_1^*)$, this completes the proof.

Proposition 6 indicates that the manufacture could improve the expected profit through green technology input,

but the expected profit in this case is higher than that under cap and trade.

5. Conclusion

In this paper, a production planning model is considered. Under cap and trade policy, the manufacture's optimal production quantity is lower than the case without carbon emission constraint. The expected profit of manufacture mainly depends on the initial carbon emission allowance required by government. To cope with the increasing awareness of environmental protection, some governments have imposed policies to control the amount of pollution created by each firm. Hence, firms are required to apply some green technologies to their productions to produce "greener" products. The manufacture could improve the production quantity and expected profit through green technology input under cap and trade policy.

The results presented in this paper can be applied to most industries with various probability density functions of demands and the optimality is easily obtained as the solution is expressed analytically. More importantly, the proposed cap-and-trade model is widely acceptable to all practitioners as the results are complied with the general economics concept. For future research direction, the assumption of constant maximum emission K will be relaxed.

Reference

- IPCC. Climate Change (2007), The third assessment report of the intergovernmental panel on climate change, London: Cambridge University Press, pp.45-50.
- Cai-Mao, S.U. and Ke, Y.L. (2006), Task planning and decoupling strategy for collaborative design. *Computer Integrated Manufacturing Systems* 12(1), 22-26.
- Feng, Z.J. and Niu, W.J. (2009), Low-carbon economy and scientific outlook on development. *China Soft Science* 9(8): 13-20.
- Brawn, E. and Wield, D. (1994), Regulation as a means for the social control of technology, *Technology Analysis and Strategic Management* 6(3): 259-273.
- Yu, S.J. (2007), Research on the conception and classification of green technology, *Journal of Wuhan Institute of Technology*, *Journal of Wuhan Institute of Technology*, 2(9):40-42.
- He, D.Y. and Ma, H.Y. (2011), Strategy of enterprise production and store under constraints of carbon emission, *Resources Industries* 13(4): 64-68.
- Du, S.P. and Dong, J.F. (2009), Optimal production policy with emission permits and trading, *Chinese Journal of Management Science* 17(3): 81-86.
- Zhao, D.Z. and Lv, J.X. (2012), Carbon-efficient strategy for integrated supply chain considering carbon emission right and trading, *Industrial Engineering and Management* 17(5): 65-71.
- Letmathe, P. and Balakrishnan, N. (2005), Environmental consideration on the optimal product mix, *European Journal of Operational Research* 167(2): 398-412.
- Song, J. and M, L. (2012), Analysis of the single-period problem under carbon emissions policies, *International Series in Operations Research & Management Science* 176(2): 297-313.
- Laffont, J., Tirole, J. (1996), Pollution permits and compliance strategies. *Journal of Public Economics* 62(1-2): 85-125.
- Dobos, I. (2005), The effects of emission trading on production and inventories in the Arrow-Karlin model, *International Journal of Production Economics* 93-94(8): 301-308.
- Hong, Z., Chu, C. and Yu, Y. (2012), Optimization of production planning for green manufacturing, 9th IEEE International Conference on Networking, Sensing and Control (ICNSC), April 11-14, 2012, Paris, France 193-196.
- Chaabane, A., A. Ramudhin, and M. Paquet. (2012), Design of sustainable supply chains under the emission trading scheme, *International Journal of Production Economics* 135(1): 37-49.
- Benjaafar, S., and Mohsen, E. A. (2012), Production-inventory system with both patient and impatient demand classes, *Transactions on Automation Science and Engineering* 9(1): 148-159.
- Benjaafar, S., Y. Z. Li, and M. Daskin. (2013), Carbon footprint and the management of supply chains: insights from simple models, *Transactions on Automation Science and Engineering* 10(1):99-115.

Supply Chain Network Optimization with Piecewise Linear Cost Function of CO₂ Emissions

A-Young Choi, Joon-Ho Na and Jian-Hua Ji

Antai College of Economics & Management, Shanghai Jiao Tong University, Shanghai

Abstract

Mitigation of climate change and reducing carbon emissions has received more concerns in many countries, and carbon pricing method is recognized as an efficient and economic instrument to achieve mitigation target. In this paper we develop to a new optimization model for green supply chain network considering with carbon emissions, and investigates carbon mitigation policies in supply chain network optimization problem, such as carbon tax. Especially, this carbon tax model is extended to non-linear situation; we consider progressive carbon tax to be assumed that is levied at different rate according to the amount of carbon emissions. The proposed model can be formulated as mixed-integer programming, and to optimize this piecewise cost function, we addressed a linearization method using SOS1 and SOS2 variables techniques. A numerical example is addressed to verify optimization model.

Keywords: supply chain network, progressive carbon tax, carbon emissions, piecewise linear cost, mixed-integer programming

1. Introduction

Climate change increasingly becomes a global concern, an awareness of environmental problem is more important to cope with future sustainable development. Green House Gases significantly contribute to global warming effect, especially Carbon dioxide is recognized as a major GHGs emitted to a atmosphere. The Intergovernmental Panel on Climate Change (IPCC) indicates that global carbon emission is needed to achieve reduction target of reducing 50% by 2050. (Parry et al., 2007). Therefore, many mitigation instruments are investigated by many researchers and policy makers in government to encourage a development of low-carbon economy.

In recent years, many researches related on sustainable and green supply chain management, as green production, recovery, reusing and remanufacturing of the used production increasingly focus on balance economic and environmental objective.

Under the low carbon economy concept, environmental problem has been increasingly integrated into supply chain network to cope with future competitive pressure. Most papers make great effort on evaluating related environmental topics and take into account on existing supply chain network problem. (Halldórsson, 2010; Sundarakani, B. et al., 2010; Benjaafar, S. et al, 2012).

Government policies and legislation have significant impacts on activities in supply chain network, including tactical decisions such as production, warehousing, distribution, packing and strategic decisions such as network design. Carbon tax and cap-and-trade mechanism are recognized as most efficient market instrument to control carbon emissions. So many researches have attempted to take these instruments account into traditional supply chain area. (Chaabane, A. et al, 2012; Diabat, Ali et al, 2009; Flachsland, C. et al, 2011)

According to Hepburn, C(2006), carbon pricing is more cost-efficient and controllable mitigation measure as a market instrument. And this policy has an important role of decision related with green supply chain.

In carbon taxation scheme, many papers consider carbon emission cost and tax scheme as linear form, which could not sufficiently control and penalize on heavy-emitters. Benjaafar et al. (2012) propose various

formulations related on green supply chain and alternative tax scheme, such as tax penalties are non-linear according to amounts of emissions. Tax scheme can be designed as non-linear and progressive, it is possible to establish another carbon tax scheme with piece-wise function that penalty according to their amounts emitted.

This paper will explore the way to formulate supply chain network problem, considering progressive carbon tax mechanism. Mathematical optimization model is proposed for decision making under carbon policy. The most noticeable contribution of this paper is that 1) present green supply chain network model with different carbon mitigation policy 2) address piecewise linear cost functions of carbon tax in optimization model.

The remainder of paper is organized as follows. In section 2, reviews the related works. In section 3, present the mathematical optimization model of supply chain network with carbon mitigation policies, and investigate the piecewise linear cost function of carbon tax. Finally, we make some discussions for solution approach in section 4 and address some implications and provide suggestions for future research in section 5.

2. Literature Review

This chapter provides an comprehensive review of previous work, and related researches can be divided into three categories: 1) supply chain network optimization, especially green and low carbon supply chain network design, 2) carbon mitigation policy such as carbon tax, cap and trade in supply chain network problem, 3) piecewise linear function and optimization problem, in order to investigate aggressive carbon tax model, this paper review related work in piecewise linear optimization.

There is a large amount of literature on supply chain network concerned with environmental topics through the green supply chain network. Related researches are started with Benjaafar et al. (2010) that made a great contribution in green supply chain network field.

Before Benjaafar et al.(2010) , Beamon (1999) described the current state of the natural environments, investigated the environmental factors and presented performance measures from the green supply chain and developed a general procedure. Diabat, A. et al.(2010) proposed a model of supply chain design considering carbon policy. Ramudhin et al. (2010) developed a decision model of green supply chain network under emission regulations.

Most work on carbon mitigation policy is related with carbon tax and cap-and-trade mechanism. And some literature attempted to compare the mitigation impacts on supply chain. In supply chain network design, most papers are focused on transportation mode selection and facility location. Hoen et al. (2010) explored the impacts of two carbon policies such as carbon tax and cap-and-trade on transportation mode selection. Piattelli et al. (2002) proposed a mathematical model under carbon tax policy.

There is a large amount of research to investigate carbon mitigation policies in macroeconomic research field. Sumner, J. et al.(2011) provided a comprehensive review of carbon tax considering policy design and implementation. Hepburn, C (2006) provided a review and comparison study of regulations by quantity and price. Subramanian, R. et al (2007) evaluate compliance strategies under different carbon policy.

Benjaafar, Saif et al. (2012) presented some research topics related operation model considering carbon emission, this paper proposed another carbon tax scheme, such as non-linear carbon tax. Piecewise linear cost functions is mainly used on transportation cost, which is modeled by price discount according to quantity of transportation. Tsiakis, P. et al. (2001) Ventura, José A et al. (2013) provided a multi-period inventory lot-sizing model for a single product in a serial supply chain considering piecewise transportation cost function.

3. Problem Description

This paper derive green supply chain network model, mainly focus on facility location and transportation problem. Let consider 3 stage supply chain network with supplier, DC, customers.

In this general model, we assume that,

- 1) Facility set up cost and transportation cost is all known
- 2) All customer demands are met.
- 3) Consider three different types of transportation mode
- 4) Consider different low carbon technologies of facility and assume that facility set-up cost is inverse proportional to low carbon technology, which means more low carbon tech, need higher set up cost of facility.

We develop the optimization model that select facility location and the amount of transportation using different transportation mode under carbon constraint to meet their carbon mitigation target. Then carbon tax model is extended to non-linear cost functions that are expressed as piecewise linear cost functions, and investigate that how aggressive carbon tax scheme have an influence on supply chain network decisions.

3.1 Notation and variables

In this model, following notation is used.

Index :

I : the sets of suppliers
 J : the sets of DCs
 K : the sets of customers
 T : the sets of transportation modes
 L : the sets of low carbon technology levels

Parameters:

SC_{jl} : set-up cost of DC j in low carbon technology level l
 $TC1_{ijt}$: unit cost of transportation from plant i to DC j using transportation mode t
 $TC2_{jkt}$: unit cost of transportation from DC j to customer k using transportation mode t
 TH_{jl} : unit throughput cost of DC j in a low carbon technology level l
 a_i : maximum producing capacity at plant i
 b_j : maximum throughput capacity at DC j
 d_k : amount of demand at customer k
 L_{ij}^1 : distance between plant i and DC j
 L_{jk}^2 : distance between DC j and customer k
 Q : maximum available numbers of construction of DC
 Cap_e : allowed emission caps in supply chain network
 α_{jl} : amount of fixed carbon emissions of DC j in low carbon technology level l
 β_t : carbon emission factor of transportation mode t
 δ_{jl} : fixed-carbon emissions of DC j in low carbon technology level l
 η_{jl} : variable carbon emissions of DC j in low carbon technology level l
 ρ : carbon tax rate

Variables :

Z_{jl} : if DC j in low carbon technology level l is selected 1, otherwise , 0.
 X_{ijt} : the amount shipped from plant i to DC j using transportation mode t

Y_{jkt} : the amount shipped from DC j to Customer k using transportation mode t

3.2 Mathematical Optimization Models

3.2.1 Basic Model

The first model is addressed without considering carbon emissions. In this model, there is no charge on carbon emission, so any carbon policy is not addressed. We consider different low carbon level SC_{jl} represent unit set-up cost of DC j in low carbon technology level l .

$$F_{basic} = \sum_{j \in J} \sum_{l \in L} SC_{jl} Z_{jl} + \sum_{i \in I} \sum_{j \in J} \sum_{t \in T} \sum_{l \in L} TH_{jl} X_{ijt} Z_{jl} + \sum_{i \in I} \sum_{j \in J} \sum_{t \in T} TC1_{ijt} L_{ij}^1 X_{ijt} + \sum_{j \in J} \sum_{k \in K} \sum_{t \in T} TC2_{jkt} L_{ij}^2 Y_{jkt} \quad (1)$$

s.t

$$\sum_j \sum_t X_{ijt} \leq a_i, \quad \forall i \quad (2)$$

$$\sum_i \sum_t X_{ijt} \leq b_j Z_j, \quad \forall j \quad (3)$$

$$\sum_i \sum_t X_{ijt} = \sum_k \sum_t Y_{ikt}, \quad \forall j \quad (4)$$

$$\sum_j \sum_t Y_{jkt} = d_k, \quad \forall k \quad (5)$$

$$\sum_j Z_j \leq Q \quad (6)$$

$$\sum_l Z_{jl} \leq 1 \quad \forall j \in J \quad (7)$$

$$Z_{jl} \in \{0,1\}, X_{ijt} \geq 0, Y_{jkt} \geq 0 \quad (8)$$

Constraint set (2) represent that amounts shipped from plant i to DC j using transportation mode t cannot exceed max producing capacity at plant i . Constraint set (3) represent that amounts shipped from plant i to DC j using transportation mode t cannot exceed max throughput at DC j . Constraint set (4) make sure flow conservation at distribution center j . Constraint set (5) represent that all customer demand are met.

Constraint set (6) represent that total amount of DC can not exceed maximum available numbers of construction of DC. Eq (1) is the objective function of proposed basic model and minimize economic cost in supply chain including fixed and variable cost of DC j in low carbon technology level l , transportation cost between plant i and DC j /between DC j and customer k using transportation mode t .

3.2.2 Carbon Tax Model (Tax rate is constant regardless of the amount carbon emissions)

In this paper, we assume that carbon emissions are derived from 2 sources.

- 1) emission associated with facility, including low carbon technologies and operations of facility. We assume that facility set up cost is different to low carbon technologies.
- 2) emission associated with transportation, assumed that different carbon emission factor of transportation mode.

So, total emissions of supply chain network from two main sources can be written as follows,

$$EQ = \sum_{j \in J} \sum_{l \in L} \alpha_{jl} Z_{jl} + \sum_{i \in I} \sum_{j \in J} \sum_{t \in T} \sum_{l \in L} \eta_{jl} X_{ijt} Z_{jl} + \sum_{i \in I} \sum_{j \in J} \sum_{t \in T} \beta_t L_{ij}^2 X_{ijt} + \sum_{i \in I} \sum_{j \in J} \sum_{t \in T} \beta_t L_{ij}^2 Y_{jkt} \quad (9)$$

According to Rameur et al(2012) and Rausch and Reilly(2012), carbon tax is regarded as one of the most powerful mitigation policy. And Chen et al (2011) investigate that levying tax on carbon procurement emission will be more influence on, inventory, production and facility size and location. So, in this model, carbon tax is used to penalize and mitigate carbon emission. We assume that carbon tax is constant and not changing according to the amount of carbon emission. Here, carbon emission cost function can be represented by Eq (10). In this model, carbon tax is constant and levied on same regardless of amounts of carbon emitted in supply chain.

$$F_{tax} = \sum_{j \in J} \sum_{l \in L} SC_{jl} Z_{jl} + \sum_{i \in I} \sum_{j \in J} \sum_{t \in T} \sum_{l \in L} TH_{jl} X_{ijt} Z_{jl} + \sum_{i \in I} \sum_{j \in J} \sum_{t \in T} TC1_{ijt} L_{ij}^1 q_{ijm} + \sum_{j \in J} \sum_{k \in K} \sum_{t \in T} TC2_{jkt} L_{ij}^2 q_{jkm} \quad (10)$$

$$+ \rho \left[\sum_{j \in J} \sum_{l \in L} \alpha_{jl} Z_{jl} + \sum_{i \in I} \sum_{j \in J} \sum_{t \in T} \sum_{l \in L} \eta_{jl} X_{ijt} Z_{jl} + \sum_{i \in I} \sum_{j \in J} \sum_{t \in T} \beta_t L_{ij}^2 X_{ijt} + \sum_{i \in I} \sum_{j \in J} \sum_{t \in T} \beta_t L_{ij}^2 Y_{jkt} \right]$$

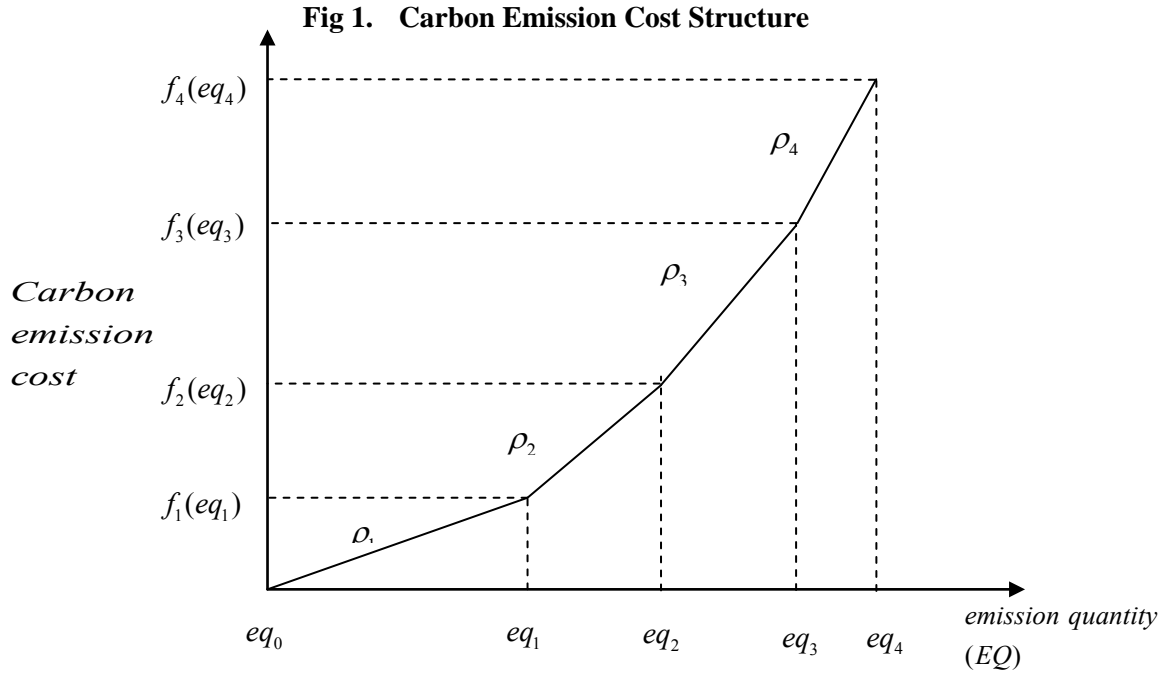
s.t

$$\sum_{j \in J} \sum_{l \in L} \alpha_{jl} Z_{jl} + \sum_{i \in I} \sum_{j \in J} \sum_{t \in T} \sum_{l \in L} \eta_{jl} X_{ijt} Z_{jl} + \sum_{i \in I} \sum_{j \in J} \sum_{t \in T} \beta_t L_{ij}^2 X_{ijt} + \sum_{i \in I} \sum_{j \in J} \sum_{t \in T} \beta_t L_{ij}^2 Y_{jkt} \leq Cap_{\varepsilon} \quad (11)$$

Subject to constraints (2) - (8) and add constraint of carbon emission Eq (11) .

δ_{jl} is fixed carbon emissions of DC j in different low carbon technology. η_{jl} represents variable carbon emission according to handling amount in DC. In this paper, we consider two types of facility of low carbon technology. We assume that introducing low carbon technology will need more set-up cost, but carbon emissions could be mitigated. (Chen, GQ et al.(2011))

3.2.3 Carbon Tax Model with Piecewise Linear Cost Function



In this model, new carbon tax model is developed. In Eq (10), carbon tax is constant and levied on same regardless of amounts of carbon emitted in supply chain. On the basis, we can extend linear cost function to non-linear piecewise cost functions. Carbon tax is levied at a different rate according to the amounts of carbon

emitted. We consider progressive carbon tax (e.g increasing convex function). Figure (1) represents the carbon emission cost structure, where carbon tax rate is $\rho_1 < \rho_2 < \rho_3 < \rho_4$.

The total carbon emission cost function can be represented as piecewise linear function in Figure (1). In this case, carbon emission cost function is not any more linear, we need another way to solve it.

$$F_i(\rho_i, eq_i) = \begin{cases} f_1 = \rho_1 eq_1 & \text{if } eq_0 \leq eq \leq eq_1 \\ f_2 = \rho_1 eq_1 + \rho_2 (eq - eq_1) & \text{if } eq_1 < eq \leq eq_2 \\ f_3 = \rho_1 eq_1 + \rho_2 (eq_2 - eq_1) + \rho_3 (eq - eq_2) & \text{if } eq_2 < eq \leq eq_3 \\ f_4 = \rho_1 eq_1 + \rho_2 (eq_2 - eq_1) + \rho_3 (eq_3 - eq_2) + \rho_4 (eq - eq_3) & \text{if } eq > eq_3 \end{cases} \quad (12)$$

According to P. Tsiakis et al (2001), In order to solve the optimization problem simplicity, we can add a new binary variable, W_r .

$$W_r = \begin{cases} 1, & \text{if } eq \in [\overline{eq}_{r-1}, \overline{eq}_r] \\ 0, & \text{otherwise} \end{cases} \quad (13)$$

In this case, we need some linear constraints.

$$eq_{r-1} W_r \leq eq_r \leq eq_r W_r, \quad \forall r \quad (14)$$

$$eq = \sum_r^{NR} eq_r \quad (15)$$

Piecewise linear cost function can rewrite as follows;

$$F(\rho, eq) = \sum_{n=1}^{NR} W_r (\rho_{r-1} \overline{eq}_{r-1}) + (eq_r - \overline{eq}_{r-1} W_r) \rho_r \quad (16)$$

$$\rho_{r-1} \overline{eq}_{r-1} = F_{r-1}$$

We can consider another way to solve piecewise linear cost function. According to Tsai, WH. et al. (2012), we can address the SOS2 variables and reformulate carbon cost functions.

This paper assume that carbon tax is regressive and total carbon cost function will be a piecewise linear. If emission is in $eq_0 \leq eq \leq eq_1$, stage 1/scenario 1 is selected, and then carbon tax will be ρ_1 . So total carbon emission cost will be $f_1 = \rho_1 eq_1$ in first emission level. If the emission is in $eq_1 \leq eq \leq eq_2$, stage 2/scenario 2 is selected, then carbon tax will be ρ_2 . So total carbon emission cost will be $f_2 = \rho_1 eq_1 + \rho_2 (eq - eq_1)$ in the second emission level. Similarly, if the emission is in $eq_2 \leq eq \leq eq_3$, total carbon emission cost can be express by $f_3 = \rho_1 eq_1 + \rho_2 (eq_2 - eq_1) + \rho_3 (eq - eq_2)$. Then, if carbon emission exceed eq_3 , namely $eq > eq_3$, total carbon emission cost can be derived as $f_4 = \rho_1 eq_1 + \rho_2 (eq_2 - eq_1) + \rho_3 (eq_3 - eq_2) + \rho_4 (eq - eq_3)$. This cost structure ensures that efficiently control and reduce carbon emission to reach mitigation target.

In this case, we can reformulate the total carbon cost function and related constraints as follows;

$$\text{Total carbon emission cost: } F(EQ) = \lambda_1 f(q_1) + \lambda_2 f(q_2) + \lambda_3 f(q_3) + \lambda_4 f(q_4) \quad (17)$$

$$\text{Total emission } EQ = \lambda_1 eq_1 + \lambda_2 eq_2 + \lambda_3 eq_3 + \lambda_4 eq_4 \quad (18)$$

$$\begin{aligned}
\lambda_0 - \gamma_1 &\leq 0 \\
\lambda_1 - \gamma_1 - \gamma_2 &\leq 0 \\
\lambda_2 - \gamma_2 - \gamma_3 &\leq 0 \\
\lambda_3 - \gamma_3 - \gamma_4 &\leq 0 \\
\lambda_4 - \gamma_4 &\leq 0 \\
\lambda_0 + \lambda_1 + \lambda_2 + \lambda_3 + \lambda_4 &= 1 \\
\gamma_1 + \gamma_2 + \gamma_3 + \gamma_4 &= 1
\end{aligned} \tag{19}$$

Where, $(\gamma_1, \gamma_2, \gamma_3, \gamma_4)$ is a set of SOS1 binary variables that certainly one variable must be non-zero; $(\lambda_0, \lambda_1, \lambda_2, \lambda_3, \lambda_4)$ is a set of SOS2 non-negative variables within which at most two adjacent variables. This technique is introduced by Beal & Tomlin (1970) and Williams (1985).

4. Numerical Example

In this section, we present numerical example. To illustrate the applicability of the mathematical formulations presented in this paper, a case study is conducted. Specifically, third-party logistics provider for parts of the car in China is used in this case study. Based on data collected, this mixed integer programming model is solved by the software LINGO and obtain the optimization solution.

A typical third party logistics company is willing to be plan and design supply chain network to provide rapidly convince for potential clients that, delivering exceptional control and service at the lowest cost. Additionally, green logistics strategies of third party logistics provider are very important to cope with new challenges in the areas of sustainable development. In this paper, we develop a supply chain network consisting of three tiers, which is supplier, distribution center, and customers. This company owns 6 distribution centers to provide spare parts logistics service for Nissan 4S stores in China. In order to simplify analysis, we consider 10 suppliers, 6 distribution centers and 11 customer locations (4S stores). And cost items as well as other data are generated randomly.

The government is going to levy carbon tax and the tax level is according to the total emissions. We divide 4 carbon tax levels according to quantity of emitted. To investigate appropriate tax rate in each level, we consider two different types of piecewise linear model. The first type of model assumes that slope of each tax level is same, which implies that tax is increasing with same degree. And the second type of model, carbon tax is increasing with increasing degree according to amount of carbon emitted.

The carbon tax rate in the first type of piece-wise model as follows: The first level of tax is 10 yuan/t for 0 to 30000 amount emitted. And the second level of tax is 20yuan/t for 30000 to 60000. The third level of tax is 30yuan/t for 60000 to 90000. Last level of tax is 40yuan above 90000.

And the carbon tax rate in the second types of piece-wise model as follows: the first level of tax is 10 same with first type of model, the second level of tax is 25, third level of tax is 50, and last level of tax is 80.

Table 1 show optimization results under different carbon tax scheme. When do not impose carbon tax in basic model, total cost is 84,943,500 yuan, total emission is 108,561 tCO_2 . In this model, we do not consider carbon emission, therefore total cost with and without carbon emissions is same result. When we impose the carbon tax as constant level, total cost increase by 88,148,433 and total cost without emission also increase by 85,015,500, but total carbon emissions significantly decrease by 104,431 tCO_2 and is cut by 3.8%. Furthermore, we investigate that carbon tax is assumed to be progressive with piecewise linear cost function. In type 1 of piecewise carbon tax model, we can see sharply increase in total cost without emission, 85,020,500yuan. But type 1 of piecewise carbon tax scheme both impact on reduction of carbon emission total

logistics cost. In other words, the adoption of type 1 piecewise carbon tax policy could be helpful to reduce both total cost and carbon emission.

Table1. Optimization result with cost and emission under different carbon tax scheme

	Basic model	Carbon tax model (constant)	Piece-wise carbon tax model (type1)	Piece-wise carbon tax model (type2)
Total cost	84,943,500	88,148,433	87,391,340	88,707,780
Total carbon emission	108,561	104,431	104,271	103,841
Total cost without emission	84,943,500	85,015,500	85,020,500	85,050,500

When the stricter regressive carbon tax scheme in type 2 model, the result represent that total emission decrease by 103,841 tCO_2 and total cost and total cost without carbon emission is increase by 88,707,780 yuan and 85,050,500 yuan. In terms of reduction of carbon emission, type 2 of piecewise carbon tax model is the best choice. But type 1 model is superior to reduction of carbon emission and total logistics cost than other carbon tax model.

5. Conclusion

This paper investigate supply chain network optimization problem concerning carbon emissions. And carbon tax is used to penalty emissions, in order to significantly control and reduce carbon emission, we introduce a new carbon tax model with piecewise linear carbon emission cost function. Linking emerging research topics such as progressive taxation concept with the basic supply chain network model under existing carbon mitigation policy will be helpful to provide a suggestion for decision-makers and policy-makers. In the future, a sensitivity analysis is needed to investigate efficient tax level, and this work also could be extended by suitable algorithm in order to solve the optimization problem. As a future work, uncertainty of carbon costs can be considered in the model, and it is needed to verify intervals in piecewise linear functions.

References

- Abdallah, Tarek et al. (2012), Green supply chains with carbon trading and environmental sourcing: Formulation and life cycle assessment, *Applied Mathematical Modelling* 36(9): 4271-4285.
- Beamon, Benita M. (1999), Designing the green supply chain, *Logistics information management* 12(4): 332-342.
- Benjaafar, Saif et al. (2012), Carbon footprint and the management of supply chains: Insights from simple models, *Automation Science and Engineering, IEEE Transactions on* 10(1): 99-116.
- Berger, Gerald et al. (2001), Ecological modernization as a basis for environmental policy: current environmental discourse and policy and the implications on environmental supply chain management, *Innovation: The European Journal of Social Science Research* 14(1): 55-72.
- Bouzemrak, Y et al. (2010), Sustainable multimodal supply chain design for recycling waterways sediments, 3rd 8th International Conference of Modeling and Simulation, MOSIM 2010: 10-12.
- Chaabane, Amin et al (2011), Trade-off model for carbon market sensitive green supply chain network design, *International Journal of Operational Research* 10(4), 416-441.
- Chaabane, Amin et al. (2012), Design of sustainable supply chains under the emission trading scheme, *International Journal of Production Economics* 135(1): 37-49.
- Chen, GQ et al. (2011), Low-carbon building assessment and multi-scale input-output analysis, *Communications in Nonlinear Science and Numerical Simulation* 16(1): 583-595
- Dekker, Rommert et al. (2012), Operations Research for green logistics—an overview of aspects, issues, contributions and challenges, *European Journal of Operational Research* 219(3): 671-679.
- Diabat, Ali et al. (2009), A carbon-capped supply chain network problem, *Industrial Engineering and Engineering Management, IEEM 2009 International Conference*, 523-527.
- Dissou, Yazid, et al. (2014), Can carbon taxes be progressive?, *Energy Economics* 42 : 88-100.
- Flachsland, C. et al. (2011), Climate policies for road transport revisited (II): Closing the policy gap with cap-and-trade, *Energy policy* 39(4) : 2100-2110.
- Gupta, Sudheer et al. (2011), Sustainable supply chain management: review and research opportunities, *IIMB*

- Management Review 23(4), 234-245.
- Gunnerud, Vidar et al. (2010), Oil production optimization—a piecewise linear model, solved with two decomposition strategies, *Computers & Chemical Engineering* 34(11): 1803-1812
- Halldórsson, Árni et al. (2010), The sustainable agenda and energy efficiency: Logistics solutions and supply chains in times of climate change, *International Journal of Physical Distribution and Logistics Management* 40(1/2): 5-13.
- Hepburn, C. (2006), Regulation by prices, quantities, or both: a review of instrument choice, *Oxford Review of Economic Policy* 22(2): 226-247.
- Ketabi, S., (2006), Network optimization with piecewise linear convex costs, *Iranian Journal of Science and Technology*, 30(A3): 315-323.
- Lin, Ming-Hua et al. (2013), A review of piecewise linearization methods, *Mathematical Problems in Engineering* 2013: 1-8.
- Lu, Ye et al. (2014), Inventory control with a fixed cost and a piece-wise linear convex cost, *Production and Operations Management*, in press, accepted.
- Niroomand, Iman (2008), Modeling and analysis of the generalized warehouse location problem with staircase costs, Concordia University.
- Parry, I. W. et al. (2007), Emissions trading versus CO₂ taxes. Washington, DC: Resources for the Future, 1.
- Parry, Martin L. (2007), Climate change 2007: impacts, adaptation and vulnerability: contribution of Working Group II to the fourth assessment report of the Intergovernmental Panel on Climate Change, Cambridge University Press vol. 4.
- Piattelli, M.L., Cuneo, M.A., Bianchi, N.P., Soncin, G., 2002, The control of goods transportation growth by modal share re-planning: the role of a carbon tax, *System Dynamics Review* 18, 47-69.
- Ramudhin, Amar et al. (2008), Carbon market sensitive green supply chain network design, *Industrial Engineering and Engineering Management*, 2008. IEEM 2008. IEEE International Conference, 1093-1097.
- Ramudhin, Amar et al. (2010), Carbon market sensitive sustainable supply chain network design, *International Journal of Management Science and Engineering Management* 5(1): 30-38.
- Sadegheih, A. (2011), Optimal design methodologies under the carbon emission trading program using MIP, GA, SA, and TS, *Renewable and Sustainable Energy Reviews* 15(1): 504-513.
- Sadegheih, A et al. (2011), Global supply chain management under the carbon emission trading program using mixed integer programming and genetic algorithm, *International Journal of Engineering, Transactions B: Applications* 24(1) : 37-53.
- Sarkis, Joseph (2003), A strategic decision framework for green supply chain management, *Journal of cleaner production* 11(4): 397-409.
- Song, Haiqing et al. (2011), The capacity acquisition and disposal problem with carbon emission cost, *Service Systems and Service Management (ICSSSM)*, 2011 8th International Conference: 1-5.
- Sorrell, Steven et al. (2003). Carbon trading in the policy mix, *Oxford Review of Economic Policy* 19(3): 420-437.
- Subramanian, Ravi et al. (2007), Compliance strategies under permits for emissions, *Production and Operations Management* 16(6): 763-779.
- Sumner, Jenny et al. (2011), Carbon taxes: a review of experience and policy design considerations, *Climate Policy* 11(2): 922-943.
- Sundarakani, Balan et al. (2010), Modeling carbon footprints across the supply chain, *International Journal of Production Economics* 128(1):43-50.
- Tsai, Jung-Fa. (2007), An optimization approach for supply chain management models with quantity discount policy, *European Journal of Operational Research* 177(2): 982-994.
- Tsai, Wen-Hsien et al. (2012), Applying a mathematical programming approach for a green product mix decision, *International Journal of Production Research* 50(4): 1171-1184.
- Tsiakis, Panagiotis et al. (2001), Design of multi-echelon supply chain networks under demand uncertainty, *Industrial and Engineering Chemistry Research* 40(16): 3585-3604.
- Ventura, José A et al. (2013), A dynamic inventory model with supplier selection in a serial supply chain structure, *European Journal of Operational Research* 230(2): 258-271.
- Wollenweber, Jens. (2008), A multi-stage facility location problem with staircase costs and splitting of commodities: model, heuristic approach and application, *OR Spectrum* 30(4): 655-673.
- Wu H, Dunn S. (1995), Environmentally responsible logistics systems, *International Journal of Physical Distribution and Logistics Management* 25(2): 20-38.

Under the Carbon Emissions and Cap-and-Trade Manufacturers Pricing Strategy Research

Changsong Ma^{*1,2}, Yinfeng Du², Zhenrui Wu³, Linlin Huang⁴ and Ying Luo⁵

¹School of Management and Economics, University of Electronic Science and Technology of China, ChengDu, SiChuan, 610000, China. Email: uestc-vip@163.com, Tel: 13880964116.

²Logistics Research Institute, Tian Fu College of Southwestern University of Finance and Economics, MianYang, Sichuan, 6210000, China. Email: dfy920112@gmail.com, Tel: 15528500530.

³Logistics Research Institute, Tian Fu College of Southwestern University of Finance and Economics, MianYang, Sichuan, 6210000, China. Email:zoewu778@gmail.com, Tel: 18381656769.

** Corresponding author*

Abstract

This paper researches on pricing strategy for manufacturers when the demand is certain or not under the policies of the Mandatory carbon emissions and cap-trade. With the certain demand, this paper provides guidance on pricing by using EOQ model and supply function; with the uncertain demand, it uses newsvendor model and demand function to help pricing. Through sensitivity analysis, studies the demand-price elasticity coefficient and output's respectively impact on profits. Whether the demand is certain or not, conclusions are as follows. Under the policies, firstly, manufacturers can make more profits if they produce according to the demand, at this time manufacturers need to buy extra carbon emissions rights from market; then manufacturers get more profits when they produce according to the demand than sell all of the carbon emissions out. By studying reasonable pricing, manufacturers can realize the biggest profit under the policies, even realize the sustainable development

Keywords: Carbon emissions policy; EOQ model; Newsvendor model; Sensitivity analysis; Pricing strategy.

1. Introduction

To mitigate the catastrophic influence of greenhouse effect, each country in the world gets agreement with emissions reductions and cap-trade. A series of legally binding conventions were formed, which related to carbon emissions. But in these conventions, countries/regions applied macro emissions reduction targets to micro manufacturers' production operation, and formed carbon allowances and cap-trade policy for emission-dependent manufacturers. As the second emitter of carbon dioxide, china showed positive attitude to emissions reductions, such as during the Eleventh Five-Year and Twelfth Five-Year, china proposed specific targets about energy reduction.

Based on the policies of the Mandatory carbon emissions, cap-trade, and many well-known international scholars made further research on carbon emissions. Benjaafar and other scholars (2012) researched supply chain problems considering carbon emissions at first and knew that under the Mandatory carbon emissions policy, manufacturers can achieve the maximum profits by modifying orders. Sundarakani (2010) analyzed the carbon emissions problems exist in supply chain, established models and solved by traffic analysis. Song (2011) researched manufacturers production strategy from single-period under the Mandatory carbon emissions policy, demonstrated the manufacturers' optimal output under the Mandatory carbon emissions policy is less than the optimal output under the unlimited condition, and pointed out that the government's carbon cap should be slightly smaller than manufacturers' largest carbon emissions under the unlimited policy. Chaabane (2012) considered sustainable supply chain model under cap-trade policy, and got a result that the policies of the Mandatory carbon emissions and cap-trade can help reduce pollution emissions. Liao analyzed the relationships between the shadow prices in the market with the equilibrium price within the carbon emissions market and trading.

The current domestic carbon trading pilot has made positive progress, but also faced with the problem about how to formulate and implement carbon emissions quotas. Manufacturers should make full use of the role of the market to reduce the cost of emissions, optimizing the allocation of resources to reduce emissions. Li Botao (2012) thought that selection of carbon dioxide and other green gas reduction policy tools is an important area of research. Shi Minjun (2012) constructed model of China's energy-economy-environment policy model based on dynamic CGE, designed a single carbon tax, a single carbon trading, and combination of carbon tax and carbon trading according to the policies of carbon tax and cap-trade, and analyzed reduction effects, economic impact and reduction costs under different policies.

When considering the impact of carbon emissions trading for production strategy, Li Yunya (2013) from operation researched the impact of carbon emissions and cap-and-trade for production strategy, discussed the production strategy under certainty and uncertainty demand. With Game Theory, in the market condition of asymmetric information monopoly, Hou Yumei (2013) researched the production strategy between two oligopolistic manufacturers, researched the optimal strategy of carbon emissions under the different purification levels which made the manufacturers reduce carbon emissions strategies. Yang Jian (2012) introduced carbon emissions trading Mechanism into production strategy. He compared the EOQ, costs and carbon emissions' capacity before and after the introduction of an emissions trading Mechanism, and analyzed the impact of quotas, price, and unit carbon emissions on optimal strategy. Pan Deng (2012) researched production decision model for single carbon emissions manufacturers and duopoly manufacturers, studied production optimization and government carbon tax decision model for manufacturers in the imperfect competition of international market, and mentioned manufacturers' reduction strategy under the policies of cap-trade and carbon tax. Zhang Jingjiang (2010) analyzed a two-stage case is made up by an emission-dependent manufacturers and an emissions supplier. He discussed from the micro-operational level to explore the impact of emissions factors on the production and supply chain efficiency. Wang Yingwu (2011) discussed the production optimization of individual carbon emissions enterprises from single-period static production and multi-periods dynamic production. From low carbon emissions, Zhu Huiyun (2012) compared carbon tax policy and cap-trade policy, standing in enterprises and government, under the constraints of a low-carbon, gave a guidance of production management and policy recommendations by low carbon-oriented. Under the background of imposing limits on carbon emissions, Kong Linghua (2013) built the optimal production strategy model of manufacturers with considering the carbon emissions costs, and acquired the optimal output, the optimal carbon emissions and the optimal profit. In the view of the efficiency of the carbon emissions trading market and the dynamic consistency of the policy, Nie Li (2013) studied on problems about the distribution and trading of carbon emissions rights.

Most of these papers studied on the problems about the production strategy of under the policies of the Mandatory carbon emissions and cap-trade, a few papers researched the pricing strategy of manufacturers. Under the policies of the Mandatory carbon emissions and cap-trade, manufacturers must ensure that their profits and reduce the costs of carbon emissions while reducing carbon emissions. Hence, reasonable pricing becomes major factor for manufacturers.

To sum up, a few scholars studied the manufacturers' production operation optimization problems and products pricing decision problems at the micro perspective under the policies of Mandatory carbon emissions and cap-trade. As a result, research manufacturers pricing strategy in certain demand and uncertain demand under the policies of Mandatory carbon emissions and cap-trade has become the focus in this paper. When the demand is certain, using the EOQ model and supply function to guide the pricing strategy of manufacturers, and manufacturers can obtain higher profits through carbon trading. When the demand is uncertain, using the newsvendor model and demand function to make pricing strategies for manufacturers. By the comparative analysis, we obtain that under the policies manufacturers can satisfy the government's Mandatory carbon emissions and make higher profits at the same time through the study of the reasonable pricing strategy.

Table 1. A list of major notations that are used in this paper

Notation	Definition
p	Price of per product
Q	output of product

c	Unit acquisition cost of the perishable product
D	Fixed demand in unit time
A	Fixed cost of per order
h	Holding cost of per unit kept in inventory per unit time
g	Shortage cost of unsatisfied demand
v	Salvage value of per unit of the unsold perishable product
α	Unit purchasing price of the carbon credits
β	Unit selling price of the carbon credits
e	Carbon emission of unit product
E	Mandatory capacity for carbon emission
x	aggregate demand
f(x)	the probability density function of aggregate demand
F(x)	the cumulative distribution function of aggregate demand

2. Assumptions and Models of the Problem

Assumption 1: In fact, the carbon emissions of manufacturers in the optimal output are generally higher than the carbon quotas from the government.

Assumption 2: For ease of calculation, we assume demand equals the economic order quantity.

Case 1. In order to help the manufacturers balance economic efficiency and social responsibility, we will discuss the optimal pricing and profit of manufacturers in the certain demand based on the policies of Mandatory carbon emissions and cap-trade. From the EOQ model, we have:

$$TC = cD + \frac{D}{Q}A + \frac{Q}{2}h \quad (1)$$

$$\text{Therefore, } Q_1^* = EOQ = \sqrt{\frac{2DA}{h}}$$

2.1 *Discussing the optimal pricing and profit of manufacturers in the certain demand under the Mandatory carbon emissions policy*

2.1.1 *The optimal pricing of manufacturers*

Theorem 1 Under the Mandatory carbon emissions policy, the optimal pricing of manufacturers is $p_1^* = \frac{E-ae}{be}$.

Proof From assumption 1, we have $eQ_1^* > E$, so under the Mandatory carbon emissions E, the max output of manufacturers are $\frac{E}{e}$

From the supply function we have Q^S , i.e.

$$Q^S = a + bp \quad (a > 0, b > 0) \quad (2)$$

$$\text{Let } Q^S = \frac{E}{e}, \text{ then } p_1^* = \frac{E-ae}{be}.$$

2.1.2 *The optimal profit of manufacturers.*

Theorem 2 Under the Mandatory carbon emissions policy, the optimal profit of manufacturers

$$\text{is } \pi_1^* = \left(\frac{E-ae}{be} + g - c \right) \frac{E}{e} - \sqrt{\frac{2DA}{h}} g.$$

Proof From theorem 1 and EOQ model, the profit model is given as:

$$\pi_1 = p_1^* \frac{E}{e} - \left(Q_1^* - \frac{E}{e} \right) g - c \frac{E}{e} \quad (3)$$

Put $p_1^* = \frac{E-ae}{be}$, $Q_1^* = \sqrt{\frac{2DA}{h}}$ into equation (3), and we get $\pi_1^* = \left(\frac{E-ae}{be} + g - c \right) \frac{E}{e} - \sqrt{\frac{2DA}{h}} g$

2.2 *Discussing the optimal pricing and profit of manufacturers in the certain demand under the policies of Mandatory carbon emissions and cap-trade*

2.2.1 *The optimal pricing of manufacturers.*

Theorem 3 Under the policies of Mandatory carbon emissions and cap-trade, the optimal pricing of manufacturers is $p_2^* = \sqrt{\frac{2DA}{b^2h}} - \frac{a}{b}$.

Proof Under the policies of Mandatory carbon emissions and cap-trade, manufacturers can produce as Q_1^* . So $Q^S = Q_1^*$, and we get $p_2^* = \sqrt{\frac{2DA}{b^2h}} - \frac{a}{b}$.

2.2.2 *The optimal profit of manufacturers*

Theorem 4 Under the policies of Mandatory carbon emissions and cap-trade, the optimal profit of manufacturers is $\pi_2^* = \left(\sqrt{\frac{2DA}{b^2h}} - \frac{a}{b} - c - \alpha e \right) \sqrt{\frac{2DA}{h}} + \alpha E$.

Proof From theorem 3 and EOQ model, the profit model of manufacturers under the policies of Mandatory carbon emissions and cap-trade is given as:

$$\pi_2 = p_2^* Q_1^* - c Q_1^* - (e Q_1^* - E) \alpha \quad (4)$$

Put $p_2^* = \sqrt{\frac{2DA}{b^2h}} - \frac{a}{b}$, $Q_1^* = \sqrt{\frac{2DA}{h}}$ into equation (4), and we get $\pi_2^* = \left(\sqrt{\frac{2DA}{b^2h}} - \frac{a}{b} - c - \alpha e \right) \sqrt{\frac{2DA}{h}} + \alpha E$

Corollary 1 When sale the all carbon emissions rights, the profit function of manufacturers is given as: $\pi_3^* = \beta E$

2.3 *Analyzing the above price and profit functions, some conclusions are as follows*

1) $p_2^* > p_1^*$, it means the optimal pricing under the policies of Mandatory carbon emissions and cap-trade is higher than that under the Mandatory carbon emissions policy.

2) $\pi_2^* > \pi_1^*$, it shows that the manufacturers can get more profits through carbon trading.

Proof Let $L_1 = \pi_2^* - \pi_1^* = \left(\sqrt{\frac{2DA}{b^2h}} - \frac{a}{b} - c - \alpha e \right) \sqrt{\frac{2DA}{h}} + \alpha E - \left(\frac{E-ae}{be} + g - c \right) \frac{E}{e} + \sqrt{\frac{2DA}{h}} g$

$$= \left(\frac{\sqrt{\frac{2DA}{h}} - a}{b} - c + g \right) \sqrt{\frac{2DA}{h}} - \left(\frac{E-a}{b} - c + g \right) \frac{E}{e} + \left(E - e \sqrt{\frac{2DA}{h}} \right)$$

Because $\sqrt{\frac{2DA}{h}} > \frac{E}{e}$, so it's easy to find $L_1 > 0$, that is, $\pi_2^* > \pi_1^*$.

3) $\pi_1^* > \pi_3^*$, it shows that the profit of the manufacturers who put all carbon emissions rights into producing is

higher than that are sold out.

In conclusion, $\pi_2^* > \pi_1^* > \pi_3$. Comparing the profit, we can learn that in order to achieve low-carbon production and economic production, the manufacturers should put the carbon emissions rights into producing instead of selling. They should consider carbon emissions trading.

Case 2. In this section, we will discuss the optimal pricing and profit of manufacturers in the uncertain demand based on the policies of Mandatory carbon emissions and cap-trade.

We combine demand function

$p = j - kQ$ ($j > 0, k$ is demand-price elasticity coefficient). With newsvendor model, the profit model of demand-price elasticity can be written as

$$\begin{aligned} \pi_4 = & (j - kQ - v) \int_0^Q xf(x)dx \\ & - (c - v) \int_0^Q Qf(x)dx + (j - kQ + g - c) \int_Q^\infty Qf(x)dx - g \int_Q^\infty xf(x)dx \end{aligned} \quad (5)$$

Let $\frac{d(\pi_4)}{dQ} = (j + g - c) - 2kQ + k \int_0^Q F(x)dx = 0$, and we get $j + g - c = (2Q - \int_0^Q F(x)dx)k$

For ease of calculation, we let $G(Q) = 2Q - \int_0^Q F(x)dx$, thus $Q_2^* = G^{-1}\left(\frac{j+g-c}{k}\right)$

2.4 *Discussing the optimal pricing and profit of manufacturers in the uncertain demand under the Mandatory carbon emissions policy*

2.4.1 *The optimal pricing of manufacturers*

Theorem 5 Under the Mandatory carbon emissions policy, the optimal pricing of manufacturers is $p_3^* = j - k\frac{E}{e}$.

Proof From assumption 1, we know under the carbon emissions E , the max output of manufacturers is $\frac{E}{e}$. Put $Q = \frac{E}{e}$ into the demand function, we get $p_3^* = j - k\frac{E}{e}$.

2.4.2 *The optimal profit of manufacturers*

Theorem 6 Under the Mandatory carbon emissions policy, the optimal profit of manufacturers is

$$\pi_5^* = (2v - j - g - c)\frac{E}{e} + k\left(\frac{E}{e}\right)^2 + \left(j + g - v - k\frac{E}{e}\right)G\left(\frac{E}{e}\right) - g$$

Proof From theorem 5 and equation (5), the optimal profit of manufacturers is

$$\begin{aligned} \pi_5 = & (p_3^* - v) \int_0^{\frac{E}{e}} xf(x)dx \\ & - (c - v) \int_0^{\frac{E}{e}} Qf(x)dx + (p_3^* + g - c) \int_{\frac{E}{e}}^\infty Qf(x)dx - g \int_{\frac{E}{e}}^\infty xf(x)dx \end{aligned} \quad (6)$$

By simplifying, we get $\pi_5^* = (2v - j - g - c)\frac{E}{e} + k\left(\frac{E}{e}\right)^2 + \left(j + g - v - k\frac{E}{e}\right)G\left(\frac{E}{e}\right) - g$

2.5 *Discussing the optimal pricing and profit of manufacturers in the uncertain demand under the policies of Mandatory carbon emissions and cap-trade*

2.5.1 The optimal pricing of manufacturers

Theorem 7 Under the policies of Mandatory carbon emissions and cap-and-trade, the optimal pricing of manufacturers is $p_4^* = j - kG^{-1}\left(\frac{j+g-c}{k}\right)$.

Proof Under the policies of Mandatory carbon emissions and cap-and-trade, manufacturers can produce as Q_2^* . Put $Q_2^* = G^{-1}\left(\frac{j+g-c}{k}\right)$ into demand function, we can learn $p_4^* = j - kG^{-1}\left(\frac{j+g-c}{k}\right)$

2.5.2 The optimal profit of manufacturers

Theorem 8 Under the policies of Mandatory carbon emissions and cap-and-trade, the optimal profit of manufacturers is

$$\pi_6^* = [2(v - g - j) - \alpha e]G^{-1}\left(\frac{j+g-c}{k}\right) + k\left[G^{-1}\left(\frac{j+g-c}{k}\right)\right]^2 - g + \alpha E$$

Proof From theorem 7 and Q_2^* , the profit model is given as:

$$\begin{aligned} \pi_6 = (p_4^* - v) \int_0^{Q_2^*} xf(x)dx - (c - v) \int_0^{Q_2^*} Q_2^* f(x)dx \\ + (p_4^* + g - c) \int_{Q_2^*}^{\infty} Q_2^* f(x)dx - g \int_{Q_2^*}^{\infty} xf(x)dx - (eQ_2^* - E)\alpha \end{aligned} \quad (7)$$

By simplifying, we get $\pi_6^* = [2(v - g - j) - \alpha e]G^{-1}\left(\frac{j+g-c}{k}\right) + k\left[G^{-1}\left(\frac{j+g-c}{k}\right)\right]^2 - g + \alpha E$

Corollary 2 Whether demand is certain or not, the optimal profit of selling all carbon emissions rights is the same. i.e. $\pi_7^* = \pi_3^*$

2.6 Analyzing the above price and profit functions, some conclusions are as follows

- 1) Whether the demand is certain or not, there is no influence on the profit of selling all carbon emissions rights.
- 2) $p_3^* > p_4^*$, it shows that in the case of uncertain demand, the optimal pricing under the policies of Mandatory carbon emissions and cap-trade is lower than that under the Mandatory carbon emissions policy.
- 3) $\pi_6^* > \pi_5^*$, it shows the manufacturers can get more profits by carbon trading.
- 4) $\pi_5^* > \pi_7^*$, it shows the profit of the manufacturers who put all carbon emissions rights into producing is higher than that are sold out.

In conclusion, we get $\pi_6^* > \pi_5^* > \pi_7^*$. When demand is uncertain, the optimal pricing under the policies of Mandatory carbon emissions and cap-trade is lower than that under the Mandatory carbon emissions policy, but the profit is higher than that under the Mandatory carbon emissions policy. To encourage the manufacturers produce more, the profit of the manufacturers who put all carbon emissions rights into producing usually higher than that be sold out.

3. Numerical Example and Sensitivity Analysis

In this section we present a typical numerical analysis to corroborate and supplement the previous developments. Considering the limited page numbers, we just do sensitivity analysis for part of profit models. Without loss of generalization, the demand of market x is assumed to follow a truncated normal distribution.

Definitely, let $x = \max(\tilde{x}, 0)$, where \tilde{x} is assumed normally distributed with mean of 100 and standard deviation of 10, i.e. $\tilde{x} \sim N(100, 10^2)$

Because $\text{Prob}(\tilde{x} < 0)$ is tiny enough to be neglected. Thus, \tilde{x} can be used to approximate x for convenience of calculation.

Besides, let $c = 30, s = 55, v = 9, \alpha = 30, \beta = 10, e = 2, E = 150, j = 134.8$. By means of Matlab, we do sensitivity analysis for k and Q (as shown in Figure1-3). Several insights can be concluded as follows:

1) In figure1, if output is lower than 109.6, then manufacturer's profit will increase when output increases; or if output is more than 109.6, then manufacturer's profit will decrease when output increases. Therefore, manufacturers attain optimal profit 3404 while output equals 109.6.

2) From figure2 and 3, we find: with the increasing of demand-price elasticity, both of price and profit will reduce.

3) Comparing figure2 and 3, we get: with increasing of output, demand-price elasticity coefficient has greater influence on price and profit.

Fig 1. Sensitivity of optimal results to outputs when p equals 80

Q	$(P-C)Q$	$(E-eQ)\beta$	$(E-eQ)\alpha$	$(Q-Q^*)v$	π
60	3000	300			572
65	3250	200			997
70	3500	100			1422
75	3750	0			1847
80	4000		-300		2072
85	4250		-600		2297
90	4500		-900		2522
95	4750		-1200		2747
100	5000		-1500		2972
105	5250		-1800		3197
109.6	5480		-2076		3404
110	5500		-2100	3.6	3403.6
115	5750		-2400	48.6	3398.6
120	6000		-2700	93.6	3393.6

Fig 2. Sensitivity of optimal results to demand-price elasticity when Q equals 75

k	p	$(p-c)Q$	π
0	134.8	7860	5957
0.25	116.05	6453.75	4550.75
0.5	97.3	5047.5	3144.5
0.75	78.55	3641.25	1738.25
1	59.8	2235	332

Fig 3. Sensitivity of optimal results to demand-price elasticity when Q equals Q^*

k	p	$(p-c)Q$	π
0	134.8	11486.08	9410.08
0.25	107.4	8483.04	6407.04
0.5	80	5480	3404
0.75	52.6	2476.96	400.96
1	25.2	-526.08	-2602.08

4. Summary

This paper researches on pricing strategy for manufacturers with the certain demand and uncertain demand under the policies of the Mandatory carbon emissions and cap-trade. Through reasonable assuming, utilizing EOQ model and supply function, get the pricing strategy and optimal profit model under the policies of the Mandatory carbon emissions and cap-trade when demand is certain; newsvendor model and demand function be used to propose the pricing strategy and profit model which is relative to demand-price elasticity coefficient, under these two policies when demand is uncertain. Whether the demand is certain or not, conclusions are gained as follows. Under the policies of the Mandatory carbon emissions and cap-trade, One, manufacturers can make more profits if they buy carbon emissions rights they need from market; two, get more profits when they buy carbon emissions rights they need from market than they sell all of them. By numerical example and sensitivity analysis, this paper get: with the increasing of demand-price elasticity coefficient, both of price and profit will reduce; with increasing of output, demand-price elasticity coefficient has greater influence on price and profit.

Without doubt, there are few deficiencies in this paper as following: Firstly, we assume the demand of product is normally distributed in the section of numerical example and sensitivity analysis, but it may be influenced by other distribution in reality. Secondly, dates are not real when we make sensitivity analysis, but it shows how the main factors influence the results of optimization and thus we know variation trend of relative variables from our analysis which contribute a lot to manufacturer's production optimization. Hence, we will focus on these two sites in the follow-up study.

Reference

- Benjaafar, S., Mohsen, E. (2012), A production-inventory system with patient and impatient demand classes, *Transactions on Automation Science and Engineering* 9(1): 148-159.
- Sundarakani B, de Souza R. (2010), Models carbon footprints across the supply chain, *International Journal of Production Economics* 128(1): 43-50.
- Song, J., M. Leng. (2012), Analysis of the single-period problem under carbon emissions policies, *International Series in Operations Research and Management Science* 176(2): 297-313.
- Chaabane, A., A. Ramudhin, M. Paquet. (2012), Design of sustainable supply chains under the emission trading scheme, *International Journal of Production Economics* 135(1): 37-49.
- Liao C, Onal H and Chen M H. (2009), Average shadow price and equilibrium price: case study of tradable pollution permits markets, *European Journal of Operational Research* 196: 1207-1213.
- Li Botao. (2012), Debate on policy instrument choice for carbon pricing, *Economic Review* (2):153-160.
- Shi Minjun, Yuan Yongna, Zhou Shenglv, Li Na. (2012), Carbon tax, cap-and-trade or mixed policy: which is better for carbon mitigation, *Journal of Management Sciences, in China* 16(9):9-19.
- Li Yunya. (2013), Optimal production decision enterprise with emission permits and trading, A Thesis Submitted to University of Electronic Science and Technology of China.
- Hou Yumei. (2013), Researching for duopoly producing and reducing emission under the cap-and-trade, *Commercial research* (429):176-182.
- Yan Jian. (2012), Study of production decision based on the carbon emission trade policy, East China University of Science and Technology.
- Pang Deng, (2012), Enterprise's optimal production decision research under the low carbon economy, Economic Management Academy of Yan Shan University.
- Zhang Jinjiang, (2012), Emission relying production optimization considering emissions permits and trading, University of Science and Technology of China.
- Wang Yingwu, (2011), Enterprise carbon emissions requirements and production operation optimization analysis, Economics and Management of North China Electric Power University.
- Zhu Huiyun, (2012), Enterprise manufacturing/remanufacturing production decision research under the Carbon policy, East China University of Science and Technology.
- Kong Linghua, (2013), Enterprise production optimization research under the Mandatory carbon emissions, University of Electronic Science and Technology of China.
- Nie li, (2013), China's carbon emissions trading game analysis, Capital University of Economics and Business.

Integration of Pricing and Production for Single Product with the Mandatory Carbon Emissions Policy

Huawei Duan^{*1}, Qin Luo², Xinyu Xu³ and Jing Mao⁴

¹School of Transportation and Logistics, Southwest Jiaotong University, ChengDu, SiChuan, 610000, China.

Email: uestc-vip@163.com, Tel: 13880933806.

²Logistics Research Institute, Tian Fu College of Southwestern University of Finance and Economics, MianYang, Sichuan, 6210000, China. Email: lq2011@sina.com, Tel: 18780583202.

³Logistics Research Institute, Tian Fu College of Southwestern University of Finance and Economics, MianYang, Sichuan, 6210000, China. Email: sealbryant@sina.com, Tel: 18584066365.

⁴Logistics Research Institute, Tian Fu College of Southwestern University of Finance and Economics, MianYang, Sichuan, 6210000, China. Email: sanluosanyue@163.com, Tel: 13350580387.

**Corresponding author*

Abstract

By the insight of manufacturer, research on integration of pricing and production for single product with the Mandatory carbon emissions policy. Through the newsvendor model, build the integration of pricing and production strategy model; integration of pricing and production with the Mandatory carbon emissions policy. Discuss changes of profits under the two integration strategy; find the optimal profile of price and production from the Integration of pricing and production strategy model under the Mandatory carbon emissions policy. By game theory and Mathematical Statistics, analyzing profits function from two situations, and getting the following conclusions: Under integration of pricing and production, the total profits of manufacturer are higher than the situation of disintegration; under the mandatory carbon emissions policy, the integration of pricing and production strategy is unique and the profits of manufacturer is lower than without constraint policy. The research would provide manufacturer of carbon emissions constraint, even achieve the sustainable development.

Keywords: the Mandatory carbon emissions policy, newsvendor model, game theory, Mathematical Statistics, integration of pricing and production.

1. Introduction

As a global issue, Climate change is already caused people's extensive concern. And we know the extreme weather affect the world economy is increasingly clear. More and more countries government agencies continue to pursue economic transformation, in order to achieve that the high carbon emissions of industrial enterprises change to the low carbon and low energy consumption. In the low carbon environment, the enterprise' production and pricing decision has attracted academic attention and exploration.

One of the biggest obstacles about achieving emission reduction commitments will tend to impede the economy, so the decision can not make a choice. However, under the theory of carbon allowance, analyzing and researching the enterprises' theory about production and pricing can good deal with playing game between environment and economy. By studying the integration of pricing and production decision on corporate carbon cap conditions, the enterprise can make a advantage decision to let itself Sustainable development and it also powerful participate in building a resource conserving, environment-friendly society. It can not only let the enterprise profit maximization, but also realize the sustainable development under low carbon economy.

Xi Chen Saif Benjaafar Adel Elomri (2004) discuss and modify the quantity of production to reduce the carbon under the model of EOQ. Imre Dobos (2004) using the model of arrow-karlin discuss the effect of

enterprises' production and inventory the emissions trading policy. And comparative analysis of the optimal production and inventory changes before and after the emission trading policy. Wang Yingwu (2011) detailed classification the enterprises' needs of emission right, and analyze the influence of various requirements about enterprise's production operation. And let the enterprises' needs of carbon cost consideration of enterprise's production optimization, then from the single period static production and multi period dynamic production angle to discussion on production optimization problem of single carbon enterprise.

Pan Deng (2012) in depth study of carbon allowance, carbon trading and carbon tax environment in many enterprise decision model and carbon tax model, and gives the carbon emissions trading and carbon tax environment reduction strategy of enterprises. Bin Zhang Liang Xu (2013) research the trading system about carbon emission and the production plan about various production, analyze the decision about producing and carbon trading, compare the carbon limit, carbon trading and the theory of carbon tax.

Kong Lingxian (2013) to study the establishment of enterprise optimal production decision model for carbon emission cost considerations under the optimal production enterprise carbon allowance emission, obtains the enterprise optimal production quantity, optimal carbon emissions and the optimal profit. Yang Jian (2012) to yield problem under stochastic demand, considering inventory at the same time. He also consider the stock may, and established manufacturers profit model under the emissions trading scheme, to obtain the optimal yield. He furthers analysis of carbon trading prices, demand changes and the yield of carbon emissions per unit how to influence of production decision. Li Yunya (2013) who based on the optimization theory, in-depth studying of enterprises' related problems of production decision that has the needs of carbon emissions under the deterministic demand and uncertain demand. it is according to the different influencing factors are respectively established mathematical model, provides a practical basis for the relevant production enterprise decision.

Ni Li is object of study the carbon emission rights trading under the control of total quantity, academic analyze about our motherland's carbon right trading. It is use market efficient and the policy dynamic consistency about carbon emissions right or another faces to analyze designing about the theory of Initial allocation, influencing factor of carbon emission right's pricing and the formation mechanism of carbon emission right under the free way of distribution. Hou Yumei, Pan Deng and Liang Congzhi (2013) use the game theory research. The production decision-making of two firms, as well as in the purification level of enterprises under the optimal decision of different carbon emissions under the situation about Production decision of two oligopoly. Zhu Huizan (2012) though the way of extending the traditional manufacturing/re-manufacturing production theory to respectively estimate the enterprise's manufacturing/re-manufacturing production decision model about twin engine drivers combining Internal and external driving factors under the system about the theory of carbon tax and the carbon trading.

Zhang Jihong, Ding Xiaosong and Chenxi (2011) consider the problem of the integration of pricing and production under the energy compensation mechanism. And they analyze the model though using dynamic programming and The concept of K convex function in order to prove the optimal production strategy. Hu Jueliang, Xu Yi and Han Shuguang (2011) study the problem of multi stage non cycle's pricing and order goods in The finite planning period under time varying demand. Mu Yingping considering the problem of exist two one-way substitution's good that integration of order and pricing. He studied the two goods' optimal order quantity and the pricing exit condition and let it expand the condition of Multi cycles though reforming the integration of ordering and pricing.

The government makes the theory of carbon allowance in order to reduce the carbon emission getting bad influences of environment. The enterprises' production and operation not only fit in the theory of the government, but also to satisfied their profit. How to balance the two sides reasonable is a key to every company.

All in all, when considering about carbon allowance, a part of the scholar research the production model under the theory of carbon limit and a small part of the scholar research the problem that production decision change after and before the theory of carbon emission limit. When considering about the integration of pricing and

production decision, a part of scholar research the problem that enterprise's supply decision under different cycles and mechanisms. thus, this paper research the emission reduction task from carbon emission right which not just make the enterprise getting Optimal production, at the same time, it can acquire the best profit under the theory of carbon allowance.

2. The assumption of the problem and the model

Many enterprises in the actual operation of the production process are basically decided by the production department, sales department determines the price, each department to optimize decisions based on their own interests. Due to the uncertainty of demand and the untimely communication of information, resulting in the decision results in the production and sales departments often do not match, or overproduction widespread product shortages In order to maximize the overall profits of the enterprise, we propose a Integration of pricing and production strategy model and analyze the optimal production and pricing of its profit function, and expand to lower carbon policy

Case 1 we will discuss the total profit and the optimal combination pricing and production under the integration pricing and production.

Table1. A list of major notations that are used in this paper

$f(\cdot)$	The Random demand with probability density function	v	salvage value per unit of the unsold perishable product
$F(\cdot)$	The Random demand with distribution function	p^*	the optimal pricing under the on carbon allowance
p	unit product price	Q^*	the optimal production under the no carbon allowance
Q	production quantity	P_0	the optimal riskless price
s	unit shortage cost	M	mandatory capacity for carbon emissions
c	unit production cost	e	Carbon emissions per unit product
i	constant quantity	g	constant quantity

2.1 The optimal combination pricing and production in the integration pricing and production

In the case of Integration of pricing and production strategy, enterprises' price functions will be affected by the production, assuming that the price of the product function is

$$p = i + gQ \quad (1)$$

i and g is constant quantity

Profit function of products:

$$\pi = \begin{cases} pD - cQ + v(Q - D), & Q \geq D \\ pQ - cQ - s(D - Q), & Q < D \end{cases} \quad (2)$$

In order to facilitate the analysis of the model, we simplify the profit function

$$\pi = \begin{cases} p(Q)D - cQ + v[Q - D], & Q \geq D \\ p(Q)D - cQ - s[D - Q], & Q < D \end{cases} \quad (3)$$

Assuming that unsatisfied demand will be lost at the end of the cycle, The remaining value of the product is 0, basing on the classic newsvendor, the enterprise's profit function can be expressed as

$$E[\pi(Q, p)] = p(Q) \left[\int_0^Q xf(x)dx + \int_Q^\infty Qf(x)dx \right] + v \int_0^Q (Q - x)f(x)dx - s \int_Q^\infty (x - Q)f(x)dx - CQ \quad (4)$$

Let $A(Q) = v \int_0^Q (Q - x)f(x)dx$ represents when the demand is less production occurred Salvage expectation.

Let $B(Q)$ indicate the out of expectation when demand more than output.

Enterprises' expectation after simplification can be expressed as

$$E[\Pi(Q, p)] = \Psi(p) - L(Q) \quad (5)$$

A function is interpreted as

$$\Psi(p) = [p(Q) - c]D \quad (6)$$

Representatives the profit function, the profit function is a deterministic equilibrium problems

$$L(Q) = B(Q) - A(Q) \quad (7)$$

Representative's loss function, the first part $B(Q)$ represents the enterprises' shortage cost production is less than the demand. The second part represents the salvage value of the product when the remaining production is greater than demand. Therefore, the formula (5), total enterprises' expected profit can be described as: the net remaining of profit under conditions of deterministic subtracted the expected loss caused by uncertainty.

The objective is to maximize expected profit:

$$\max E[\Pi(Q, p)] \quad (8)$$

2.1.1 Optimal production under the integration of the production and pricing strategy

Theorem 1: optimal production of Enterprises under the integration of the production and pricing strategy is

$$Q^* = f^{-1}\left(\frac{gD+s}{s-v}\right)$$

Prove1 .Q which is the Maximum expected profit of the enterprise for a first order partial derivatives

$$\frac{\partial E[\Pi(Q, p)]}{\partial Q} = gD + (v-s)f(Q) + s = 0$$

$$f(Q) = \frac{gD+s}{s-v}$$

$$Q = f^{-1}\left(\frac{gD+s}{s-v}\right)$$

Under the enterprise in the integration of the production and pricing strategy can be solved for the optimal output $Q^* = f^{-1}\left(\frac{gD+s}{s-v}\right)$

2.1.2 The optimal pricing under the integration of the production and pricing strategy

Theorem 2: the optimal pricing of enterprise under the integration of the production and pricing strategy is

$$P^* = i + gf^{-1}\left(\frac{gD+s}{s-v}\right)$$

Prove2. In this paper we assume that under the integration of the production and pricing strategy the price function of the enterprise is $p = i + gQ$, Basing on the optimal production in theorem 1, $Q^* = f^{-1}\left(\frac{gD+s}{s-v}\right)$,

the optimal pricing is $P^* = i + gf^{-1}\left(\frac{gD+s}{s-v}\right)$

2.1.3 Expected profits under the integration of the production and pricing strategy

Theorem 3 under the integration of the production and pricing strategy, the expected profits of enterprise is

$$E[\Pi(Q^*, p^*)] = [i + gf^{-1}\left(\frac{gD+s}{s-v}\right) - c]D - s + s[F^{-1}\left(\frac{s}{s-v}\right) - 1]$$

Prove3. basing on Theorem 1 and Theorem 2 the optimal output under the integration of the production

and pricing strategy is $Q^* = f^{-1}(\frac{gD+s}{s-v})$, the optimal price is $P^* = i + gf^{-1}(\frac{gD+s}{s-v})$ Combining Q^* and

P^* , the expected profit of enterprise under the integration of the production and pricing strategy is $E[\Pi(Q^*, P^*)] = \Psi(P^*) - L(Q^*)$

$$\begin{aligned} &= (P^* - c)D + v \int_0^{Q^*} (Q - x)f(x)dx - s \int_{Q^*}^{\infty} (x - Q)f(x)dx \\ &= (P^* - c)D + (v - s)F(Q) + s(Q - 1) \\ &= [i + gf^{-1}(\frac{gD+s}{s-v}) - c]D - s + s[F^{-1}(\frac{s}{s-v}) - 1] \end{aligned}$$

2.1.4 Profits under integration of the production and pricing strategy is higher than the production decision of disintegration

Theorem 4 the optimal production Q^* is between Q_1 and Q_2 so the profits under integration of the production and pricing strategy is higher than the production decision of disintegration

$$\begin{cases} E[\Pi(Q^*, p)] = \Psi(p) - L(Q^*) > E[\Pi(Q_1, p)] = \Psi(p) - L(Q_1) \\ E[\Pi(Q^*, p)] = \Psi(p) - L(Q^*) > E[\Pi(Q_2, p)] = \Psi(p) - L(Q_2) \end{cases}$$

Prove 4. Therefore, this paper studied integration decision of pricing and production from the perspective of carbon emission right under the new policy of carbon emission which not only can make the enterprise get optimal production, but also can acquire the best profit under the theory of carbon limit. When without considering the integration of production and pricing decision, enterprises' maximize production tends to be more reasonable and profit, often through a cost, shortage cost and inventory game to decision of enterprise based on reasonable forecast production, according to increase the production history data or reduce a certain amount of production.

If the unit cost of $s >$ unit inventory cost h , Enterprises will increase production Q_2 based on historical data.

If the unit cost of $s <$ unit inventory cost h , Enterprises will decrease production Q_1 based on historical data.

The optimal production under the integration of production and pricing not only consider demand function, but also consider The influence of price on demand, decrease the enterprise's Bullwhip Effect in the produce, decrease the influence on market random demand, and also decrease the expect loss about $A(Q)$ and $B(Q)$.

$$\begin{cases} A(Q^*) < A(Q_1), A(Q^*) < A(Q_2) \\ B(Q^*) < B(Q_1), B(Q^*) < B(Q_2) \end{cases}$$

Similarly, the loss function expected profit of enterprises in the production pricing joint decision in the lower joint of production decision $L(Q^*) < L(Q_1), L(Q^*) < L(Q_2)$

According to Enterprise total profit function expression, at the same situation, enterprise's sale profit p is not change, loss function D will decide the profit change. Comparing integration pricing and production

decison, and the single production decision is follow to see:
$$\begin{cases} Q_M \geq Q^* (1) \\ Q_M < Q^* (2) \end{cases}$$

Prove the profit under the integration of pricing and production higher than not integration.

2.2 Optimal combination of production and pricing under the environment of carbon allowance

Case 2, In order to analyze the optimal combination of production and pricing, we will let the model about the

integration of pricing and production under the environment of carbon allowance.

2.2.1 Enterprise's profit function

Theorem 5, enterprise's profit function under the carbon allowance is:

$$E[\pi(Q, p)] = p(Q) \left\{ \int_0^Q xf(x)dx + \int_Q^\infty Qf(x)dx \right\} - s \int_0^Q (Q-x)f(x)dx - h \int_Q^\infty (x-Q)f(x)dx - cd(p)$$

S.t

$$0 \leq eq \leq M$$

Prove5. In the above theorem we obtained in the carbon free quota under the expected profit for enterprises

$$E[\pi(Q, p)] = p(Q) \left[\int_0^Q xf(x)dx + \int_Q^\infty Qf(x)dx \right] + v \int_0^Q (Q-x)f(x)dx - s \int_Q^\infty (x-Q)f(x)dx - CQ$$

However, in the policy of carbon allowance, the government made the biggest emission quantity M. The enterprise's carbon emission in the production will not allow exceeding the government making. If the enterprise's optimal quantity is q_2 under the carbon allowance, then the integration of pricing and production about expect profit under the carbon allowance is:

$$E[\pi(Q, p)] = p(Q) \left\{ \int_0^Q xf(x)dx + \int_Q^\infty Qf(x)dx \right\} - s \int_0^Q (Q-x)f(x)dx - h \int_Q^\infty (x-Q)f(x)dx - cd(p)$$

S.t

$$0 \leq eq \leq M$$

2.2.2 Exist and only exist an optimal combination of pricing and production

Theorem 6, the enterprise's profit function exist and only exist an optimal combination of pricing and production is bout demand function under the situation about carbon allowance.

Prove 6: when $eQ > M$, because of the exits of government's carbon allowance, the manufacturer's optimal production quantity under the carbon allowance is not more than not under the carbon allowance. Under the quantity of carbon emission N, manufacture the most produce $\frac{M}{e}$ product, at this time, Q is also the enterprise's optimal production, $Q = \frac{M}{e}$ ($e > 0$). So the enterprise's optimal pricing is: $p = i + g \frac{M}{e}$.

This time, the enterprises expect profit is: $E[\pi(Q, p)] = \left(i + g \frac{M}{e} - c \right) D - (v - s) F\left(\frac{M}{e}\right) + s(Q - 1)$

2.3 Enterprises' combination production and pricing changing and profit changing under the two different situations

Case 3. This part we can consider the enterprises' combination production and pricing changing and profit changing under the two different situations--- have or not have carbon allowance.

Theorem 7: the enterprises' optimal profit under the integration of pricing and production in the theory of carbon allowance less than the enterprises' optimal profit under the integration of pricing and production decision in the theory of no allowance.

$$\left[f^{-1}\left(\frac{gD+s}{s-v}\right) - \frac{M}{e} \right] (Dg + v)$$

Prove7: we will assume that the same prices in the market compare the two different situation of enterprises' profit under the integration of pricing and production ---- have or not have the theory of carbon emission. Because of the same price, the price P has the same effect on demand function D . In this time, production

has absolute influence on profit. According to the variety of carbon allowance, we discuss separately.

$$\begin{cases} Q_M \geq Q^* (1) \\ Q_M < Q^* (2) \end{cases}$$

formula (1) indicate the allowed optimal production under the integration of pricing and production decision greater or equal the optimal production under integration of pricing and production in unlimited carbon. So, in this time, the twin fact optimal production is equal and the profit function also equal.
 $E[\Pi(Q_M, p)] = E[\Pi(Q^*, p)]$

formula (2) indicate the allowed optimal production under the integration of pricing and production less than the optimal production under integration of pricing and production in unlimited carbon. At this time, the twin

reality optimal production is $Q_M < Q^*$, the profit function's changing is:

$$\begin{aligned} \Delta E[\Pi(Q, p)] &= \Psi(p^*) - L(Q^*) - [\Psi(p_M) + L(Q_M)] \\ &= (p^* - c)D + (v - s)F(Q^*) + s(Q^* - 1) - [(p_M - c)D + (v - s)F(Q_M) + s(Q_M - 1)] \\ &= \{[i + g f^{-1}(\frac{gD+s}{s-v}) - c]D - (v - s)F[f^{-1}(\frac{gD+s}{s-v})] + s[f^{-1}(\frac{gD+s}{s-v}) - 1]\} \\ &\quad - \left[\left(i + g \frac{M}{e} - c \right) D - (v - s)F\left(\frac{M}{e}\right) + s\left(\frac{M}{e} - 1\right) \right] \\ &= Dg[f^{-1}(\frac{gD+s}{s-v}) - \frac{M}{e}] + s[f^{-1}(\frac{gD+s}{s-v}) - \frac{M}{e}] + (v - s)[f^{-1}(\frac{gD+s}{s-v}) - \frac{M}{e}] \\ &= [f^{-1}(\frac{gD+s}{s-v}) - \frac{M}{e}](Dg + v) \end{aligned}$$

Considering about the realities operation in the theory of carbon allowance, the carbon allowances always lower than the enterprises' optimal production. So, the situation about enterprises' profit not changing is barely existed. Therefore, formula (2) is the changing condition that the optimal profit under the integration of pricing and production less than the optimal profit under the integration of pricing and production in no carbon allowance.

3. Summary

In recent years, since the rise of the Energy consumption, it is common knowledge that carbon emission leads to globe climate changing bring a series of significant bad influence on the human survive environment of all the countries in the world. So, researching on the problem of production theory under the theory of carbon allowance has an important realistic meaning. This paper uses the newsboy model, game theory etc to research on the theory of enterprise's production. It can get the follow advantage conscious though researching the problem. (1) Compared with the situation of single production decision, the integration of pricing and production make the enterprises' total profit increase. (2) Under the theory of carbon allowance, the integration of pricing and production existence and uniqueness a optimal group of pricing and production. (3) The enterprises' total profit under the integration of pricing and production less than under the no carbon allowance. If the enterprises want to increase total profit, it should decrease the unit of carbon emission though carbon trading or investing green technology.

This paper having the advantages decision can give reference and guide suggestion. However, may this paper's some hypothesis may have a little different from reality. And this study is just only considering an enterprise's problem of the integration of pricing and production. In the future, we can future release some assumptions, discuss how to make production strategy in order to let themselves profit maximization under the environment of the carbon trading and investing green technology.

Reference

- Xi Chen, Saif Benjaafar, Adel Elomri.H. (2011), The Carbon-Constrained EOQ International Journal of Production Economics 128(1): 21-28.
- Bin Zhang, Liang Xu.H. (2013), Multi-item production planning with carbon cap and trade mechanism, International Journal of Production Economics 135(1): 56-72.
- Imre Dobos.H. (2004),The effects of emission trading on production and inventories in the Arrow–Karlin model, International Journal of Production Economics 78(2): 34-47.
- Pan Deng. M.S. (2012), A Study On Enterprise's Optimal Production Decisions Under The Low-carbon of Economy, Yan Shan University.
- Wang Yingwu. M.S. (2011), Analysis of enterprise demand for carbon emission options and research on operation optimization for enterprise with emission, North China Electric Power University.
- Kong Linhua, M.S. (2013), Enterprise production optimization research under the limit carbon emissions, University of Electronic Science and Technology of China.
- Yang Jian, M.S. (2012), Study of production decision based on the carbon emission trade policy, East China University of Science and Technology.
- Li Yayun. M.S. (2013), Optimal production decision for enterprise with emission permits and trading, University of Electronic Science and Technology of China.
- Hou Yumei, Pan Deng, Liang Congzhi. H. (2013), The Study Of Duopoly Enterprises' Production And Carbon Emission Reducing Under The Right Of Carbon Emission.Trading Commercial Researcher (1):176-182
- Nie Li.M.S.(2012), Game analysis of Chinese carbon emissions trading, Capital University of Economics and Business.
- Zhu Huiyun. M.S. (2012), Research on enterprises' manufacturing/remanufacturing production decisions under carbon emission policies, East China University of Science and Technology.
- Zhang Jihong, DING Xiaosong, CHEN Xi. H. (2011), Pricing and inventory for an energy buy-back program, Journal of Systems Science and Mathematical Sciences 31(10):1298-1305.
- Hu Jueliang, Xu Yi, HAN Shuguang. H. (2012), Research on non-periodic multi-stage pricing and ordering strategy with time-varying demand, Journal of Textile Research 33(1): 32-36.
- Mu Yinping. H. (2011), Integration of pricing and ordering for downward substitution products with stochastic demand, Chinese Journal of Management 8(5): 752-757.

Pricing Strategy Research for Enterprises under Carbon Constraint Policy with Two Products

Hua He^{*12}, Li Zhang², Ruiyu Wang², Shucheng Zhou² and Liang Ming²

¹School of Transportation and Logistics, Southwest Jiao tong University, ChengDu, SiChuan, 61000, China.

Email: uestc-vip@163.com, Tel: 13558768252.

²Logistics Research Institute, Tian Fu College of Southwestern University of Finance and Economics, MianYang, Sichuan, 621000, China. Email: candice20@foxmail.com, Tel: 18780584050.

**Corresponding author*

Abstract

We have clearly witnessed an increasing serious impact on carbon dioxide on the environment. China's Central Economic Conference proposed to develop a green economy in response to global warming. As the main reason for energy consumption, enterprises bore the tremendous pressure of the carbon constraint policy. This paper establishes a cost function and Lagrange function to get the optimal production strategy and pricing decision whether the policy exists or not. So conclusions can be drawn as: with carbon constraint and random demand, for two products: (1) the optimal production would not be higher than the situation without carbon constraint policy; (2) the optimal pricing strategy would not be higher than the situation with none-constraint; (3) the expected profit of enterprises is always less than the situation with none-constraint. Based on the policy made a bad effect on profit enterprises, this paper developed the optimal production strategy to minimize effect.

Keywords: Carbon constraint policy; Pricing strategy; Stochastic demand.

1. Literature Review

The Earth Federation has noted that human activities are the main factors on global climate change over the past 50 years, due to the excessive use of fossil fuels. China is now under a tremendous pressure on carbon emission reduction due to China's extensive economic development model. In 2011 the 17th Party "United Nations Convention on Climate Change" held in Durban, South Africa, China expressed its willingness to conditionally accept a quantified emission reduction agreement after 2020. Using fossil resources is one of the basic input elements of enterprises' production and consumption. Naturally carbon emissions are considered sustainable economic development issues. Hence Chinese government began to implement carbon constraint policy on enterprises to support it. By the way, the carbon constrain policy is also named as the mandatory carbon emission capacity.

Under these circumstances how to maximize profit in the case of a rational allocation of enterprise's resources has been became a focus of enterprises even to society. In the study of production strategies, Peter Letmathe et al. (2004) thought that without any systematic plan under carbon constraint policy, many enterprises always got high fines because of exceeding the standard of carbon emissions. Song and Leng (2011) put forward that enterprises could get the optimal production strategies by government carbon quotas, carbon market trade. However, Zhou et al (2011) thought it was uncertainty for enterprises to choose production strategies of low-carbon products by their own. Therefore, based on this, He and Ma (2011) obtained optimal production strategies and the impact of fluctuations in product demand, product price changes for optimal business decisions. Then Yang et al (2012) found that only the reasonable emission credits can guide the supply chain partners to reduce emissions. Gu and Ju (2012) considered the risk and funding as constraint to establish a cost function, and got the optimal production when the cost function was minimal. In order to get optimal profit, Kong (2013) investigated the proportion of green products and ordinary products under carbon constraint policy. In the study of pricing strategies, Kincaid and Darling (1963) firstly investigated single-product

dynamic pricing problem by establishing a stochastic dynamic programming model and gave the nature of the revenue function. Yan and Liu (2007) got the optimal price by presenting an inventory model. Suresh P. SETHI (2008) investigated the pricing strategies by sensitivity analysis. At the same time, Yin (2008) introduced the marginal cost pricing, Ramsey pricing and monopoly pricing for multi-product pricing strategies in the mobile communications industry. Zhao and Sun (2009) established a dynamic pricing model which maximized enterprises' expected profit through introducing time-space network. Customers' strategic behavior and risk attitudes were considered by Huang *et al* (2010) in enterprises' pricing problem. But aimed at pricing strategies of several non-substitution products, Guan and Ren (2011) presented that enterprises could forecast the market demand by observation and Bayesian rule to gain maximal profit. But sometimes, these strategies couldn't avoid the risk of the improper forecast. Therefore, Liu *et al* (2013) investigated optimal joint pricing and ordering strategies in a single-period newsvendor model with shortage penalty and gave a specific expression of optimal decisions.

To conclude, on product's pricing strategies, a large amount of papers have introduced. But there are few scholars take non-substitutable green products and ordinary products into consideration. Therefore, based on the newsvendor model and the Lagrange function, this paper firstly discussed the pricing strategies without the mandatory carbon emission capacity, and then obtained the pricing strategies with policy. At last, it compared prices, outputs and expected profit of two products under these two conditions.

2. Description of the Problems and Assumptions

This paper studies the production strategy of single enterprise on how to allocate and utilize enterprise resources in a cycle of producing two non-substitutable products (Products1 represents a green product adopted green technology, Products2 represents an ordinary product with standard production technique, product1 and product2 are extremely different types, e.g. optical mouse and keyboard). The price and cost of green products per unit is high. Green consumption is becoming an epidemic concept which not only meets the individual needs of the consumer value but also increase the value of the social image of consumers. It makes green products obtain a certain market share. And based on this, we consider how the two products at reasonable pricing to maximize the expected profits of enterprise.

Table 1. A list of major notations that are used in this paper

Notation	Definition
p_i	Retail price per unit product($i=1,2$)
C_i	Production cost per unit product($i=1,2$)
$C(Q_i)$	Producing cost per single product($i=1,2$)
h_i	Inventory cost per unit product ($i=1,2$)
g_i	Shortage cost per unit product ($i=1,2$)
Q_i	Product output($i=1,2$)
E_i	Carbon emissions per unit product($i=1,2$)
E	Mandatory capacity for carbon emissions
$E[(p_i)]$	Expected profit per single product($i=1,2$)
$f(\cdot)$	Probability density function of the random demand
$F(\cdot)$	Probability distribution function of $f(\cdot)$

In this paper, the above parameters must meet certain conditions so that it can make the model meaningful, this paper assumes that:

- 1) $x \sim U[a, b]$, demand for product on interval $[a, b]$ subjected to uniform distribution.
- 2) $h_1 = h_2$, this condition described that as non-perishable goods the enterprise produced we could consider that the cost of both normal goods and green goods were equal.
- 3) ≤ 0 , this condition described that the policy would make a negative impact on the minimum production cost.

3. A Mathematical Model

3.1 Production strategy

In this chapter, firstly we establish a cost function based on production cost, inventory cost and shortage cost, and then discuss the optimal production strategy in the case of lowest cost.

3.1.1 Production strategy without policy (the mandatory carbon emission capacity)

In this paper, $Q_i > x$ represents the demand exceeds supply, and $Q_i \leq x$ represents supply exceeds or equal to demands. Considering the market demand for product is random, the total cost of enterprises contains two parts which are over supply and short supply, that is:

$$C(Q_i) = \begin{cases} c_i Q_i + h_i(Q_i - x), & Q_i > x \\ c_i Q_i + g_i(x - Q_i), & Q_i \leq x \end{cases} \quad (1)$$

Theorem 1 Without the mandatory carbon emission capacity, there is a combination of the optimal production (Q_1^*, Q_2^*) , which can minimize the total cost of enterprise.

Proof: Deform Eq. (1) can get the cost without carbon emissions limit of enterprise; the above model can be simplified as a product to study:

$$C(Q_i) = \int_0^{Q_i} [c_i Q_i + h_i(Q_i - x)]f(x) dx + \int_{Q_i}^{\infty} [c_i Q_i + g_i(x - Q_i)]f(x) dx \quad (2)$$

In order to get the optimal production Q_i^* , we only need to find out the minimum cost function $\min C(Q_i)$ of products.

$$\begin{aligned} \text{Take first derivative of Eq. (2): } \frac{d[C(Q_i)]}{dQ_i} &= \frac{(h_i + g_i)Q_i}{b - a} + c_i - g_i = 0 \\ Q_i &= \frac{(g_i - c_i)(b - a)}{h_i + g_i} \end{aligned}$$

$$\text{Take second derivative of Eq. (2): } \frac{d^2[C(Q_i)]}{dQ_i^2} = \frac{(h_i + g_i)}{b - a} > 0$$

Q_i is a concave function on $C(Q_i)$, and it appears concave up curves, there is a unique minimal value $\min C(Q_i)$. Therefore, Q_i is the optimal production with minimum cost Q_i^* , and then derive:

$$\begin{cases} Q_1^* = \frac{(g_1 - c_1)(b - a)}{h_1 + g_1} \\ Q_2^* = \frac{(g_2 - c_2)(b - a)}{h_2 + g_2} \end{cases} \quad (3)$$

Theorem 1 shows that there are a combination of the optimal production (Q_1^*, Q_2^*) to minimize the total cost for enterprises without policy. Therefore, producing Q_1^* green products and Q_2^* ordinary products can maximize expected profit of the enterprise.

3.1.2 The production strategy with policy (the mandatory carbon emission capacity)

From the above we know the total production cost without policy:

$$\begin{cases} C(Q_1, Q_2) = \sum_{i=1}^2 \left\{ \int_0^{Q_i} [c_i Q_i + h_i(Q_i - x)]f(x) dx + \int_{Q_i}^{\infty} [c_i Q_i + g_i(x - Q_i)]f(x) dx \right\} \\ s. t \quad \sum_{i=1}^2 E_i Q_i \leq E \end{cases} \quad (4)$$

The constraints express that the enterprise can only produce a certain amount of carbon emission required by the government, so there are two cases exist:

Theorem 2 Under the mandatory carbon emission capacity:

1) When $\sum_{i=1}^2 E_i Q_i^* \leq E$, then the optimal production $Q_i = Q_i^*$

2) When $\sum_{i=1}^2 E_i Q_i^* > E$, then there is $Q_i < Q_i^*$.

Insert Eq. (4) and simplify it, and let λ be Lagrange multiplier constraint condition, and then establish Lagrange function $L(Q_1, Q_2, \lambda)$ as:

$$L(Q_1, Q_2, \lambda) = \sum_{i=1}^2 \left[\frac{(\frac{1}{2}h_i + g_i)Q_i^2}{b-a} + (c_i - g_i)Q_i + g_i \int_{Q_i} x \cdot f(x)dx \right] + \left(\sum_{i=1}^n E_i Q_i - E \right) \quad (5)$$

When $\lambda = 0$, from Eq. (5), we can get : $L(Q_1, Q_2, \lambda) = C(Q_1, Q_2)$, and then get $\sum_{i=1}^2 E_i Q_i \leq E$. Thus the optimal production can be obtained from this case. case 1) is proved.

When $\lambda < 0$, let $\frac{\partial L}{\partial Q_1} = 0$ and can derive:

$$\frac{(h_1 + g_1)Q_1}{b-a} + c_1 - g_1 + E_1 = 0 \quad (6)$$

Similarly, let $\frac{\partial L}{\partial Q_2} = 0$ and can derive:

$$\frac{(h_2 + g_2)Q_2}{b-a} + c_2 - g_2 + E_2 = 0 \quad (7)$$

Take second partial derivative of Q_1 $L(Q_1, Q_2, \lambda)$ on Q_1 and can get: $\frac{\partial^2 L}{\partial Q_1^2} = \frac{(h_1 + g_1)}{b-a} > 0$

$L(Q_1, Q_2, \lambda)$ is a concave function on Q_1 , and it appears concave up curves, there is a minimal value $\min L(Q_1, Q_2, \lambda)$. Therefore, Q_2 is the optimal production with minimum cost Q_2 .

To sum Eq. (6) - (7) up, then we can derive the optimal production:

$$Q_i = \frac{(g_i - c_i - E_i)(b-a)}{h_i + g_i} \quad (8)$$

Insert Eq. (8) into Eq. (5), by calculating $\frac{\partial L}{\partial \lambda} = 0$, we can get:

$$= \frac{g_i^2 E_i (h_i + g_i - c) + g_i h_i E_i (b - a - c_i) + c_i h_i E_i (a - h_i) - E (h_i + g_i)^2}{h_i E_i^2 (g_i + b - a) + g_i^2 E_i^2}$$

Take second derivative of $L(Q_i, \lambda)$, and then get:

$$\frac{\partial^2 L}{\partial \lambda^2} = \frac{E_i^2 (h_i + 2g_i)(b-a)}{(h_i + g_i)^2} + \frac{E_i^2 (b-a)}{h_i + g_i} - \frac{E_i^2 (b-a)}{h_i + g_i} = \frac{E_i^2 (h_i + 2g_i)(b-a)}{(h_i + g_i)^2} > 0$$

$L(Q_i, \lambda)$ Is a concave function on λ , and it appears concave up curves, there is a minimal value $\min L(Q_i, \lambda)$.

Therefore, Q_i^* is the optimal production with minimum cost C_i^* .

That is:

$$Q_i^* = \frac{g_i^2 E_i (h_i + g_i - c) + g_i h_i E_i (b - a - c_i) + c_i h_i E_i (a - h_i) - E (h_i + g_i)^2}{h_i E_i^2 (g_i + b - a) + g_i^2 E_i^2} \quad (9)$$

This is the optimal value which is solved when the Lagrange function has minimum value. So, we can put the Eq. (9) into relation Eq. (8), and then we can derive the optimal production with policy, That is:

$$\begin{cases} Q_1 = \frac{[c_1 h_1 E_1 (h_1 - b) + E (h_1 + g_1)^2] (b - a)}{h_1^2 E_1 (g_1 + b - a) + g_1 h_1 E_1 (h_1 + 2g_1 - a) + g_1^3 E_1} \\ Q_2 = \frac{[c_2 h_2 E_2 (h_2 - b) + E (h_2 + g_2)^2] (b - a)}{h_2^2 E_2 (g_2 + b - a) + g_2 h_2 E_2 (h_2 + 2g_2 - a) + g_2^3 E_2} \end{cases} \quad (10)$$

Thence, when $\frac{\partial L}{\partial Q_i} < 0$, by Eq. (6)-(7) we can get $\frac{\partial L}{\partial Q_i} = \frac{(h_i + g_i) Q_i}{b - a} + c_i - g_i = -E_i > 0$, further step we can get $\sum_{i=1}^2 E_i Q_i > E$. Thence we can derive the optimal production with policy: $Q_i < Q_i^*$. Then case 2) is proved.

Therefore, the theorem 2 expresses: on the one hand, the government's carbon constraint policy has no effect on the production decisions of enterprises when the enterprises' carbon emissions do not exceed the carbon quota set by government, the optimal production meet the Eq. $Q_i = Q_i^*$. In other words, the production of ordinary product and green product equal to the case of no policy. On the other hand, if enterprises' carbon emissions exceeded the allotted carbon emissions required by government, enterprises must adjust their production strategies for the mandatory carbon emissions capacity. The optimal production meet the formula $Q_i < Q_i^*$, that is to say, the production of both two product are less than the case of no policy.

In summary, based on newsvendor model, we established Lagrange function and cost function with random demand, and then we obtained optimal production Q_i^* with maximum expected profit of enterprise in the case of no policy and optimal production Q_i with policy. By comparing those two cases, we have found that $Q_i \leq Q_i^*$, it explains that the policy restrict the enterprises' production strategy. Meanwhile the enterprises' production strategy we derived will help provide references to enterprises for rational allocating resources to minimize cost.

3.2 Pricing strategy

Pricing strategy is related to survival and development of enterprise, and also price is the only marketing factors (product, price, place, and promotion) which can generate revenue directly in the microeconomics. But the supply and demand of product in market is a key element to impact enterprises' pricing strategy. Therefore, under with the random demand of product, we introduce newsvendor model to establish a profit function, and then derive the optimal pricing strategy of enterprises with policy or without policy.

3.2.1 Pricing strategy without policy

Based on cost function and expected profit function is established as:

$$E[(p_1, p_2)] = \sum_{i=1}^2 \left\{ \int_0^{Q_i} [p_i x - c_i Q_i - h_i (Q_i - x)] f(x) dx + \int_{Q_i}^{\infty} [p_i Q_i - c_i Q_i - g_i (x - Q_i)] f(x) dx \right\} \quad (11)$$

Theorem 3 It does exist the optimal pricing strategy (p_i^*, p_i) that maximizes the expected profit of enterprise in the case of random market demand.

Proof: likewise, let Eq. (11) converts into a single product model:

$$E[(p_i)] = \int_0^{Q_i} [p_i x - c_i Q_i - h_i(Q_i - x)]f(x)dx + \int_{Q_i} [p_i Q_i - c_i Q_i - g_i(x - Q_i)]f(x)dx$$

$$\text{Let } \frac{\partial E[(p_i)]}{\partial Q_i} = 0, \text{ and then derive: } p_i = \frac{(h_i + g_i)Q_i + (g_i - c_i)(b - a)}{b - a - Q_i}$$

Take second derivative of $E[(p_i)]$ can get: $\frac{dE[(p_i)]^2}{dp_i^2} = 1 - \frac{Q_i}{b-a} < 0$

$E[(p_i)]$ Is a concave function on p_i , and it appears concave up curves, there is a maximal value $\max E[(p_i)]$. Therefore, p_i is the optimal price when expected profit maximized.

3.2.2 Pricing strategy with policy

In case of no policy, Q_i^* is the optimal production when cost is lowest. In a further step we can derive optimal price p_i by production Q_i , then we can derive p_i^* when expected profit is maximum, so:

$$\begin{cases} p_1^* = \frac{(h_1 + g_1)Q_1^* + (g_1 - c_1)(b - a)}{b - a - Q_1^*} \\ p_2^* = \frac{(h_2 + g_2)Q_2^* + (g_2 - c_2)(b - a)}{b - a - Q_2^*} \end{cases} \quad (12)$$

Under the mandatory carbon emissions capacity, similarly available, we can derive p_i when expected profit is maximum, that is:

$$\begin{cases} p_1 = \frac{(h_1 + g_1)Q_1 + (g_1 - c_1)(b - a)}{b - a - Q_1} \\ p_2 = \frac{(h_2 + g_2)Q_2 + (g_2 - c_2)(b - a)}{b - a - Q_2} \end{cases} \quad (13)$$

Therefore, the theorem 3 expresses: After enterprises developed optimal production strategies, There is always a group of optimal pricing strategy which allows companies to maximize profits expectation whether there is policy with stochastic demand or not. The result can provide references for enterprises to minimize the loss of profits with policy.

Corollary 1 the optimal price of enterprises with the mandatory carbon emissions capacity is lower than the case without policy, that is $p_i \leq p_i^*$.

Proof: let Δp_i represents the optimal price gap between two conditions per unit product.

$$\Delta p_i = p_i - p_i^* = \frac{[(b - a)h_i + (2g_i - c_i)(b - a)](Q_i^* - Q_i)}{(b - a - Q_i^*)(b - a - Q_i)}$$

From Eq. (3) we can get: $g_1 \geq c_1$ therefore $2g_1 - c_1 > 0$

From the theorem 1 we know: $Q_i \leq Q_i^*$

In summary $\Delta p_i \geq 0$, then $p_i \leq p_i^*$, theorem 1 proved.

Corollary 1 expresses: The policy results in lower production volume of enterprises. With stochastic demand market, we found that the optimal price of enterprises with policy is still lower than the case without policy.

3.3 Expected profit of enterprise

Regard newsvendor model as a theoretical basis, then we establish a profit function model and simplify the profit function as follows:

$$E[(p_1, p_2)] = \sum_{i=1}^2 \left\{ (p_i + g_i - c_i)Q_i - (p_i + g_i + h_i) \frac{Q_i^2}{2(b-a)} - \frac{1}{2}g_i(b-a) \right\}$$

3.3.1 Expected profit without policy

$$E(\pi) = \sum_{i=1}^2 \left\{ \int_0^{Q_i^*} [p_i^*x - c_iQ_i^* - h_i(Q_i^* - x)]f(x)dx + \int_{Q_i^*}^b [p_i^*Q_i^* - c_iQ_i^* - g_i(x - Q_i^*)]f(x)dx \right\}$$

Substitute the optimal price with no policy (Eq.12) and optimal production (Eq. 3) into the above equation, and then obtain:

$$E(\pi) = (p_1^* + g_1 - c_1)Q_1^* + (p_2^* + g_2 - c_2)Q_2^* - \left[(p_1^* + g_1 + h_1)Q_1^{*2} + (p_2^* + g_2 + h_2)Q_2^{*2} \right] \cdot \frac{1}{2(b-a)} - \frac{1}{2}(g_1 + g_2)(b-a)$$

3.3.2 Expected profit with policy

$$E(\pi) = \sum_{i=1}^2 \left\{ \int_0^{Q_i} [p_i x - c_iQ_i - h_i(Q_i - x)]f(x)dx + \int_{Q_i}^b [p_i Q_i - c_iQ_i - g_i(x - Q_i)]f(x)dx \right\}$$

Substitute the optimal price with carbon emission limit Eq. (13) and optimal production Eq. (10) into the above equation, and then obtain:

$$E(\pi) = (p_1 + g_1 - c_1)Q_1 + (p_2 + g_2 - c_2)Q_2 - \left[(p_1 + g_1 + h_1)Q_1^2 + (p_2 + g_2 + h_2)Q_2^2 \right] \cdot \frac{1}{2(b-a)} - \frac{1}{2}(g_1 + g_2)(b-a)$$

Corollary 2 The expected profit under the mandatory carbon emissions capacity is lower than the case that with no policy, that is $\pi \leq \pi^*$.

Proof: From theorem 2, we can get:

When $\sum_{i=1}^2 E_i Q_i \leq E$, then $Q_i = Q_i^*$, from it can derive $\pi = \pi^*$.

When $\sum_{i=1}^2 E_i Q_i > E$, then $Q_i < Q_i^*$, from it can derive $\pi < \pi^*$.

Therefore, the expected profit of enterprise under carbon constraint policy $\pi \leq \pi^*$

Corollary 2 shows that the expected profit of enterprises under the mandatory carbon emissions capacity is lower than the condition without policy.

4. Conclusion

This paper studies on pricing strategy for two non-substitutable products of single manufacturing enterprise in a production cycle. By comparing the changes of the manufacturing enterprise's production, price, profit on two different conditions (with or without the mandatory carbon emission capacity), then we draw a conclusion that the mandatory carbon emissions capacity would have an adverse affect on the development of enterprise. Meanwhile, we develop production strategy and pricing decision for enterprise under the policy to maximize profit from the perspective of enterprise. We hope that our conclusions can provide a useful reference for enterprises' business decision-making behavior and lay a theoretical foundation for the study of two non-substitutable products under carbon tax policy. Furthermore, this paper only considers the mandatory carbon emissions capacity, in the further study, we can introduce the cap-and-trade policy (enterprises can trade carbon credits), which standardize carbon market mechanism and encourage enterprises to develop low carbon economy by the dual means ---regulation and market. Then we can introduce the green-tech investment in further research, and finally extend to study on two substitute products. In pursuit of a low-carbon economy, at the same time, we constantly correct market failures of enterprises due to external factors and achieving sustainable economic development.

References

- Letmathe P, Balakrishnan N. (2004), Environmental considerations on the optimal product mix, *European Journal of Operational Research* 2004(167): 398-412.
- Song J, Leng M. (2011), Analysis of the single-period problem under carbon emissions policies, *Springer's Handbook*, October 2011: 1-15.
- Zhou J, Nie H, Zhang G, et al. (2011), Game analysis of the production strategy at the background of low-carbon economic, *Science & technology progress and policy* 28(24): 088-091.
- He D, Ma H. (2011), The production and storage strategy of enterprises under carbon emission constraints, *Resources and Industries* 13(2): 063-068.
- Jun Yang, Li J, Lu W. (2012), The impact of the system dynamic's carbon emissions policy on supply chain, *Industrial Engineering and Management* 17(4): 021-030.
- Gu S, Ju Y. (2012), The optimal solution research on multi-product newsboy model with capital and risk constraints, *Soft Science* 26(3): 129-133.
- Kong L. (2013), Optimization research of production strategy under the limit of carbon emissions, Chengdu Sichuan: UESTC.
- Kincaid W.M, Darling, Donald A. (1963), An inventory pricing problem, *Mathematical Analysis and Applications* 7(2): 183-208.
- Xiaoming Yan, Ke Liu. (2007), Optimal Dynamic Pricing for Perishable Product, The ninth youth information and management scholars conference in China, Wuhan, August 20-24, 2007, 407-414.
- Suresh P.SETHI. (2008), Optimal pricing of a personalized, *System Science and System Engineering* 1004-3756: 1-6.
- Xiaolin Yin. (2008), Multi-product pricing strategies research in the mobile communications industry, Chengdu Sichuan: UESTC, June 8, 2008.17-20.
- Dawei Zhao, Xiaoyu Sun (2009), Multi-product dynamic pricing strategies research under uncertain demand, *Commercial Research* 04 (385): 1-4.
- Song Hong, Chao Yang, Xi Zhang (2010), The price and inventory control problem of a class of a newsvendor model when considering customers' strategic behavior, *Operations Research and Management Science*, 19(3): 1-6.
- Zhenzhong Guan, Jianbiao Ren (2011), Perishable high-tech products pricing strategy research under uncertain demand, *Journal of Systems Engineering* 26(1): 2-8.
- Yushuang Liu, Jihui Zhang, Lili Wang (2013), The optimal joint price and order of a newsvendor model under two demand model, *Control and Decision* 28(9): 2-4.

Predicting Consumers' Behavioral Intention of Adopting Green Logistics Service Providers

Chiung-Lin Liu¹ and Ting-Yu Chang²

¹Department of Shipping and Transportation Management, National Taiwan Ocean University, Keelung, Taiwan, ROC. Tel.: +886-2-2462-2192 ext. 3425, Email:realsky@ntou.edu.tw/realskyer@googlemail.com.

²Department of Shipping and Transportation Management, National Taiwan Ocean University, Keelung, Taiwan, ROC. Email: jeff200318@hotmail.com.

*Corresponding author

Abstract

This study aimed to evaluate the relationships among attitude toward green practices of LSPs (logistics service providers), attitude toward adopting GLSPs (green logistics service providers), and behavioral intention of adopting GLSPs in a consumer perspective. A survey of 201 consumers in Taiwan was carried out, using factor analysis and structural equation modelling. The results indicated that attitude toward adopting GLSPs had positive influence on behavioral intention of adopting GLSPs. Furthermore, the research suggested that attitude toward green practices of LSPs cannot always directly influence behavioral intention of adopting GLSPs, through a positive attitude toward adopting GLSPs, consumers will have positive behavioral intention of adopting GLSPs.

Keywords: Green logistics; Customer' behavioral intention; Green logistics service providers

1. Introduction

Sustainable development has attracted more and more attention from the transportation and logistics industry (Beskovnik and Twrdy, 2012); examples include green road freight transportation (Furst and Oberhofer, 2012), green railroad transportation (McClellan, 2011), and green maritime transportation (Lu et al., 2014). In recent years, many LSPs have started to implement the policy of energy saving and carbon reduction (e.g., using biofuels to replace fossil fuels). Besides, more and more citizens are environmentally conscious, LSPs' green practices can only fulfill the corporate social responsibility (CSR) (Furst and Oberhofer, 2012) but also increase their reputation and probability (Lieb and Lieb, 2010).

LSPs' green practices can satisfy customers' expectation (Lieb and Lieb, 2010) and also decrease companies' operating cost (Chen, 2005; Lieb and Lieb, 2010). Previous studies (e.g., Lieb and Lieb, 2010; Lin and Ho, 2008) have analyzed factors that influence if LSPs implement green practices. Previous studies (e.g., Cheng and Lee, 2010; Wolf and Seuring, 2010) also have examined the factors affecting GLSP selection from a shipper's perspective. However, there have been few empirical researches discussing LSPs' green practices and citizens' intention of using these LSPs' service. Literature review of environmental management shows convenience is a key factor that determines if citizens devote themselves to environmental protection activities (do Valle et al., 2004; Ramayah et al., 2010). Under the trend of sustainable development, if LSPs can understand consumers' behavioral intention in advance and formulate corresponding green development strategy, then they can sustain their competitive advantage and decrease their operating risks.

Previous studies on green logistics were mostly done by European and American researchers, and there were few Asian perspectives. One possible explanation for this phenomenon is that Asian countries are less environmentally friendly than European and American countries and thus less developed in regards to green logistics. Nevertheless, in the past few years, Taiwan, a small, resource-absent, and densely populated island, has become one of the environmentally friendly Asian countries. For example, Taiwan, since 2002, has started implementing its restricted use policies on plastic materials (one of them has been that shops could no longer

provide plastics bags for consumers). Since 2006, all public institutions have stopped using disposable tableware. Taiwan's municipal waste recycling rate has also increased rapidly from 2002's 11.6% to 2012's 57.46% (Environmental Protection Administration (Taiwan), 2014). Apparently, Taiwanese citizens are aware of sustainable living and willing to support it as well as implement it to daily life. This provides very favorable advantage for Taiwan's LSPs to develop green service or even become green logistics service provider (GLSPs). This brings to the key question posed by the research:

Does attitude toward green practices of LSPs influence attitude toward adopting GLSPs and behavioral intention of adopting GLSPs?

2. Literature Review and Research Hypotheses

2.1 Theory of reasoned action (TRA)

The key concept of the TRA predicts the impact of personal attitude on their behavior (Ajzen and Fishbein, 1980). This theory argues that behavior is determined by behavioral intention, which is determined by attitude and subjective norm (Ajzen and Fishbein, 1980).

Unlike the theory of planned behavior (TPB) (Ajzen, 1985, 1991), which is an extended theory of the TRA, the TRA does not take non-volitional factors (e.g., personally controlled resources) into consideration (Ajzen, 1985). For this reason, when discussing behavior that is not completely determined volitionally, TRA will have less explanatory power for behavior (Ajzen, 1985). For this study, however, since there have been none certified GLSP in Taiwan, it is not easy to examine consumers' non-volitional factors, such as consumers' acceptance of the service charge by current GLSPs. Under this circumstance, the TRA has been widely utilized as a model to predict behavioral intention of a person (Ryu and Han, 2010). Therefore, the TRA can establish a theoretical base for this study.

2.2 Green practices of LSPs

Green practices of LSPs in this study represent the "considerations taken in respect of the natural environment" in the supply of logistics services (Martinsen and Björklund, 2012). A number of previous studies have identified examples of green practices of LSPs. For example, green categories in LSPs' offerings identified by Wu and Dunn (1995) include raw materials acquisition, inbound logistics, transformation, outbound logistics, marketing, and after-sales service. As for the green practices of the world's top 50 largest third party logistics providers, those more relevant to consumers can be divided into three aspects: green transportation, green pickup, and green package (DHL International, 2013; FedEx, 2013; UPS, 2013).

2.3 The relationship between attitude toward green practices of LSPs and attitude toward adopting the GLSPs

Previous studies suggest that the attitude toward green purchase is positively correlated to attitude toward the willingness to trade material welfare for environmental benefits (Ek, 2005). Besides, consumers' attitude toward different LSPs' green practices, which are influenced by personal rights (e.g., convenience of pickup) and overall evaluation of personal environmental protection belief, will in turn influence their attitude toward adopting GLSPs. Therefore, this study proposes the following additional hypotheses:

- H1 Attitude toward green practices of LSPs positively influences attitude toward adopting GLSPs
- H1-1 Attitude toward green transportation of LSPs positively influences attitude toward adopting GLSPs
- H1-2 Attitude toward green pickup of LSPs positively influences attitude toward adopting GLSPs
- H1-3 Attitude toward green package of LSPs positively influences attitude toward adopting GLSPs

2.4 The relationship between attitude toward green practices of LSPs and behavioral intention of adopting GLSPs

Behavior of adopting GLSPs is a pro-environmental behavior, representing a behavior of “seeking to minimize the negative impact of one’s actions on nature” (Kollmuss and Agyeman, 2002). Previous studies indicate that pro-environmental behavior will be influenced by mental conditions, such as altruistic attitudes (Clark et al., 2003) and environmental attitudes (Clark et al., 2003; Flamm, 2009; Flamm and Agrawal, 2012). On the other hand, Stern et al. (1993) argue that people’s pro-environmental behavior is only concerned with each individual’s combination of egoistic, social-altruistic, and biocentric value orientations. In this study, consumers’ attitude toward green practices of LSPs can be seen as an environmental attitude as well as a combination of egoistic, social-altruistic, and biocentric value orientations. For example, before adopting green pickup service, consumers can comprehensively evaluate environmental protection as well as the convenience of pickup. Moreover, the TRA says that factors that influence behavior will exercise their influence on behavior through behavioral intention. To sum up, this study infers that the attitude toward green practices of LSPs positively influence behavioral intention of adopting GLSPs. Such inference leads to the following hypotheses:

- H2 Attitude toward green practices of LSPs positively influences behavioral intention of adopting GLSPs
- H2-1 Attitude toward green transportation of LSPs positively influences behavioral intention of adopting the GLSPs
- H2-2 Attitude toward green pickup of LSPs positively influences behavioral intention of adopting GLSPs
- H2-3 Attitude toward green package of LSPs positively influences behavioral intention of adopting GLSPs

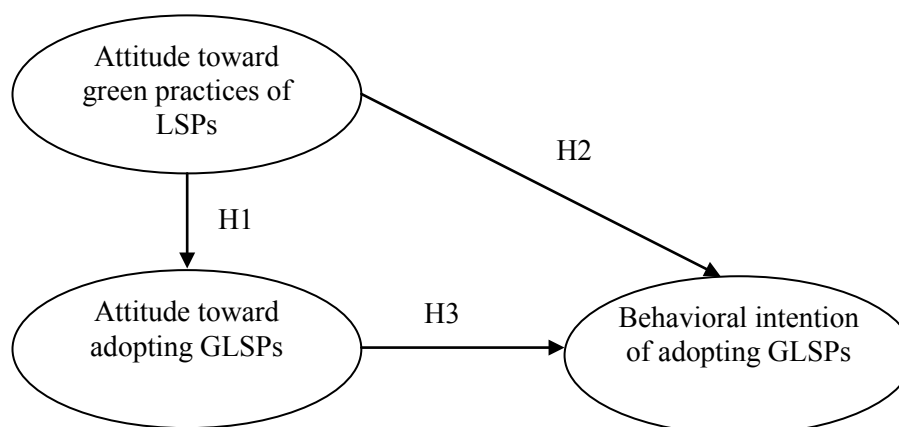
2.5 The relationship between attitude toward adopting GLSPs and behavioral intention of adopting GLSPs

Based on the TRA theory, the green behavioral intention of consumers is influenced by an individual’s attitude toward the behavior. Researchers have also suggested that the green behavior intention is positively correlated to an individual’s attitude toward the green behavior (Chan, 2001; Han et al., 2010; Lee et al., 2010). Stated in a hypothesis form, here is the H3:

H3 Attitude toward adopting GLSPs positively influences behavioral intention of adopting GLSPs.

With reference to the foregoing literature review, a conceptual model is proposed in Figure 1.

Fig 1. The proposed model of the present study



3. Method

3.1 Sampling

The sample source of this study was from a Taiwan’s BBS forum. The forum is a comprehensive forum that has the highest daily visits in Taiwan. In its daily peak hours, there are more than 150,000 users online at the same time. Ages of the users are mostly 15-45, corresponding to the age distribution of Taiwan’s major online

shoppers (ages of 70% of Taiwan's online shoppers are 15-45 (Institute for Information Industry (Taiwan), 2013), and the forum for taking the questionnaire corresponds to the age distribution and gender balance.

3.2 *Instrument*

The design of this study's questionnaire follows Dillman's suggestions (Dillman, 2007). It consisted of three parts: attitude toward green practices of LSPs, attitude toward adopting GLSPs, and behavioral intention of adopting GLSPs. 19 items selected as measures of attitude toward green practices of LSPs were based upon previous literature (refer to section 2.2 for green practice more relevant with consumers). Respondents were asked to indicate their level of support for each item, where 1 represented "strongly not support" and 7 represented "strongly support."

Four items and a 7-point semantic differential scale were employed to assess attitude toward adopting GLSPs that had been employed in previous literature ("For me, adopting a green logistics service provider is" 1 = extremely negative, 7 = extremely positive; 1 = very worthless, 7 = very valuable; 1 = very unimportant, 7 = very important; 1 = extremely foolish, 7 = extremely wise) (Han et al., 2010; Litvine and Wüstenhagen, 2011; Sparks and Pan, 2009). Moreover, this study adopted existing validated items to assess behavioral intention of adopting GLSPs (e.g., Han et al., 2010) that were all measured using a 7-point scale (e.g., "I am willing to adopt a green logistics service provider" 1 = strongly disagree, 7 = strongly agree).

3.3 *Analysis methods*

A partial least squares structural equation modeling (PLS-SEM/PLS) approach was used to test the research hypotheses. This study chose the PLS approach since the study was exploratory rather than theory confirmatory (Marcoulides and Saunders, 2006). Moreover, the main objective of this study was to predict target constructs (Hair et al., 2014). PLS was thus an appropriate analysis technique for this study. In this study, all analyses were carried out using the SPSS version 12.0 and the SmartPLS version 2.0.M3 statistical packages.

4. **Analysis Results**

4.1 *Data screening and representativeness*

The data collection phase of the study began in the beginning of February 2014 and ended in the middle of February 2014. This study adopted the following approaches to increase the quality and representativeness of the analyzed data. First, samples with overly short responding time were deleted (through the pretesting of the questionnaire, it was concluded that reasonable responding time for this questionnaire should be at least 3.5 minutes). Second, respondents lacking online shopping experience were deleted. Last, the rest samples were treated with stratified sampling so the age distribution of the respondents would correspond to the survey results of Institute for Information Industry (Institute for Information Industry (Taiwan), 2013). After the above screening, there were 201 effective samples left, which satisfied the PLS's minimal requirement for sample number (Hair et al., 2014). Besides, since all items of online questionnaire employed by this study were set to be required, the raw data would not have the issue of missing value.

4.2 *Profile of respondents*

The occupations of these respondents belonged to included student (25.9%), service sector employee (22.9%), manufacturing industry employee (18.4%), military, public, and teaching personnel (16.9%), freelancers (9%), and other occupations (7%). The online shopping experiences of the respondents ranged evenly from 1 to 10 years. Their online shopping frequency of the recent year were mainly 2-3 times (40.8%) and 0-1 time (37.8%). Their monthly average expense of the recent year was within NT\$2000 dollars (or US\$67) (55.2%).

4.3 *Assessment of common method variance*

The three scales with 26 items were factor analyzed by using principal components analysis where the

unrotated factor solution was examined (Podsakoff and Organ, 1986). The results indicated the existence of 5 factors with eigenvalues greater than one. These five factors explained 65% of the variance among the 26 items, while the first factor accounted for only 37% of the variance. Thus common method variance did not appear to be a serious threat to validity (Podsakoff and Organ, 1986).

4.4 Exploratory factor analysis (EFA)

The original 19 items of attitude toward green practices of LSPs were reduced to a manageable set of underlying factors and principal axis method with direct oblimin rotation employed to identify key dimensions of LSPs' green practices. A combination approach using a scree test followed by a parallel analysis approach was used to determine the number of factors (Lance and Vandenberg, 2009). The criteria for identifying significant factor loadings (values > 0.4) based on sample size recommended by Hair (2010).

Table 1. Exploratory factor analysis of attitude toward green practices of LSPs

Items	Factor 1	Factor 2	Factor 3
g12 Electronic invoice is used to replace paper invoice.	.411		
g13 Paper box is printed with eco-friendly ink.	.733		
g14 Proper-sized paper box is used when the safety of goods is ensured.	.847		
g15 Paper box is made of recycled paper when the safety of goods is ensured.	.882		
g16 More streamlined package is adopted when the safety of goods is ensured.	.881		
g17 Decomposable packing materials are used when possible and when the safety of goods is ensured.	.653		
g18 Recyclable packing materials are used when possible.	.966		
g19 Packing materials are unified when possible for the purpose of easy recycling.	.627		
g8 Distributing starts when vehicles have certain amount of loading, although the delivery time will become uncertain.		.506	
g9 Goods are accumulated before being delivered at night, so as to reduce oil consumption caused by traffic jam, although the pickup time will be prolonged		.671	
g10 Charges are differentiated by if consumers can pick up the item on the time specified by distributors		.574	
g11 Charges are differentiated by whether consumers choose pickup at a convenience store or home delivery, so as to encourage pickup at a convenience store		.534	
g2 Carbon emissions during transportation are marked down.			.412
g3 Recycled water (e.g., rainwater) is used to wash delivery vehicles.			.406
g4 Green vehicles (e.g., hybrid electric vehicles) are used for delivery.			.795
g5 Delivery vehicles use biofuels (e.g., soybean) to replace fossil fuels.			.813
g6 Delivery vehicles are made of lighter materials to reduce oil consumption.			.467
Eigenvalue	6.806	1.864	1.441
Percentage variance	40.033	10.963	8.474
Cronbach Alpha	.903	.672	.767

Table 1 illustrates the two items deleted from the EFA procedures. Three latent factors were identified and accounted for around 59% of the total variance based on the 17 significant variables after the deletion. The first factor, as shown in Table 1, consisted of eight items and accounted for 40.03% of the total variance. All items were related to green package, and this factor, therefore, was called green package. Factor 2 consisted of four items and those items were related to green pickup. This factor, therefore, was termed green pickup and accounted for 10.96% of the total variance. Factor 3 included five items and all items were related to green transportation. Thus, this factor was named green transportation, and it accounted for 8.47% of the total variance.

Cronbach α values, the most common form of internal consistency reliability coefficient, were statistically determined for each dimension. Cronbach α values for each dimension were also presented in Table 1. All of the reliability scores exceeded the minimum reliability standard of 0.60 (Hair, 2010).

4.5 Measurement model

Results of the PLS analysis are presented in Tables 2 and 3. The loadings and cross-loadings of indicators were examined for convergent and discriminant validity of the measurement model. One variable was deleted because of factor loading < 0.6 (Marcoulides and Saunders, 2006). All of the indicators presented in Tables 2 load higher on the construct of interest than on any other variables, thereby assuring discriminant validity (Hair et al., 2014). Most of the individual loadings were greater than 0.707 (Hair et al., 2014), thereby providing evidence for these constructs' convergent validity.

Reliability results are shown in Table 3. The composite reliabilities of the different measures ranged from 0.801 to 0.947, which exceeded the recommended threshold value of 0.700 (Fornell and Larcker, 1981). Table 3 also presents average variance extracted (AVE) as well as correlations among constructs. The AVE for every measure fulfilled Fornell and Larcker's (1981) accepted value of 0.5. These results support the convergent validity of our measures. The correlation matrix indicates that the square root of AVE of each measure was higher than corresponding correlation values for that variable in all cases, thereby assuring discriminant validity (Hair et al., 2014). In sum, the results of Tables 2 and 3 provide support for the measures' reliability and validity.

Table 2. Factor loadings (bolded) and cross loadings

Items	Green transportation	Green pickup	Green package	Attitude	Behavioral intention
g2	0.626	0.226	0.329	0.272	0.239
g3	0.678	0.303	0.448	0.225	0.284
g4	0.817	0.207	0.469	0.286	0.404
g5	0.772	0.113	0.401	0.271	0.338
g6	0.691	0.274	0.399	0.304	0.270
g8	0.197	0.687	0.144	0.217	0.247
g9	0.175	0.778	0.170	0.248	0.305
g10	0.198	0.649	0.143	0.108	0.185
g11	0.292	0.717	0.376	0.265	0.268
g13	0.479	0.269	0.809	0.429	0.476
g14	0.472	0.291	0.855	0.379	0.446
g15	0.498	0.183	0.891	0.366	0.446
g16	0.453	0.278	0.878	0.365	0.484
g17	0.582	0.282	0.827	0.402	0.414
g18	0.432	0.208	0.898	0.382	0.478
g19	0.473	0.286	0.767	0.322	0.429
a1	0.385	0.335	0.532	0.876	0.576
a2	0.281	0.313	0.325	0.891	0.493
a3	0.306	0.189	0.380	0.902	0.507
a4	0.331	0.227	0.289	0.838	0.528
b1	0.382	0.300	0.482	0.549	0.919
b2	0.406	0.327	0.513	0.553	0.942
b3	0.412	0.375	0.489	0.568	0.906

Table 3. Inter-construct correlations: consistency and reliability tests

	AVE	Composite Reliability	Attitude	Behavioral intention	Green transportation	Green package	Green pickup
Attitude	0.769	0.930	0.877				
Behavioral intention	0.851	0.945	0.604	0.923			
Green transportation	0.518	0.842	0.376	0.434	0.720		
Green package	0.718	0.947	0.447	0.536	0.570	0.848	
Green pickup	0.503	0.801	0.309	0.363	0.303	0.303	0.709

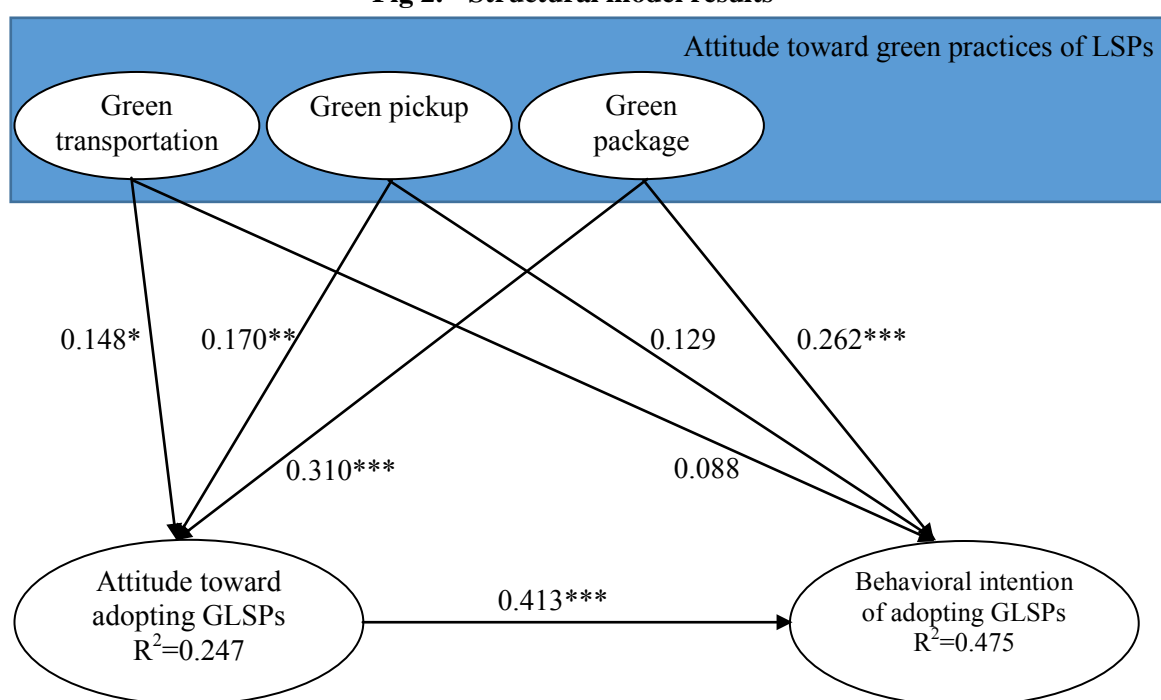
* Square root of the AVE on the diagonal.

4.6 Structural Model

The results of the PLS analysis for the research model are presented in Figure 2 and Table 4. Bootstrapping was used to evaluate the standard errors and t-values of path coefficients. 5000 samples in the bootstrapping settings were used (Hair et al., 2014). The R^2 here indicates the amount of variance explained by the model (Esposito Vinzi et al., 2010).

Results indicated that attitude toward all three types of green practices of LSPs demonstrated a direct, statistically significant, positive correlation with attitude toward adopting GLSPs (path coefficient = 0.148, $p < 0.05$ for green transportation; path coefficient = 0.170, $p < 0.01$ for green pickup; path coefficient = 0.310, $p < 0.001$ for green package). These results support H1-1, H1-2 and H1-3. Moreover, attitude toward green package of LSPs demonstrated a direct, statistically significant, positive correlation with behavioral intention of adopting GLSPs (path coefficient = 0.262, $p < 0.001$), and thus the results support H2-3. In contrast, attitude toward green transportation and pickup of LSPs did not demonstrate a direct, statistically significant correlation with behavioral intention of adopting GLSPs, and thus H2-1 and H2-2 are not supported. Additionally, attitude toward adopting GLSPs had a positive influence (path coefficient = 0.413, $p < 0.001$) on behavioral intention of adopting GLSPs, and thus H3 is supported. It was confirmed that the attitude toward adopting GLSPs plays an intermediary role between attitude toward green practices of LSPs and behavioral intention of adopting GLSPs.

Fig 2. Structural model results



* Represents significant level $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$

Table 4. Structural model results

	Paths	Path coefficient	Standard Error	t-value	Supported/ Not-supported
H1-1	Green transportation → Attitude	0.148	0.075	1.966	Supported
H1-2	Green pickup → Attitude	0.170	0.065	2.621	Supported
H1-3	Green package → Attitude	0.310	0.073	4.244	Supported
H2-1	Green transportation → Behavioral intention	0.088	0.066	1.342	Not Supported
H2-2	Green pickup → Behavioral intention	0.129	0.071	1.804	Not Supported
H2-3	Green package → Behavioral intention	0.262	0.067	3.942	Supported
H3	Attitude → Behavioral intention	0.413	0.071	5.840	Supported

5. Conclusion and Implications

The objective of this study was to evaluate the relationship among attitude toward green practices of LSPs, attitude toward adopting GLSPs, and behavioral intention of adopting GLSPs. The purpose was to provide a basis for LSPs to formulate and design their green logistics service in the future.

The results indicated that attitude toward adopting GLSPs positively influenced behavioral intention of adopting GLSPs (H3). The results supported the TRA that attitude has a positive influence on behavioral intention. The results also supported earlier findings (e.g., Chan, 2001) that green purchase intention was explained by attitude toward green purchase.

A positive and significant correlation was found between attitude toward green practices of LSPs and the attitude toward adopting GLSPs (H1-1, H1-2 and H1-3). However, among all three kinds of green practices, only attitude toward green package had a positive influence on behavioral intention of adopting GLSPs (H2-3). Compared to green transportation focusing on the environmental protection behavior during delivery, green package had a more direct relationship with consumers. Also, unlike green pickup that compromises consumers' pickup timeliness and convenience, green package caused less loss of consumer rights. The results indicated that, even when consumers supported green practices of LSPs, only those green practices that were more relevant to them and not negatively influencing their pickup timelessness as well as convenience could directly influence their behavioral intention of adopting GLSPs.

Even among all green practices of LSPs, only the positive toward green package could positively influence behavioral intention of adopting GLSPs (H2-3), but all positive support for every green practice of LSPs, through positive attitude toward adopting GLSPs, could positively influence behavioral intention of adopting the GLSPs. As for the positive attitude toward green practices of LSPs, it only proved that consumers had positive feeling and perception for these practices. However, the key is still whether consumers have positive attitude toward adopting GLSPs, so their behavioral intention of adopting the GLSPs can be positively influenced.

Several contributions have been made by this study to both the theory and practice. Firstly, this study provides a theoretical framework to connect attitude toward green practices of LSPs, attitude toward adopting GLSPs, and behavioral intention of adopting GLSPs. Secondly, attitude toward green practices of LSPs cannot totally directly influence behavioral intention of adopting GLSPs, through a positive attitude toward adopting GLSPs, consumers will have positive behavioral intention of adopting GLSPs.

The findings of this study have implications for practice and research. The results showed that even when consumers had positive attitude toward green practices of LSPs, only those green practices that were more relevant to them and not negatively influencing their pickup timelessness as well as convenience could directly influence their behavioral intention of adopting GLSPs. Thus, when LSPs attempt to become green enterprises in the future, they should first consider this finding when providing green service, so they can enjoy highest benefit. Second, the research findings revealed that attitude toward adopting GLSPs was the critical source of positive behavioral intention of adopting GLSPs. LSPs should test providing green service first in an area with positive attitude toward adopting GLSP; in this way, they can understand feedbacks from the market and lower their operational risks. On the other hand, LSPs should also figure out how to continuously improve consumers' attitude toward adopting GLSPs, so their green practices can have continuous development.

As with all research, the current study has certain limitations. First, this research was limited to the study of markets in Taiwan. Secondly, the research samples for consumers were drawn from consumers at the age of 15-45. Although consumers of this age account for 70% of Taiwan's online shoppers (Institute for Information Industry (Taiwan), 2013). Finally, since Taiwan's GLSPs have not been truly developed, this research can only investigate consumers' behavioral intention, instead of their actual behavior.

Several important issues for further research are suggested. First, future research can conduct a cross-national comparison to understand if different environmental protection ideas among nations have an influence on the choice of GLSPs. Secondly, future research can introduce other variables to increase the explanatory power

for behavioral intention of adopting GLSPs, such as consumers' environmental friendly activities (Han et al., 2010), demographic determinants (Clark et al., 2003), and the framework of the TPB (Ajzen, 1985, 1991).

Acknowledgment

The authors would like to thank the National Science Council of the Republic of China, for financially supporting this research under Contract No. NSC 102-2410-H-019-018.

References

- Ajzen, I. (1985), From Intentions to Actions: A Theory of Planned Behavior. In Kuhl, J. and Beckmann, J. (eds.) *SSSP Springer Series in Social Psychology, Action Control* :11-39, Springer Berlin Heidelberg.
- Ajzen, I. (1991), The theory of planned behavior, *Organizational Behavior and Human Decision Processes* 50(2): 179-211.
- Ajzen, I. and Fishbein, M. (1980), *Understanding attitudes and predicting social behavior*. Englewood Cliffs, London: Prentice-Hall.
- Beskovnik, B. and Twrdy, E. (2012), Green logistics strategy for south east europe: To improve intermodality and establish green transport corridors, *Transport* 27(1): 25-33.
- Chan, R. Y. K. (2001), Determinants of Chinese consumers' green purchase behavior, *Psychology and Marketing* 18(4): 389-413.
- Chen, C.-C. (2005), Incorporating green purchasing into the frame of ISO 14000, *Journal of Cleaner Production* 13(9): 927-933.
- Cheng, Y.-H. and Lee, F. (2010), Outsourcing reverse logistics of high-tech manufacturing firms by using a systematic decision-making approach: TFT-LCD sector in Taiwan, *Industrial Marketing Management* 39(7): 1111-1119.
- Clark, C. F., Kotchen, M. J. and Moore, M. R. (2003), Internal and external influences on pro-environmental behavior: Participation in a green electricity program, *Journal of Environmental Psychology* 23(3): 237-246.
- DHL International. (2013), Official website, Accessed 1 March, 2013 on World Wide Web: <http://www.dhl.com/en.html>.
- Dillman, D. A. (2007), *Mail and internet surveys : the tailored design method : with new internet, visual, and mixed-mode guide*. 2nd ed. 2007 update ed. Hoboken, N.J.: Wiley ; Chichester : John Wiley.
- do Valle, P. O., Reis, E., Menezes, J. and Rebelo, E. (2004), Behavioral Determinants of Household Recycling Participation: The Portuguese Case, *Environment and Behavior* 36(4): 505-540.
- Ek, K. (2005), Public and private attitudes towards "green" electricity: the case of Swedish wind power, *Energy Policy* 33(13): 1677-1689.
- Environmental Protection Administration (Taiwan). (2014), *Yearbook of Environmental Protection Statistics, 2013*. Accessed 8 March, 2014 on World Wide Web: <http://www.epa.gov.tw/ch/SitePath.aspx?busin=4177&path=4327&list=4327>.
- Esposito Vinzi, V., Chin, W. W., Henseler, J. and Wang, H. (2010), *Handbook of partial least squares: concepts, methods and applications*. Berlin; London: Springer.
- FedEx, (2013), Official website, Accessed 1 March, 2013 on World Wide Web: www.fedex.com.
- Flamm, B. (2009), The impacts of environmental knowledge and attitudes on vehicle ownership and use, *Transportation Research Part D: Transport and Environment* 14(4): 272-279.
- Flamm, B. J. and Agrawal, A. W. (2012), Constraints to green vehicle ownership: A focus group study, *Transportation Research Part D-Transport and Environment* 17(2): 108-115.
- Fornell, C. and Larcker, D. F. (1981), Evaluating Structural Equation Models with Unobservable Variables and Measurement Error, *Journal of Marketing Research (JMR)* 18(1): 39-50.
- Furst, E. and Oberhofer, P. (2012), Greening road freight transport: evidence from an empirical project in Austria, *Journal of Cleaner Production* 33: 67-73.
- Hair, J. F. (2010), *Multivariate data analysis : a global perspective*. 7th ed. / Joseph F. Hair ... [et al.]. ed. Upper Saddle River, N.J. ; London: Pearson Education.
- Hair, J. F., Hult, G. T. M., Ringle, C. and Sarstedt, M. (2014), *A primer on partial least squares structural equations modeling (PLS-SEM)*, Los Angeles: SAGE.
- Han, H., Hsu, L.-T. and Sheu, C. (2010), Application of the theory of planned behavior to green hotel choice:

- testing the effect of environmental friendly activities, *Tourism Management* 31(3): 325-334.
- Institute for Information Industry (Taiwan). (2013), Analysis of the e-shopping experience in Taiwan, *Journal of Digital Knowledge* 34: 3-7 (in Chinese).
- Kollmuss, A. and Agyeman, J. (2002), Mind the Gap: why do people act environmentally and what are the barriers to pro-environmental behavior?, *Environmental Education Research* 8(3): 239-260.
- Lance, C. E. and Vandenberg, R. J. (2009), Statistical and methodological myths and urban legends : doctrine, verity and fable in the organizational and social sciences. New York ; London: Routledge/Psychology Press.
- Lee, J.-S., Hsu, L.-T., Han, H. and Kim, Y. (2010), Understanding how consumers view green hotels: how a hotel's green image can influence behavioural intentions, *Journal of Sustainable Tourism* 18(7): 901-914.
- Lieb, K. J. and Lieb, R. C. (2010), Environmental sustainability in the third-party logistics (3PL) industry, *International Journal of Physical Distribution & Logistics Management* 40(7): 524-533.
- Lin, C.-Y. and Ho, Y.-H. (2008), An empirical study on logistics service providers' intention to adopt green innovations, *Journal of Technology Management & Innovation* 3(1).
- Litvine, D. and Wüstenhagen, R. (2011), Helping "light green" consumers walk the talk: Results of a behavioural intervention survey in the Swiss electricity market, *Ecological Economics* 70(3): 462-474.
- Lu, C. S., Liu, W. H. and Wooldridge, C. (2014), Maritime environmental governance and green shipping, *Maritime Policy & Management* 41(2): 131-133.
- Marcoulides, G. A. and Saunders, C. (2006), PLS: A silver bullet?, *Mis Quarterly* 30(2): Iii-Ix.
- Martinsen, U. and Björklund, M. (2012), Matches and gaps in the green logistics market, *International Journal of Physical Distribution & Logistics Management* 42(6): 562-583.
- McClellan, J. W. (2011), Railroads and the New Normal Impact of Lean and Green on the Future of Railroads, *Transportation Research Record* (2261): 5-12.
- Podsakoff, P. M. and Organ, D. W. (1986), Self-reports in organizational research: Problems and prospects, *Journal of management* 12(4): 531-544.
- Ramayah, T., Lee, J. W. C. and Mohamad, O. (2010), Green product purchase intention: Some insights from a developing country, *Resources, Conservation and Recycling* 54(12): 1419-1427.
- Ryu, K. and Han, H. (2010), Predicting tourists' intention to try local cuisine using a modified theory of reasoned action: The case of new orleans, *Journal of Travel & Tourism Marketing* 27(5): 491-506.
- Sparks, B. and Pan, G. W. (2009), Chinese Outbound tourists: Understanding their attitudes, constraints and use of information sources, *Tourism Management* 30(4): 483-494.
- Stern, P. C., Dietz, T. and Kaloof, L. (1993), Value Orientations, Gender, and Environmental Concern, *Environment and Behavior* 25(5): 322-348.
- UPS. (2013), Official website. Accessed 1 March, 2013 on World Wide Web: www.ups.com.
- Wolf, C. and Seuring, S. (2010), Environmental impacts as buying criteria for third party logistical services, *International Journal of Physical Distribution & Logistics Management* 40(1): 84-102.
- Wu, H.-J. and Dunn, S. C. (1995), Environmentally responsible logistics systems, *International Journal of Physical Distribution & Logistics Management* 25(2): 20-38.

The Impact of the External Integration Capabilities of Taiwan's 3PLs on Their Performance

Chiung-Lin Liu^{1*}, Pei-Yu Lai² and Chun-Wei Chiang³

¹Department of Shipping and Transportation Management, National Taiwan Ocean University, Keelung, Taiwan, ROC, Tel.: +886-2-2462-2192 ext. 3425. Email: realsky@ntou.edu.tw/realskyer@googlemail.com.

²Department of Shipping and Transportation Management, National Taiwan Ocean University, Keelung, Taiwan, ROC. Email: sjjf525@hotmail.com.

³Department of Shipping and Transportation Management, National Taiwan Ocean University, Keelung, Taiwan, ROC. Email: o771121@hotmail.com.

*Corresponding author

Abstract

The aim of the research was to examine whether there is a relationship between the external integration capabilities and the performance of 3PL (third party logistics) providers. A survey of 80 3PLs in Taiwan was carried out. Research model was tested using structural equation modelling technique along with the Partial Least Square (PLS) approach. Results indicated that there was a positive correlation between 3PLs' external integration capabilities and operational performance. The results also suggested that cost competitiveness positively influenced 3PLs' financial performance. Although it was not supported that the external integration capabilities of 3PLs had the impact on their financial performance, the relationship between external integration capabilities and financial performance was mediated by the cost competitiveness of 3PLs.

Keywords: 3PLs; Logistics integration; Performance

1. Introduction

In recent years, companies have started to outsource their logistics activities (e.g. warehousing, distribution) to 3PLs (third party logistics providers). This measure can not only decrease companies' logistics cost (Coyle, 2013) but let companies focus their limited resources on their core capabilities; companies, in this way, can sustain their competitiveness (Porter, 1980). The logistics outsourcing trend of companies increases the demand for more complex services (e.g. customization) that 3PLs need to provide. Effective integration between 3PLs and their customers – the external integration capabilities of 3PLs – allows 3PLs to rapidly respond to consigners' needs, increase customer satisfaction, and, with effective resource reallocation, lower their operating cost.

Although companies' logistics integration capabilities have already played important roles in the supply chain management system (Huo, 2012), and previous researches have investigated the benefits brought by the integration between companies and 3PLs (Jayaram and Tan, 2010), very few adopted 3PLs' perspective to study the relationship between 3PLs' external integration capabilities and their performance. In a supply chain management system, integration capabilities are involved with two aspects: inside and outside companies. The latter indicates the cooperation between companies and other members of the supply chain on their operational strategies and operations. For current 3PLs, it has become a crucial issue for their sustainable development that how to improve their external integration capabilities to fulfill mutual benefits among supply chain members and ultimately increase the performance of their own companies. One key question posed by the research is:

Do the external integration capabilities of 3PLs have any influence on their performance?

2. Literature Review and Research Hypotheses

2.1 *Resource-based theory*

The RBT (resource-based theory) discusses why there remain performance differences between companies, and how companies can employ their “resources” to sustain their competitive advantage (Barney, 2001). The RBT has been widely applied to many logistics researches to evaluate the contributions of different resources to a company’s performance. Resources, according to the RBT, can be divided as tangible and intangible resources. Tangible resources include the physical services provided a company, such as transportation and warehousing (Lai, 2004; Liu and Lyons, 2011). Intangible resources include a series of intangible capabilities, such as the benchmarking capability (Shang and Marlow, 2005).

2.2 *External integration capabilities*

In the domain of logistics, a company’s integration capabilities are involved with the coordination between its internal departments and its external partners (Bowersox et al., 2010). Stank et al. (2001) took the perspective of manufacturers and divided a company’s logistics integration capabilities into three operational aspects: internal integration, customer integration, and material supplier integration. The latter two were related to a company’s external integration. For 3PLs, the external integration consists of integrating consigners and consignees, and the key topic of this research is the 3PLs’ external integration capabilities of integrating their consigners.

Previous researches have revealed the causal relationship between companies’ external integration capabilities and their performance (Huo, 2012; Sanders, 2005). Stank et al. (2009) argue that, through integration among companies, customer satisfaction can be increased and equipment can be more effectively used to lower the cost. Based on the RBT, effective integration between 3PLs and consigners can allow 3PLs rapidly respond to consigners’ needs under the service trend, increase customer satisfaction, and, with effective resource reallocation, lower their operating cost. Moreover, 3PLs with a better external integration capabilities may be in a better position to meet customers’ needs, so they can accumulate better operational competitiveness in their industry. This discussion leads to the following hypotheses:

H1 External integration capabilities of 3PLs positively influence operational performance

H1-1 External integration capabilities of 3PLs positively influence resource usage ratio

H1-2 External integration capabilities of 3PLs positively influence cost competitiveness

H2 External integration capabilities of 3PLs positively influence financial performance

H2-1 External integration capabilities of 3PLs positively influence QoQ (quarter on quarter) growth

H2-2 External integration capabilities of 3PLs positively influence operating profit margin

2.3 *Operational performance*

Previous researches have different opinions toward the index that logistics providers can use to evaluate their operational performance, but almost all of them can be divided into five categories: delivery, quality, flexibility, cost, and innovation (Liu and Lyons, 2011). This research focused on the cost category, which can be divided as two parts: resource usage ratio and cost competitiveness. In the domain of logistics management, the positive correlation between companies’ operational performance and financial performance has been proven (Shang and Marlow, 2005). As for 3PLs, they can improve the resource usage ratio or cost competitiveness, so as to increase their revenues and profits. Therefore, this research proposes the following additional hypotheses:

H3 Operational performance of 3PLs positively influences financial performance

H3-1 Resource usage ratio of 3PLs positively influences QoQ growth

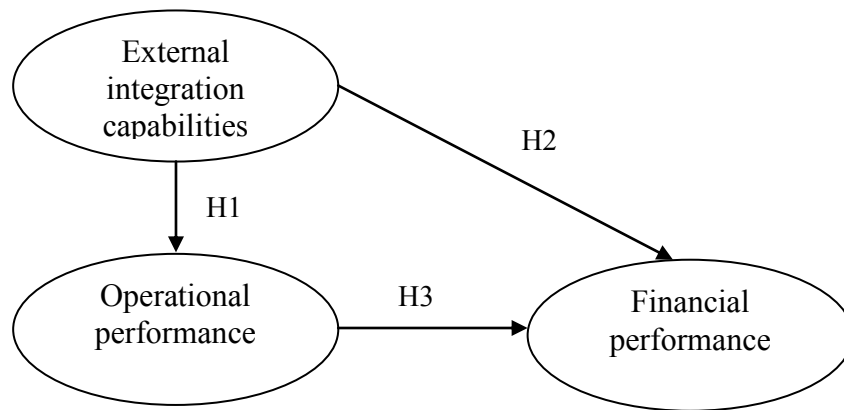
H3-2 Resource usage ratio of 3PLs positively influences operating profit margin

H3-3 Cost competitiveness of 3PLs positively influences QoQ growth

H3-4 Cost competitiveness of 3PLs positively influences operating profit margin

With reference to the foregoing literature review, a conceptual model is proposed in Figure 1.

Fig 1. The proposed model



3. Method

3.1 Sample selection

289 Taiwan's 3PLs were identified from the Logistics Information Network database (Ministry of Economic Affairs (Taiwan), 2007) and China Credit Information Service database (China Credit Information Service Ltd., 2007). All of these 3PLs provide both transportation and warehousing services, so they fit the definition of 3PL service scope provided by (Langley et al., 1999).

3.2 Survey Measures and Items

This research followed the questionnaire design procedure suggested by Dillman (2007). A preliminary survey was pre-tested in Taiwan by interviewing experts of 3PLs. The questionnaire consisted of four parts: external integration capabilities, operational performance, financial performance, and business profiles. 17 items selected as measures of external integration capabilities of 3PLs were based upon previous literature (Stank et al., 2001). Respondents rated their agreement level with their firms' external integration capabilities on a seven-point Likert scale ranging from 1 for "strongly disagree" to 7 for "strongly agree."

Operational and financial performances were measured using a 7-item (5 for operational performance and 2 for financial performance) performance scale which had been employed in previous logistics literature (Lai et al., 2007; Liu and Lyons, 2011). Respondents were asked to provide a rating of the company's performance relative to the industry average using a seven-point Likert scale anchored by "1= much worse" and "7= much better".

3.3 Analysis methods

A partial least squares structural equation modeling (PLS-SEM/PLS) approach was used to test the research hypotheses. The choice of the PLS was due to the following reasons: (1) PLS "works efficiently with small sample sizes" and "makes practically no (distribution) assumptions about the underlying data" (Hair et al., 2014). (2) PLS can handle single-item constructs (Hair et al., 2014). These made PLS an appropriate analysis method for this study. All analyses were performed using the SPSS version 12.0, AMOS version 19, and the SmartPLS version 2.0.M3.

4. Analysis Results

4.1 Data screening, representativeness, and response rate analysis

The data collection phase of the study began on the beginning of November 2013 and concluded on the middle of January 2014. The effective population size was reduced to 232 as 14 respondents indicated that their companies only provided services for internal users, 43 service providers did not provide transportation

and warehousing services. 12 of the 92 returned questionnaires were discarded because respondents had put the same answers on all Likert-scale items. The total usable number of responses was 80. Therefore, the overall response rate was 34.5% (80/232).

4.2 Missing data analysis and the imputation approach

The amount of missing data on each variable was less than 3%, implying that the pattern of missing data did not appear to be a serious threat to validity (Roth, 1994). Moreover, a model-based method known as the Bayesian method suggested by Buhi et al. (2008) was used for missing-values imputation for all variables except the demographic ones.

4.3 Profile of respondents

The profile of respondents and their companies revealed that more than 47.5% of responses were from managers, vice presidents, or members of even higher levels; thus, the reliability of survey findings was supported. Moreover, more than 50% of 3PL providers had operated in the logistics industry for over 25 years.

4.4 Measurement model

Results of the PLS analysis were presented in Tables 1 and 2. The loadings and cross-loadings of indicators in Table 1 were examined for convergent and discriminant validity of the measurement model. Two variables were deleted because of factor loading < 0.7 (Marcoulides and Saunders, 2006). All of the indicators presented in Tables 1 loaded higher on the construct of interest than on any other variable, thereby assuring discriminant validity (Hair et al., 2014). All of the individual loadings were greater than 0.707 (Hair et al., 2014), thus providing evidence for the constructs' convergent validity.

Table 1. Factor loadings (bolded) and cross loadings

	External integration capabilities					Operational performance		Financial performance	
	Connectivity	Financial linkage	Information receiving	Information sharing	Segmental focus	Resource usage ratio	Cost competitiveness	QoQ growth	Operating profit margin (by season)
cn1	0.921	0.734	0.600	0.538	0.456	0.329	0.210	0.115	0.174
cn2	0.916	0.683	0.494	0.500	0.549	0.388	0.261	0.054	0.105
fl1	0.675	0.900	0.541	0.490	0.428	0.416	0.207	0.167	0.145
fl2	0.692	0.869	0.391	0.437	0.326	0.291	0.231	0.120	0.154
ir3	0.392	0.487	0.785	0.455	0.460	0.451	0.151	0.128	0.224
ir1	0.545	0.439	0.914	0.509	0.391	0.432	0.172	0.052	0.070
ir2	0.585	0.439	0.858	0.455	0.364	0.257	0.234	0.021	0.018
is1	0.514	0.419	0.407	0.774	0.392	0.410	0.068	0.098	0.064
is2	0.590	0.518	0.415	0.786	0.349	0.421	0.166	0.329	0.337
is3	0.222	0.261	0.394	0.802	0.230	0.523	0.268	0.209	0.245
is4	0.365	0.392	0.500	0.736	0.272	0.497	0.333	0.126	0.208
sf1	0.346	0.240	0.348	0.307	0.831	0.347	0.129	0.038	0.042
sf2	0.391	0.405	0.430	0.341	0.832	0.393	0.184	0.204	0.199
sf3	0.638	0.459	0.434	0.440	0.866	0.503	0.157	0.200	0.244
sf5	0.401	0.294	0.355	0.249	0.809	0.270	-0.014	0.082	0.055
ol	0.337	0.416	0.335	0.541	0.423	0.921	0.137	0.238	0.301

o2	0.376	0.317	0.484	0.540	0.424	0.904	0.228	0.140	0.171
o3	0.194	0.202	0.203	0.255	0.142	0.194	0.958	0.395	0.444
o4	0.284	0.290	0.203	0.197	0.126	0.156	0.922	0.485	0.534
o5	0.225	0.179	0.200	0.288	0.131	0.208	0.905	0.322	0.412
f1	0.093	0.164	0.078	0.249	0.165	0.209	0.440	1.000	0.710
f2	0.152	0.169	0.120	0.276	0.174	0.262	0.505	0.710	1.000

Reliability results were shown in Table 2. The composite reliabilities of the different measures ranged from 0.909 to 1.000, which exceeded the recommended threshold value of 0.700 (Fornell and Larcker, 1981). Table 2 also presented average variance extracted (AVE) as well as correlations between constructs. The AVE for most measures fulfilled accepted value of 0.5 given by Fornell and Larcker (1981). These results supported the convergent validity of our measures. The correlation matrix indicated that the square root of AVE of each measure was higher than corresponding correlation values for that variable in all of the cases, thereby assuring discriminant validity (Hair et al., 2014). In sum, the results of tables 1 and 2 provided support for the measures' reliability and validity.

Table 2. Inter-construct correlations: consistency and reliability tests

	AVE	Composite Reliability	Cronbachs Alpha	Cost competitiveness	Resource usage ratio	Operating profit margin (by season)	QoQ growth	External integration capabilities
Cost competitiveness	0.863	0.950	0.921	0.929				
Resource usage ratio	0.833	0.909	0.800	0.198	0.913			
Operating profit margin (by season)	1.000	1.000	1.000	0.505	0.262	1.000		
QoQ growth	1.000	1.000	1.000	0.440	0.209	0.710	1.000	
External integration capabilities	0.438	0.920	0.907	0.281	0.593	0.232	0.196	0.662

*Square root of the AVE on the diagonal.

4.5 Structural model

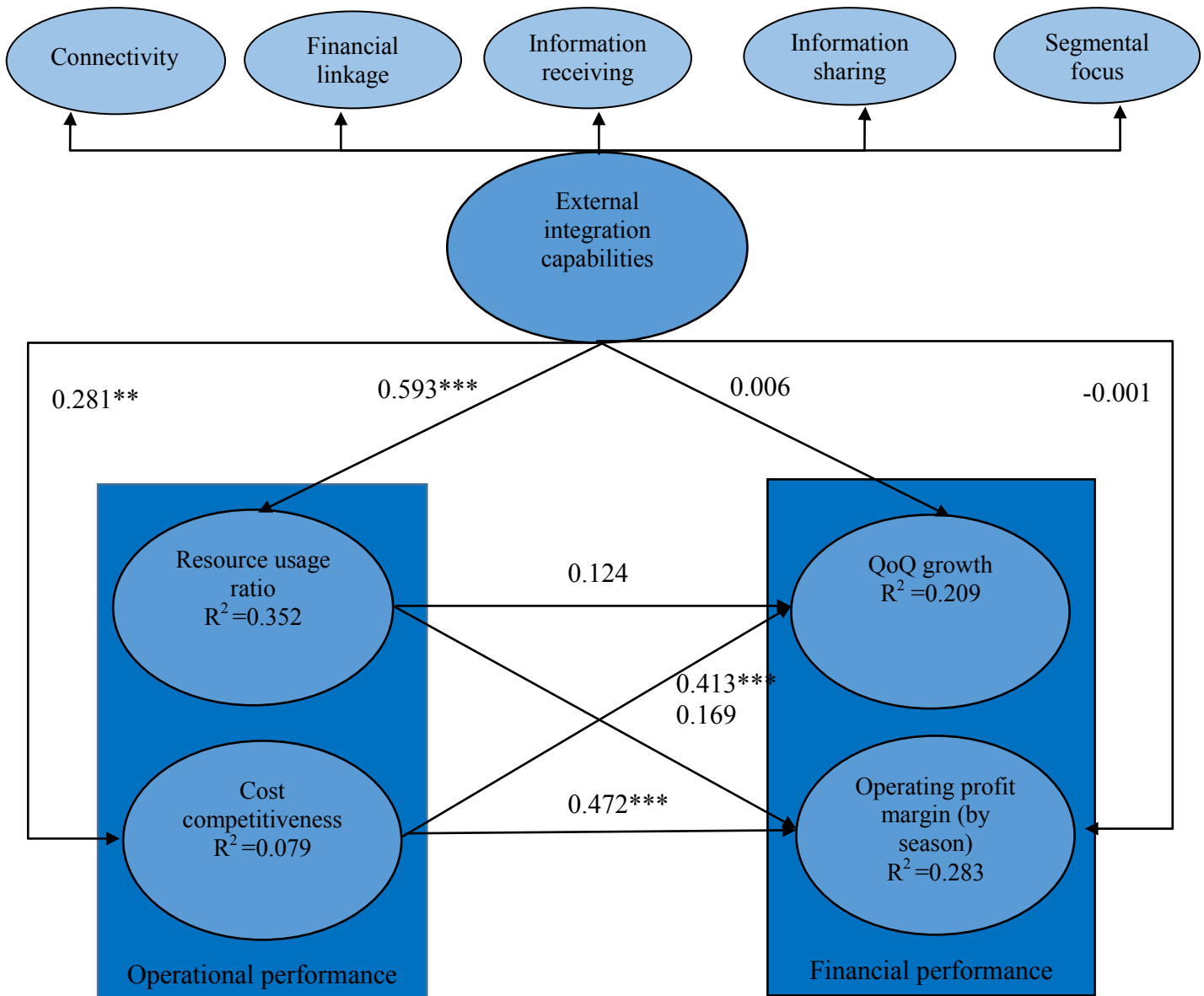
The results of the PLS analysis of the research model were presented in Figure 2 and Table 3. This research used bootstrapping with 5000 samples (Hair et al., 2014) to evaluate the significance of path coefficients. Results indicated that external integration capabilities of 3PLs demonstrated a direct, statistically significant relationship with the resource usage ratio (path coefficient = 0.593, $p < 0.001$) and cost competitiveness (path coefficient = 0.281, $p < 0.001$). These results supported H1-1 and H1-2. In contrast, external integration capabilities of 3PLs did not demonstrate a direct, statistically significant relationship with QoQ growth and operating profit margin, so H2-1 and H2-2 were not supported.

Table 3. Structural model results

Paths	Path coefficient	Standard Error	t-value	Supported/Not-supported
H1-1 External integration capabilities → Resource usage ratio	0.593	0.086	6.913	Supported
H1-2 External integration capabilities → Cost competitiveness	0.281	0.088	3.196	Supported
H2-1 External integration capabilities → QoQ growth	0.006	0.153	0.043	Not Supported
H2-2 External integration capabilities → Operating profit margin (by season)	-0.001	0.133	0.006	Not Supported
H3-1 Resource usage ratio → QoQ growth	0.124	0.149	0.831	Not Supported
H3-2 Resource usage ratio → Operating profit margin (by season)	0.169	0.141	1.197	Not Supported
H3-3 Cost competitiveness → QoQ growth	0.413	0.097	4.245	Supported
H3-4 Cost competitiveness → Operating profit margin (by season)	0.472	0.109	4.337	Supported

The resource usage ratio did not demonstrate a direct, statistically significant relationship with 3PLs' QoQ growth and operating profit margin, thus H3-1 and H3-2 were not supported. In contrast, cost competitiveness demonstrates a direct, statistically significant relationship with 3PLs' QoQ growth (path coefficient = 0.413, $P < 0.001$) and operating profit margin (path coefficient = 0.472, $P < 0.001$), thus results support H3-3 and H3-4. Here cost competitiveness was proven to play an intermediary role between external integration capabilities and financial performance.

Fig 2. Structural model results



*Representing significant level of $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$; The R^2 represents the amount of variance explained by the model.

5. Conclusion and implications

The objective of this study was to evaluate the relationship among external integration capabilities of 3LPs, operational performance, and financial performance. The purpose was to provide guidance for 3LPs to formulate their future operational strategy.

The results indicated that 3PLs' external integration capabilities and operational performance were positively correlated. That is, the stronger the external integration capabilities, the higher the positive effect on the operational performance (H1). The results also indicated that cost competitiveness positively influenced 3PLs' financial performance (H3-3 and H3-4). Although the impact of external integration capabilities on the 3PL providers' financial performance (H2) was not supported, the relationship between external integration capabilities and financial performance was mediated by cost competitiveness for 3PLs.

Several contributions have been made by this research. Firstly, it has provided a theoretical framework to link external integration capabilities, operational performance, and financial performance for 3PLs. Secondly, this research has given a clearer operational procedure in order to assess validity and reliability through the survey.

The findings of this research have implications for both practice and research. The results suggested that excellence in cost competitiveness had higher impact than the resource usage ratio for 3PLs. Moreover, the results are useful for current customers since they can refer to the list of 17 aspects of external integration capabilities to evaluate their potential 3PL partners.

The study findings, however, suffer from several limitations. First, the samples only included Taiwan's 3PLs. Second, the questionnaires were distributed by mailing so the response quality might be less ensured. Third, the external integration dimension of this research was a second-order model, and thus this research did not further investigate if there were differences among the relationships of each sub-dimension with the operational performance or the financial performance.

Several important issues for further research are suggested: First, this research only studied Taiwan's 3PLs. Further research can conduct a cross-national comparison study. Second, this is a quantitative research. Further research can adopt a case-study approach to deeply investigate the relationship between the integration capabilities of 3PLs and the operational performance. Third, according to the RBT, further research can attempt to find other company resources and examine if these resources have any influence on the 3PLs' performance.

Acknowledgment

The authors would like to thank the National Science Council of the Republic of China, for financially supporting this research under Contract No. NSC 102-2410-H-019-018.

References

- Barney, J. B. (2001), Is the resource-based "view" a useful perspective for strategic management research? Yes, *Academy of Management Review* 26(1): 41-56.
- Bowersox, D. J., Closs, D. J. and Cooper, M. B. (2010), *Supply chain logistics management*. 3rd ed. Boston: McGraw-Hill/Irwin.
- Buhi, E. R., Goodson, P. and Neilands, T. B. (2008), Out of sight, not out of mind: strategies for handling missing data, *American Journal of Health Behavior* 32(1): 83-92.
- China Credit Information Service Ltd. (2007), *China Credit Information Service Database*. Accessed on World Wide Web: http://www.credit.com.tw/newweb/index_all.cfm.
- Coyle, J. J. (2013), *Managing supply chains : a logistics approach*. 9th ed., International ed. / John J. Coyle ... [et al.]. ed. Australia ; United Kingdom: South-Western Cengage Learning.
- Dillman, D. A. (2007), *Mail and internet surveys : the tailored design method : with new internet, visual, and mixed-mode guide*. 2nd ed. 2007 update ed. Hoboken, N.J.: Wiley ; Chichester : John Wiley [distributor].
- Fornell, C. and Larcker, D. F. (1981), Evaluating Structural Equation Models with Unobservable Variables and Measurement Error, *Journal of Marketing Research (JMR)* 18(1): 39-50.
- Hair, J. F., Hult, G. T. M., Ringle, C. and Sarstedt, M. (2014), *A primer on partial least squares structural equations modeling (PLS-SEM)*. Los Angeles: SAGE.
- Huo, B. (2012), The impact of supply chain integration on company performance: an organizational capability perspective, *Supply Chain Management* 17(6): 596-610.

- Jayaram, J. and Tan, K. C. (2010), Supply chain integration with third-party logistics providers, *International Journal of Production Economics* 125(2): 262-271.
- Lai, F., Zhao, X. and Wang, Q. (2007), Taxonomy of information technology strategy and its impact on the performance of third-party logistics (3PL) in China, *International Journal of Production Research* 45(10): 2195.
- Langley, C. J., Jr, Newton, B. F. and Tyndall, G. R. (1999), Has the future of third-party logistics already arrived, *Supply Chain Management Review* 5(Autumn): 85-94.
- Liu, C. L. and Lyons, A. C. (2011), An analysis of third-party logistics performance and service provision, *Transportation Research Part E-Logistics and Transportation Review* 47(4): 547-570.
- Marcoulides, G. A. and Saunders, C. (2006), PLS: A silver bullet?, *Mis Quarterly* 30(2): Iii-Ix.
- Ministry of Economic Affairs (Taiwan). (2007), Logistics Information Network Database. Accessed on World Wide Web: <http://gcis.nat.gov.tw/link/Common/Main.aspx?Page=BSSearch>.
- Porter, M. E. (1980), *Competitive strategy : techniques for analyzing industries and competitors*. New York: Free Press.
- Roth, P. L. (1994), Missing data: A conceptual review for applied psychologists, *Personnel Psychology* 47(3): 537-560.
- Sanders, N. R. (2005), IT Alignment in Supply Chain Relationships: A Study of Supplier Benefits, *Journal of Supply Chain Management* 41(2): 4-13.
- Shang, K. C. and Marlow, P. B. (2005), Logistics capability and performance in Taiwan's major manufacturing firms, *Transportation Research Part E: Logistics and Transportation Review* 41(3): 217-234.
- Stank, T., Brzica, M. and Ficenec, J. (2009), The benefits of supply chain integration using a third-party integrator, *Transfusion* 49(11): 2536-2538.
- Stank, T. P., Keller, S. B. and Closs, D. J. (2001), Performance benefits of supply chain logistical integration, *Transportation Journal* 41(2/3): 32-46.

Supply Chain Security: An Empirical Study of Drinking Milk Producers in Egypt

Islam El-Nakib

College of International Transport and Logistics, Arab Academy for Science, Technology and Maritime Transport, Alexandria, Egypt.

Abstract

Global supply chains are facing different risks such as piracy, theft, terrorism, strikes, natural disasters and energy shortages, which made companies more aware of the vulnerability of their supply chains, and encouraged them to seek ways to reduce risks of such unforeseeable situations and increase stability along their supply chains. Therefore, the aim of this research is to examine how companies understand the business value of supply chain security investments by identifying the collateral benefits security initiatives can bring to companies, and whenever possible quantifying the level of benefits that can be realized. The research was examining the Egyptian drinking milk producers in their supply chain security practices and experiences since the 25th of January 2011 revolution until now. In order to support the purpose of the research, a questionnaire was conducted to assess the supply chain security capabilities for further improvements. In addition, the questionnaire aimed to identify the benefits of their supply chain security investments, and the extent of improvement they experienced. Finally, the research provided some recommendations that companies should not consider such investments solely as expenses that are required to meet government regulations and mitigate risk, but rather as investments that can have business justification, result in operational improvements, and ultimately may promote cost reduction, higher revenues and growth leading to positive ROI. Moreover, it is important to understand that these benefits are not realized automatically. However, companies should be creative in determining ways to gain the most benefits from their security investments.

Keywords: Supply Chain Security; Dairy Products; Egypt.

1. Introduction

Supply chain management (SCM) plays a key role in the national economy of countries (CSCMP, 2013). The progressive liberalization of cross-border transactions, advances in production technology and information services, and improvement in SCM have provided companies with greater incentives to delocalize SCM operations. SCM where cost reduction strategies result in goods often being produced with intermediate inputs originating from several countries, are now common in many industries and extend over to an increasing number of developing countries (UNCTAD, 2013). From an economic standpoint, the emergence of SCM related to the concept of comparative advantage by relocating SCM processes such as Research and Development (R&D), logistics, manufacturing, packaging, marketing, distribution and retailing in different countries (Durowoju et al., 2012). SCM has an important role to improve both profitability and competitive performance for the organization (Ballou, 2004). International trade is a key element for economic prosperity, which is a goal pursued by all the economies of different countries. The ability to move goods safely and efficiently is a major contribution to the international trade and economic development of nations (Durowoju et al., 2012). Moreover, the international practices that aimed at liberalizing international trade arise many risks and threats to the Global Supply Chain Security (GSCS). Thus, the efforts to enhance the security of global supply chains are vital to mitigate and reduce the dangers that threaten the safety of supply chains (Bichou, 2011). It was noticed since 9/11, that means of transport can be used to commit acts of terrorism and organized crime (Closs and McGarrell, 2004). Therefore, based on these different risks and vulnerabilities, the World Customs Organization (WCO) is concerned about the security. The WCO facilitated global supply chains operations are tries to balance between facilitating trade, and tightening the control in order to ensure the flow of legitimate trade across the borders safely (WTO, 2010). In addition, the WCO assured the national customs administrations to enforce the principles of security of global supply chains, where those customs

administrations serve as the main gates that pass through international trade across borders, and that the safe passage from these gates is the fundamental guarantee for the growth of international trade and boost the economy (WTO, 2012b). Therefore, it is necessary for all stakeholders in the GSCS to strengthen global supply chains operations with high level of collaboration with the customs administrations in countries, in order to conduct serious steps towards enhancing the security of global supply chains without affecting the flows of legitimate trade (ECA, 2013). Moreover, it is necessary to prevent any negative economic impact resulting from threatening the security of international supply chains that require protection from the point of origin and to the point of destination (Widdowson, 2007).

Based on previous rationale, the research starts with a literature review, which focuses mainly on supply chain security initiatives and dimensions. In addition, the role of WCO to ensure the GSCS through the Authorized Economic Operations (AEO) program is reviewed. Furthermore, a review of the status of drinking milk producers in Egypt is highlighted and the main dimensions of the supply chain security improvement are discussed. The research methodology is then presented to support the aim of this research through the appropriate research method that is based on case study approach. The research findings focus on analysing the experiences and best practices that were gained from the drinking milk producers working in the Egyptian market. Then the research proposes suggestions and solutions for better implementation of investments in supply chain security that can improve companies' business performance and to quantify those improvements. Moreover, the research recommends security investments to manufacturers within major dimensions of improvement, which were identified in inventory management and customer service; visibility; efficiency; resilience; and customer relations.

2. Background Literature

In this section, supply chain security initiatives and supply chain security dimensions will be reviewed; the WCO has a role and policies in securing the global supply chains with a special emphasis on the significance of the EU AEO programs. In addition, the situation of the drinking milk producers sector in Egypt is highlighted.

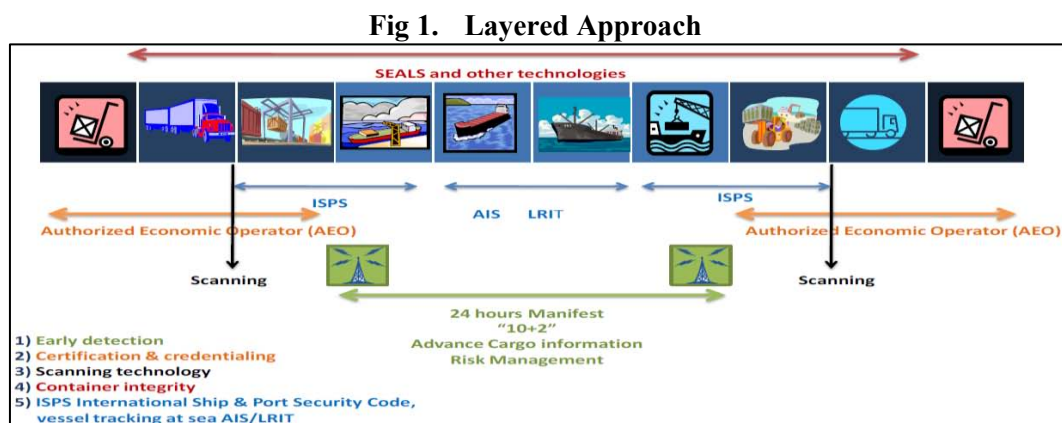
2.1 Supply Chain Security Initiatives and Dimensions

Risks have exposed the vulnerability of supply chains to disruptions. Governments and many companies are aware of the potential impact to the global economy that disruptions in supply chains can cause and recognize the need to invest in security measures that will mitigate the risks to the global supply chain upon which business depends. Supply chains as a network of companies and logistics providers that starts from acquiring raw materials through manufacturing processes and all parties concerned to the delivery of goods to the end user (Mikuriya, 2007). Many companies have a direct or an indirect role in the operations of supply chains that enhance the value of vendors, wholesalers, distributors, and retailers (Yang, 2010). There are other parties involved in supply chain operations, including governments, carriers, terminal operators, seaports and airports as well (Schmitt and Singh, 2012). Therefore, Supply Chain Security (SCS) aims at enhancing the security of the supply chain, the transport and logistics system for the world's cargo (Bichou, 2011).

Supply chain security activities include: the credentialing of participants in the supply chain, screening and validating of the contents of cargo being shipped, advance notification of the contents to the destination country, ensuring the security of cargo while in-transit via the use of locks and tamper-proof seals and inspecting cargo on entry (Coleman et al. 2012). Companies have been taking multiple steps against terrorist attacks in last two decades to secure transit of their goods across international borders (Olson and Wu, 2010). Simultaneously, natural disasters and other logistical risks made companies more aware of the vulnerability of their supply chains, and encouraged them to seek ways to reduce risks of such unforeseeable situations and increase stability along their supply chain (Marlow, 2010).

According to Peleg-Gillai et al. (2006) they mentioned some of the initiatives taken by the U.S. government to assess and minimize the risk involved in the global supply chain of goods such as: the Container Security Initiative (CSI), the Customs-Trade Partnership Against Terrorism (C-TPAT), International Ship and Port Facility Security (ISPS), the Advanced Manifest Rule (AMR) and the Free and Secure Trade initiative

(FAST). Other initiatives, which took place outside the U.S., include the publication of the ISO/PAS 28000:2005 standard Specification for security management systems for the supply chain, the development of the Framework of Standards to Secure and Facilitate Global Trade by members of WCO; a series of measures that were presented by the European Commission to accelerate implementation of the WCO Framework, including the Authorized Economic Operator (AEO) program; as well as various initiatives that were taken by the World Trade Organization (WTO) to better facilitate trade. These and other initiatives allow companies to maintain their level of operations and/or to reduce risks, they require significant levels of investment (Hendricks and Singhal, 2003). A multi-layered approach as shown in Figure 1 is supported by the most active SCS drivers, namely the US Department of Homeland Security (DHS) and the WCO. The respective layers focus on different segments of the supply chain, providing multi-angle assessments of the cargo and ensuring that security does not rely on any single point that could be compromised. The idea is that the layers complement each other and reinforce the whole.



Source: Donner and Kruk (2009)

In addition, several studies such as in Closs and McGarrell (2004), Hintsa et al. (2009) and Schmitt and Singh (2012) were interested in the requirements necessary to achieve the SCS. Hintsa et al. (2009) stated that as to manage the security of supply chains that cover all processes, techniques and resources used in an orderly manner to combat crimes supply chains from beginning to end, the main objective of SCS is to prevent crime, discover the crime, or to recover from the incident as soon as possible. This means that the SCS is located in all elements of the supply chain of goods, facilities, human resources, information technology and administrative systems (Closs and McGarrel, 2004). Therefore, the SCS collaborates among supply chain parties, building organizational awareness and proactively investing in technology, that have shown promise to create collateral benefits and to safeguard the end-to-end supply chains operations (Bichou, 2011).

Table 1. Supply Chain Security Dimensions

SCS Dimensions	Descriptions	SCS Dimensions	Descriptions
Inventory Management and Customer Service	<ul style="list-style-type: none"> Internal Inventory Management Operations Product Safety/Genuineness Customer Service Cost Savings 	Resilience	<ul style="list-style-type: none"> Actual Benefits Expected Benefits
Visibility	<ul style="list-style-type: none"> Access to Data Timeliness of Data Data Accuracy Cost Savings 	Customer Relations	<ul style="list-style-type: none"> Customer Satisfaction Communication/ Collaboration with Customers
Efficiency	<ul style="list-style-type: none"> Improved Product Handling Process Improvements Required Personnel Cost Savings and Speed Improvement Cargo Inspection and Customs Clearance 		

Source: Peleg-Gillai et al. (2006)

It is worth mentioning that the five elements of supply chain security dimensions which are: *Inventory management and customer service; visibility; efficiency; resilience and customer relations* are considered the most vulnerable areas in the supply chain. Moreover, each area has certain factors that affect the supply chain performance, Table 1, summarizes the supply chain security dimensions for improving the stakeholders investments in the supply chains to prevent their operations against risks.

2.1.1 WCO Role in Supply Chain Security

WCO is considered the voice of the customs community at the international level, 174 WCO Members, 156 have signed the letter of intent to implement the SAFE Framework of Standards to secure and facilitate global (SAFE FoS), representing approximately 95 % of global international trade. According to Peleg-Gillai et al. (2006) SAFE FoS aims to establish standards that provide supply chain security and facilitation at a global level to promote certainty and predictability, enable integrated supply chain management for all modes of transport, enhance the role, functions and capabilities of customs to meet the challenges and opportunities, strengthen co-operation between customs administrations to improve their capability to detect high-risk consignments, strengthen customs/business co-operation and promote the seamless movement of goods through secure international trade supply chains. In addition, SAFE FoS consists of 4 core elements: 1) harmonizes the ACI requirements on inbound, outbound and transit shipments, 2) Each country that joins the Framework commits to employ a consistent risk management approach to address security threats, 3) The Framework requires that at the reasonable request of the receiving nation, based upon a comparable risk targeting methodology, the sending nation's customs administration will perform an outbound inspection of high-risk containers and cargo, preferably using non-intrusive detection equipment such as large-scale X-ray machines and radiation detectors and 4) the framework defines benefits that customs will provide to businesses that meet minimal supply chain security standards and best practices. The framework consists standards of two pillars. First: the relationship between customs administrations and each other. Second: the relationship between customs and business - private sector- is made up of six criteria, and through this substrate can private companies get laid opaque without being a partner of the departments of customs in the implementation of policies for security of supply chains, the framework of standards has been known entities that perform this role with the customs authorities and are approved AEO (Ireland, 2009).

However, the implementation of the SAFE Framework is suffering from same problems similar to those experienced during the implementation phase of the ISPS Code (Wakolbinger, and Cruzb, 2011). The level of awareness and preparedness is extremely variable from one country to another. The progress in the implementation of the SAFE Framework directives, therefore, remains largely uneven, which has prompted the WCO to multiply its efforts towards capacity building and large-scale training (WCO, 2012a). Meanwhile, businesses are often left with serious doubts about their own way forward, and the costs thereof, as a result of increased awareness regarding the vulnerability of GSCM including international terrorism, organized crime, drug trafficking, fraud etc. the increased expectations of border control while ensuring trade facilitation have affected the strategic objectives of companies (Donner and Kruk, 2009).

2.1.2 Authorized Economic Operator (AEO)

The European Union's AEO is comparable to the US C-TPAT program. However comparable to US C-TPAT, the EU AEO differs in several key areas: 1) EU AEO certification is only available to companies or economic operators with status as a legal entity of a European Union member country and certain airlines and steamship lines outside of the E), whereas US C-TPAT makes allowance foreign-based manufacturer and carrier entities. The EU AEO also addresses both import and export transactions while C-TPAT is strictly import focused at this time (Polner, 2012). The second pillar of WCO-SAFE Framework of Standards is the partnership between customs and the private sector "Customs to Business". Therefore, under this pillar "Customs can establish a partnership program with the private sector to protect and secure international supply chains, and the focus of this pillar on the establishment of an international system for identifying private sector companies that offer a high degree of collateral security in relation to their roles in the supply chains, which gain significant benefits as a result of this partnership represented in the acceleration processes and clearance procedures and standards other relevant" (WCO, 2012b). It describes the framework of the WCO standards for the security and facilitate international trade entities that perform this role with the customs authorities and are adopted as

Authorized Economic Operator (AEO) which is defined as: “a party - manufacturers, importers, exporters, clearance companies, carriers, intermediaries, air and sea ports, border facility operators, integrated operators, warehouses, distributors and freight forwarders- involved in the international movement of goods in whatever function that has been approved by or on behalf of a national customs administration as complying with WCO or equivalent supply chain security standards”. Since it is not a mandatory program for companies, there are thought to be numerous benefits through becoming AEO certified, such as, expedited cargo releases, reduced transit times, access to special measures during times of trade disruptions or elevated threat levels, and priority during cargo checks (WCO, 2005). All companies looking to become AEO certified will need to engage in a self-assessment of their global supply chains using a pre-determined set of security standards and best practices. In this assessment, suppliers will need to demonstrate an adherence to policies and procedures that safeguard against any loss of integrity of their shipments until released from customs control at destination (Butter et al., 2012). The self-assessment process must include the following: Pre-determined security best practices are incorporated into existing business practices, validation process has been completed by a recognized customs agency, Modern technology is utilized to maintain all shipments (including the container) integrity and open communication with customs authorities to receive minimum-security standards updates and SCS best practices.

2.2 Drinking Milk Sector in Egypt: An Overview

Table 2. Drinking Milk Products Company Shares 2008-2012

Producers	Retail value RSP Company %				
	2008	2009	2010	2011	2012
Juhayna Food Industries	34.8	38.5	43.5	45.6	47.4
Nestlé Egypt SAE	18.2	16.4	15.6	15.4	14.7
ECAFI (Faragello)	7.9	8.7	8.4	8.1	7.6
International Co for Agro-Industrial Projects	3.9	3.4	6.3	6.2	6
Nile Co for Food Industries (Enjoy)	5.0	5.6	5.3	5.3	5.1
Seclam Co	1.7	1.7	1.8	1.9	1.9
Al Sakr for Food Industries	0.5	0.8	1.0	1	0.9
Arla Foods Amba	2.7	2.6	1.3	0.9	0.8
Riri Co	0.2	0.1	0.3	0.3	0.3
Investment Co For Dairy Products	-	0.2	0.3	0.3	0.3
Fonterra Co-operative Group	0.2	0.2	0.3	0.3	0.3
Middle East Dairy & Foodstuff Co	0.3	0.3	0.2	0.3	0.3
Arab Farmers El Tanbouli	-	0.2	0.2	0.2	0.2
ACCC (Corona)	2.8	2.4	2.2	1.6	1
Tag El Melouk Co	0.2	0.1	0.1	0.2	-
National Food Industries Co Ltd	0.3	0.3	-	-	-
Egyptian Dairy & Foodstuff Co SAE (EDAFCO)	0.3	-	-	-	-
Arabian Food Industry Co (Domty)	-	-	-	-	-
Others	21.0	18.5	13.2	12.4	13.2
Total	100.0	100.0	100.0	100.0	100.0

Source: Euromonitor International (2012)

Fast Moving Consumer Goods (FMCG), also known as Consumer Packaged Goods (CPG), is briefly described as packaged commercial products that are consumed through use. They include pre-packaged food, drinks, cosmetics and anything that can be bought right off the shelf, and use up through daily living (GAIN, 2011). Furthermore, FMCG business in Egypt has an absolute profit made from the relatively small products, as these products are basically sold in large numbers, the overall profit on such products can be massive. The Egyptian FMCG sector is the fifth largest sector in the economy with a total market size of US\$ 42.6 billion (Euromonitor International, 2013). It has a strong multinationals companies presence and is characterised by a well-established distribution network, intense competition between the organized and unorganized segments and low operational cost (GAFI, 2011). Availability of key raw materials, cheaper labor costs and presence across the entire value chain gives Egypt a competitive advantage (GAIN, 2011). According to Euromonitor

International (2012) drinking milk products see retail current value and volume growth of 22% and 15% respectively. Milk is the highest growth category in retail current value and volume terms in 2012, with respective growth rates of 26% and 18%. Retail current value sales increase significantly due to an 11% increase in the price of raw milk in 2012, which increases the prices of drinking milk products by between 4% and 8%. In addition, Juhayna Food Industries increases its lead in drinking milk products by two percentage points to reach a 47% share in 2012. Table 2 presents the drinking milk products company shares between 2008-2012 that is used in the sample of the research questionnaire and investigations.

The 25th of January 2011 revolution affected manufacturing and resulted in distribution disturbances which reduced current value growth from 24% in 2010 to 21% in 2011 and impacted on the supply and price of raw milk in 2012. Retail volume sales of drinking milk products in 2011 grew at a slower rate than last year's forecast of 20%. The growth rate was slower as low-income consumers downgraded to cheaper unpackaged milk. However, retail volume sales are expected to increase by 15%; slower than the review period CAGR of 18%, due to tightening supplies in 2012. Milk is expected to see the highest growth in retail current value and volume terms in 2012, with respective growth rates of 26% and 18% (CAPMAS, 2013). The industry is investing in converting low-income consumers from purchasing unpackaged milk, which makes up around 72% of the total milk market, to packaged milk. Moreover, the price of raw milk is expected to increase by at least 11% in 2012, because of supply pressures brought on by foot and mouth disease and competition for raw milk supplies between fresh milk and skimmed powder milk production. A pricing formula will be implemented for valuing raw milk to tackle the monopolistic practices of key players in the industry, which coerce farmers into selling raw milk at prices lower than the market value. The ensuing price increase in raw materials is expected to lead to price increases of between 4% and 8% in the price of drinking milk products in 2012 (Business Monitor International, 2013). Furthermore, drinking milk distribution channels are expected to shift back to independent small grocers, as various dairy manufacturers invest in distribution channel expansion to semi-rural and rural retailers. This will further be supported by the initiative to convert consumers from unpackaged milk to packaged milk (Euromonitor International, 2012).

It is worth noting that most of the drinking milk producers in Egypt are importing raw materials and exporting their finished goods through global supply chains, which create vulnerabilities and risks to the products. Shortages in raw materials for instance cause an increase in the price of dairy products, signalling a potential for vendors to search for substitutes with less expensive materials for the expected products. Inexpensive materials used which contaminated the milk as well as many other examples that affecting the safety of such products. Therefore, it is essential to test how these drinking milk producers in Egypt are ready to deal with such events.

3. Research Methodology

Companies are aware of the potential impact to the global economy that disruptions in supply chains can cause and recognize the need to invest in security measures that will mitigate the risks to the global and local supply chain upon which business depends (Yang and Wei, 2013). However, the author found that the situation of supply chain security of drinking milk producers in the Egyptian market have exposed the vulnerability of supply chains to disruptions which face challenges since the 25 of January 2011 revolution and disruptions started from such event. Therefore, the research question is formulated as "How can drinking milk producers in Egypt enhance their Supply Chain Security initiatives to better understand the threat to supply chains from disruptions?". To answer this question, five SCS dimensions have been examined *Inventory management and customer service; visibility; efficiency; resilience and customer relations*, which was previously adopted by Peleg-Gillai, et al. (2006). Moreover, the research would demonstrate the potential business benefits of security investments and in doing so would help other companies to identify ways in which they can use their security investments to improve their business performance.

This research uses the case study approach that is an ideal methodology when a holistic, in-depth investigation needed. Case studies have been used in varied investigations, particularly in sociological studies, but increasingly, in instruction. Yin (1994) has developed robust procedures. When these procedures are followed, the researcher will be following methods as well developed and tested as any in the scientific field. Case studies, on the other hand, are designed to bring out the details from the viewpoint of the participants by using

multiple sources of data. (Stake, 1995). Therefore, this empirical research aimed at examining SCS initiatives such as collaboration among supply chain parties, building organizational awareness and proactively investing in technology, that have shown promise to create collateral benefits. In order to identify collateral benefits companies can potentially realize, and quantify the level of benefits that realized based on the experience of drinking milk producers in the Egyptian market.

A purposive sampling technique was used to identify the respondents for this research. The total sample size was 18 drinking milk producers who are presenting about 86.8% of the market share in sector in 2012-2013. The questionnaire data was collected from executives working in the 18 producers mentioned in Table 2 during the period from November to February 2014. The data on experience of the executives, functional work areas, age and educational qualifications were used as the basis for selecting the respondents to ensure proportionate representation in the sample. The average age of the respondents was 35 years and the average experience 22 years.

The research uses the questionnaire that was designed and empirically tested by Peleg-Gillai, et al. (2006) on the topic of supply chain security. This questionnaire was selected, as it was the most comprehensive in terms of the variables that reflect the significant issues related to supply chain security. The structured questionnaire comprised of 56 statements related to measurement of supply chain security dimensions, which comprises of five sections: inventory management and customer service; visibility; efficiency; resilience and customer relations. The questionnaire was prepared after reviewing literature and validated by four professionals and consultants in the research area. Respondents were asked to identify their opinion on the statements by selecting 'Yes, No, or Don't Know'. In case of answering with 'Yes' to a question the respondent have to indicate by how much (estimated percentage). The use of estimated percentages in case of application is intended to reflect a more realistic and valid representation of the extent of application. The questionnaire lists all the identified potential benefits and asks respondents to state for each of these benefits whether their company has realized such a benefit following their supply chain security investments, and magnitude of improvement they experienced. In addition, respondents were asked to describe the supply chain security initiatives that their company has implemented since 25 of January 2011. Regular follow-up phone calls were conducted to boost the number of participating companies.

4. Research Findings

Although, most of the 18 producers presented a wide range of benefits, there is one producer - *Juhayna Food Industries*- had a well supply chain security system applied to sustain and prevent their supply chains from such risks and disruptions. Therefore, the analysis is outlined based on the detailed list of potential benefits for each of the identified five areas of improvements in the questionnaire. Table 3 presents the frequencies and percentages of the questionnaire responses.

Table 3. Frequencies of the Questionnaires Responses

Values	Inventory Management and Customer Service		Visibility		Efficiency		Resilience		Customer Relations	
	Frequency	Percent	Frequency	Percent	Frequency	Percent	Frequency	Percent	Frequency	Percent
Yes	10	55.6	10	55.6	11	61.1	9	50.0	6	33.3
No	7	38.9	7	38.9	6	33.3	8	44.4	11	61.1
I Don't Know	1	5.6	1	5.6	1	5.6	1	5.6	1	5.6
Total	18	100.0	18	100.0	18	100.0	18	100.0	18	100.0
Mean	32.22		45.83		33.79		31.54		29.58	
Std. Deviation	7.06		19.34		11.07		8.28		14.17	

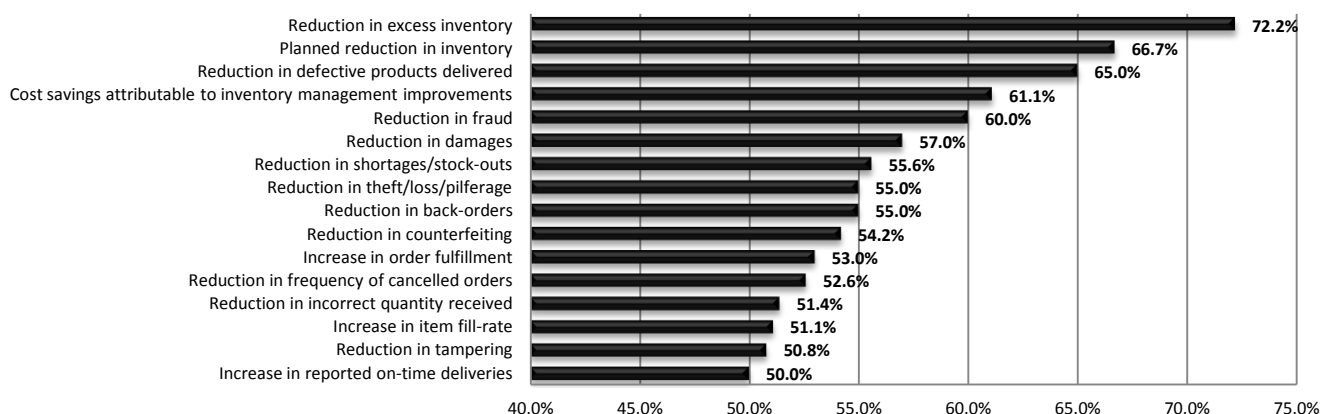
Most companies view security as an expense without benefit, which makes them reluctant to invest in SCS efforts. However, the questionnaire responses showed that drinking milk producers in Egypt had positive benefits from their SCS efforts. They found that security efforts lead to improvements in profitability,

relationships, and internal operations. Thus, the SCS measures can lead to positive performance for organizations, if SCS is approached in a proactive manner. Security collateral benefits include becoming less prone to disruption and better able to bounce back when disruptions occur. Therefore, resources dedicated to securing the supply chain may benefit firms in ways that go well beyond better security. These collateral benefits may create competitive advantages. The remainder of the following sub-section describes the benefits analyzed by the participating producers. The discussion is organized by the five benefits sections in the questionnaire.

4.1 Section 1: Inventory Management and Customer Service

Companies' responses presented several improvements in their inventory management practices due to their security investments, which positively affected their customers. 72.2% reported a remarkable effort have made to reduce the excess inventory level and to implement a proper planning for reducing their inventories by 66.7%. Product safety and genuineness shows 65% reduction in defective products delivered and around 60% in minimising the fraud and damages of goods. Customer service presents goods attributes in reducing the shortages and stock outs by 55.6% in addition to reducing the backorders with 55% and increasing the order fulfilments by 53%. Regarding the cost savings, 61.1% of companies stated cost savings associated with improved inventory management, but only one of them was able to quantify those benefits. Figure 2 summarizes the benefits related to inventory management and customer service.

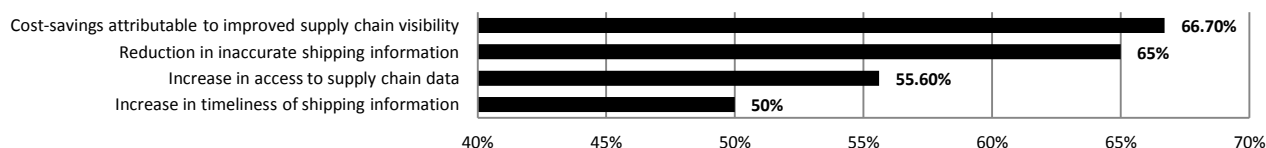
Fig 2. Benefits Related to Inventory Management & Customer Service



4.2 Section 2: Visibility

Most of the respondents were able to improve their visibility to the location and condition of their goods as they move along the supply chain. Figure 3 shows the average percent improvement in visibility based on data provided by several of the participating companies. Obviously, the most significant benefits that companies witnessed were in the cost saving to improve supply chain visibility by 66.7% and in the reduction of inaccurate shipping information by 65% and then the access to supply chain data by 55.6%.

Fig 3. Benefits Related to Visibility

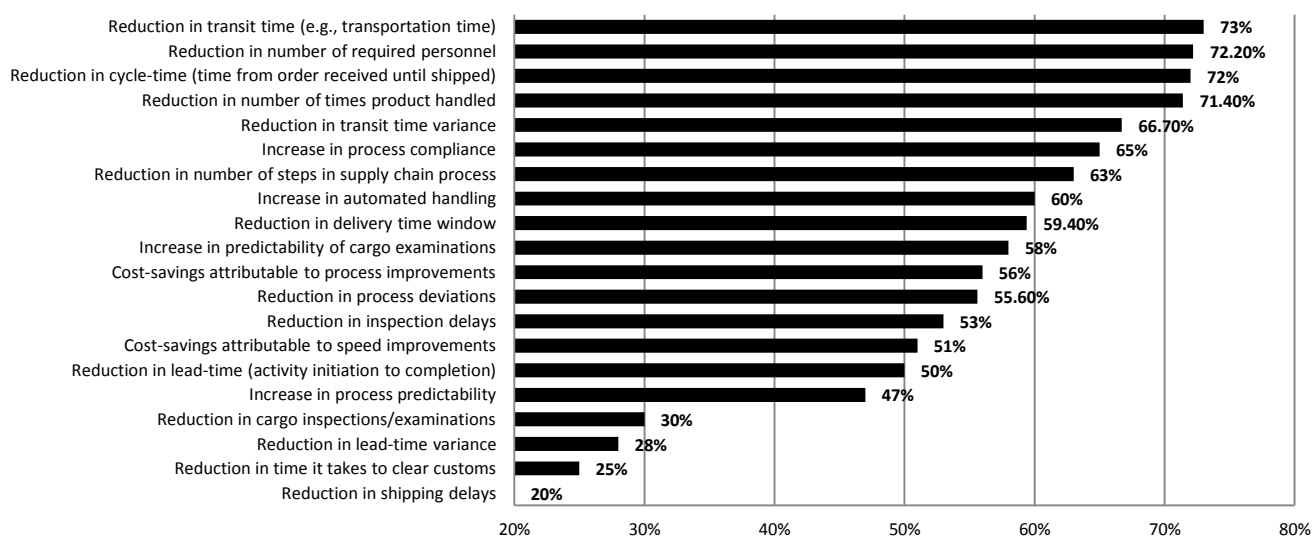


4.3 Section 3: Efficiency

The efficiency section in the questionnaire focused on both process improvements as well as improvements in transportation and in the customs clearance process. Figure 4 presents the responses about efficiency-related improvements because of their security investments. 73.3% of responses reduced the transit time, while 72.2%

percent of companies reduced the number of personnel. Such improvements are likely to lower the number of cycle time and product handling time. Companies stated multiple improvements in their processes. 65% of companies increased process compliance, 63% were able to reduce the steps in supply chain. Furthermore, 60% of companies increased in automated handling, while 58% responses were able to reduce the time window deliveries, which is likely to result in higher customer satisfaction in addition to internal benefits.

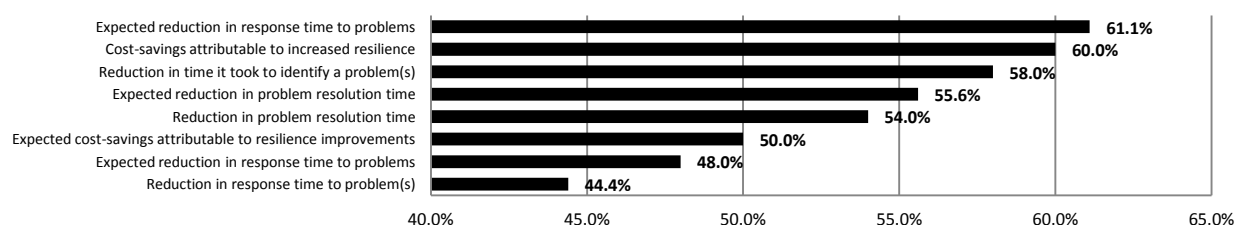
Fig 4. Benefits Related to Efficiency



4.4 Section 4: Resilience

The relationship between the security measures taken by the different drinking milk producers in Egypt and their ability to identify, respond to and resolve problems related to breaches in security or to delays and other issues companies may face while their goods are in transportation. Figure 5 shows several responses saw improvements in resilience area. 61.1% of responses reduced the problem identification time, while 60% of them achieved cost savings due to increase of resilience and 58% shortened problem resolution time. In addition, 50% of companies expect to realize cost savings that can be attributed to these improvements.

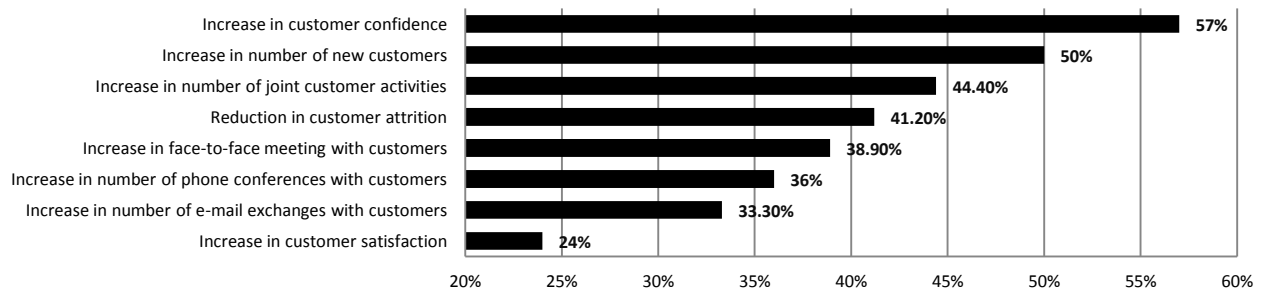
Fig 5. Benefits Related to Resilience



4.5 Section 5: Customer Relations

Drinking milk producers in Egypt were able to improve the relationship with their customers and improve customer satisfaction as Figure 6 presents, it showed by 57% customer confidence. As for the size and stability of their customer base, 50% of companies increased the number of new customers and 41.2% of companies saw a reduction in customer attrition. On the other hand, regarding the communication and collaboration with customers 44.4 % of companies presented an increase in the number of joint customer activities, which indicates a tighter relationship with these customers. However, 24% of companies have increase in their customer satisfaction.

Fig 6. Benefits Related to Customer Relations



5 Discussion and Conclusions

Most of the 18 drinking milk producers in Egypt were able to understand several benefits from their security investments e.g. Juhayna. Therefore, these investments in supply chain security are leading to improve internal operations, strengthen relationships with their customers. However, they are not a financial burden that should be kept to the minimum level necessary, but rather as an opportunity for improving business performance and profitability. In order to improve the security investments in different types of companies, they should focus on the SCS five dimensions. However, the findings of this research show claims that are not very accurate when all collateral benefits associated with security investments are considered. Moreover, it clearly proves that security investments can be beneficial, and that these benefits can be quantified and have business justification, result in operational improvements, ultimately may promote cost reduction and growth. Despite the findings of the questionnaire that revealed that the majority of the respondents did not believe in the potential business benefits of SCS investments to improve their business performance, it is highly recommended that they adopt the needed practices as it will have positive impact on their SCS as it was demonstrated in Peleg-Gillai, et al. (2006); Azevedo, et al. (2012) and Wakolbinger and Cruzb (2011). Moreover, some of drinking milk producers are experiencing significant examinations of cargo by the Egyptian Customs Authorities, due to the participation of international agreements and conventions of security programs. Therefore, government authorities need to continually re-evaluate the effectiveness of their security initiatives, to ensure that they do reach their goal of protecting their countries and that in parallel they provide meaningful benefits to participating companies.

On the other hand, the author recommends future researches that can examine the awareness, visibility, and importance of supply chain security challenges and issues by fostering public-private sector collaboration and cooperation. In addition, investigating the values and best practices related to SCS in Egyptian different sectors in Egypt. Moreover, analysing the role of education and training institutes in developing best practices and approaches of SCS.

Acknowledgements

The author would like to thank all the managers in the drinking milk producers in Egypt for their precious collaboration in the research.

References

- Azevedo, S., Govindan, K., Carvalho, H. and Cruz-Machado, V. (2012), Ecosilient index to assess the greenness and resilience of the upstream automotive supply chain, *Journal of Cleaner Production* 56(1): 131-146.
- Ballou, R. (2004), *Business Logistics/Supply Chain Management*, Pearson Education: New York.
- Bichou, K. (2011), Assessing the impact of procedural security on container port efficiency, *Maritime Economics and Logistics* 13 (1): 1-28.
- Business Monitor International, (2013), *Egypt Food and Drink Report*, Dublin: Research and Markets.
- Butter, F., Liu, J. and Tan, Y. (2012), Using IT to engender trust in government-to-business relationships: The Authorized Economic Operator (AEO) as an example, *Government Information Quarterly*, 29(2): 261-274.

- CAPMAS (2013), Egypt profile. Cairo: Central Agency for Public Mobilization and Statistics.
- Closs, D. and McGarrell, E. (2004), Enhancing security throughout the supply chain, IBM Center for BG.
- Coleman, J., Bolumole, Y. and Frankel, R. (2012), Benchmarking individual publication productivity in logistics, *Transportation Journal* 51 (2): 164-196.
- CSCMP, (2013), Supply chain visions, logistics terms and glossary. CSCMP, (UDAT/02/2013).
- Donner, M. and Kruk .C (2009), Supply Chain Security Management, IBRD, World Bank.
- Durowoju, A., Chan, K., and Wang, J. (2012), Entropy assessment of supply chain disruption, *Journal of Manufacturing Technology Management* 23(8): 998–1014.
- ECA, (2013), System directory service key customers, CAVIP, Egyptian Customs Authority (3/5), ALXEGY.
- Euromonitor International , (2012), Drinking milk products in Egypt, Passport, November 2012.
- Euromonitor International's website: www.euromonitor.com, last accessed January 2014.
- GAFI (2011), Invest in Egypt. Cairo: General authority for Investment.
- GAIN (2011), Retail Food Sector in Egypt. Washington, DC: USDA Foreign Agricultural Service.
- Hendricks, K. and Singhal, V. (2003), The effect of supply chain glitches on shareholder wealth, *Journal of Operation Management* 21(5): 500-522.
- Hintsa J., Gutiérrez X., Hameri P., and Wieser P. (2009), Supply chain security management: an overview. *International Journal of Logistics Systems and Management* 5(3/4): 344-355.
- Ireland, R. (2009), WCO SFS: Avoiding Excess in Global SCS Policy. WCO, Brussels, Belgium.
- Marlow, P. (2010), Maritime security: an update of key issues, *Maritime Policy and Management* 37 (7): 667-76.
- Mikuriya, K. (2007), Supply chain security: the customs community's Response, *World Customs Journal* 1(2): 51-89.
- Olson, D. and Wu, D. (2010), A review of enterprise risk management in supply chain, *Kybernetes* 39(5): 6694-6706.
- Peleg-Gillai, B., Bhat, G. and Sept, L. (2006), Innovators in supply chain security: better security drives business value, The Manufacturing Innovation Series, Stanford University.
- Polner, M. (2012), Compendium of authorized economic operator programs, brussels, WCO.
- Schmitt, A. and Singh, M. (2012), A quantitative analysis of disruption risk in a multi-echelon supply chain, *International Journal of Production Economics* 49(13): 4063-4084.
- Stake, R. (1995), The art of case research. Sage Publications: Newbury Park, CA.
- Wakolbinger, T. and Cruzb, J. (2011), Supply chain disruption risk management through strategic information acquisition and sharing and risk-sharing contracts, *International Journal of Production Research* 49(13): 4063-4084.
- WCO (2005), AEOs and small and medium-sized businesses, WCO, Brussels, Belgium.
- WCO (2012a), WCO Safe Framework of Standards to Secure and Facilitate Trade, WCO, Brussels, Belgium.
- WCO (2012b), The global prevention-training program, WCO, Brussels, Belgium.
- Yang, C. and Wei, H. (2013), The effect of supply chain security management on security performance in container shipping operation, *Supply Chain Management: An International Journal* 18(1): 74-85.
- Yang, Y. (2010), Impact of the container security initiative on Taiwan's shipping industry, *Maritime Policy and Management* 37(7): 699-722.
- Yin, R. (1994), Case study research: Design and methods. Sage Publishing: Thousand Oaks, CA.

Sustainable Shipping Management Strategy: Vessel Sharing in Liner Shipping Alliances

Xiwei Zhao, Jasmine Siu Lee Lam and Xuan Qiu*

Division of Infrastructure Systems and Maritime Studies, School of Civil and Environmental Engineering, Nanyang Technological University, 50 Nanyang Avenue, Singapore 639798. *Email: sllam@ntu.edu.sg.

**Corresponding author*

Abstract

In view of regulatory control and the need for fulfilling corporate social responsibility, shipping companies are required to attain higher social and environmental standards. However, to the best of our knowledge, there is relatively limited literature on sustainability in shipping. This paper aims to develop a sustainable shipping management strategy with a focus on liner shipping vessel sharing. It analyses the benefits of sustainability derived from vessel sharing by developing mathematical models to compare two scenarios: one with vessel sharing and another without vessel sharing. The results show that vessel sharing is a sustainable policy, and the benefits of it will be more significant when more liner companies cooperate to better utilize their vessels. Although many liner companies have signed vessel sharing agreements, the existing agreements in practice are based on a fixed ratio for contractual parties and it sometimes hampers the efficiency of vessel sharing. This paper shows that a flexible ratio will be more efficient as there are fewer constraints.

Keywords: Sustainability; Shipping; Vessel sharing; Liner shipping alliance.

1. Introduction

Due to the quest of environmental protection and the increasing attention on corporate social responsibility, there has been much pressure on companies to pursue sustainability practices (Lee and Lam, 2012). Historically, a company's profitability was a very important measure to gauge the competitiveness of the company. However, there has been more and more emphasis on the importance of environmental and social challenges faced by a company. A modern company is expected to play a responsible role in introducing new policies or products and/ or new processes to address pollution, minimize resource usage, and to improve stakeholder relationships (Crane, 2000).

In the domain of shipping, sustainability has also becoming highly addressed by many companies. In recent years, the oversupply of vessels results in major financial challenges for shipping companies. What is more, shipping activities produce a large amount of CO₂ emission along with the huge quantity of cargoes moved. According to the International Maritime Organisation (IMO), maritime transport emitted 1046 million tons of CO₂ in 2007, representing 3.3% of the world's total emissions (Buhaug et al., 2009). Achieving economic, social, and environmental performances simultaneously becomes a major concern of the shipping industry. As a result, sustainability has been drawing more attention from shipping companies. For example, the Mediterranean Shipping Company's MSC Sustainability Ambitions 2020 and Maersk's sustainability strategies are some of the representatives of what the shipping industry is striving to do. However, there is relatively limited literature on sustainability in shipping.

In liner shipping, the Vessel Sharing Agreement (VSA) has been introduced and many companies have adopted this policy. This policy enables companies to share the available slots in their vessels in different ports so as to provide better service and reduce cost per container. Vessel sharing seems to be more economically and environmentally advantageous comparing to non-vessel sharing. Thus, vessel sharing might be a viable approach for liner companies to tackle the challenge of sustainability. This study aims to develop a sustainable shipping management strategy with a focus on liner shipping vessel sharing. It analyses the benefits of

sustainability derived from vessel sharing. Firstly, the economic aspect of sustainability is displayed through the comparison of revenue earned under two scenarios: one is with VSA and another is without VSA. For each of the two scenarios, a mathematical model will be developed for total revenue maximization. The traditional VSA has a fixed ratio of sharing spaces between two companies; however, the model constructed in this study will show that a flexible combination of containers should be preferred. While the maximum revenue is achieved, the corresponding decision variables will be used to calculate the CO₂ emission from vessels in these two scenarios. The calculated CO₂ will be compared to illustrate whether the scenario with vessel sharing will also has less harmful environmental impact in terms of CO₂ emission.

The remaining part of this paper is organized as follows. The literature related to our study is reviewed in Section 2 and it is followed by Section 3 which presents the two optimization models and a brief discussion of how these models will be solved in this study. In Section 4, we run the two mathematical models under our hypothesized shipping process to obtain the maximum revenue. We will also discuss the environmental influence corresponding to those two models. Finally Section 5 concludes this study and discusses the future extension of this study.

2. Literature Review

2.1 General Sustainable Business Model

Sustainability of business has been a hot topic as businesses are confronted with increasingly tightened policies enacted by government as well as newly emerging societal expectations beyond purely economic issues (Handelman&Arnold, 1999; Hoffman et al., 2003). The most recognized definition of sustainability comes from the World Commission on Environment and Development (WCED) report (1987) which includes three aspects of sustainability, namely economic, social, and environmental aspects. There are many other definitions available for this concept (see, e.g., Cotgrove, 1982; Gladwin et al., 1995; O’Riordan, 1991).

The literature presents various perspectives on the business model: Magretta’s (2002), Zott and Amit (2010) and Beattie and Smith (2013) take business models as a holistic description on how a firm does business. Teece (2010) describes that a business model articulates how the company will convert resources and capabilities into economic value.

Most of the literature addresses business model innovation for sustainability while taking a wider range of stakeholders’ view. Business model innovation is recognized as important to deliver social and environmental sustainability in the industrial system (Lüdeke-Freund, 2010). Stubbs and Cocklin (2008) and Porter and Kramer (2011) suggest that business model redesign makes it possible for mainstream business to readily integrate sustainability into their business, and business model innovations can support a systematic, on-going creation of business cases for sustainability(Schaltegger et al.,2012). A sustainable business functions in such a way to coordinate technological and social innovations with system-level sustainability (Bocken et al., 2013). Business model innovation emphasizes more on the importance of changing “the way you do business” rather than “what you do” and thus must go beyond process and products (Amit and Zott, 2012). New systems instead of individual technology should be developed in order to fulfil the purpose of business model innovation (Johnson and Suskewicz, 2009). Stubbs and Cocklin (2008) assert that sustainable business model aligns the interests of stakeholders and bases on the triple bottom line approach to define the firm’s purpose and measure performance. Beattie and Smith (2013) also address sustainable business model as shifting focus from shareholders to other key stakeholders. This is in line with Bocken et al. (2013) who proposes that sustainable business models capture economic, social, and environmental values for a wide range of stakeholders.

To the best of our knowledge, the existing literature has very limited analysis of specific sustainable business models for specific industries. In practice, various industries possess very different characteristics. The literature does not provide a guide to refer to when a business model is to be built in a real situation. Bocken et al. (2013) have proposed some archetypes to refer to, but they are not specific enough, especially for the maritime domain.

2.2 Sustainable Strategies in Shipping

Green shipping practices (GSPs) are environmental management practices undertaken by shipping firms with an emphasis on waste reduction and resource conservation in handling and distributing cargoes (Lai et al. 2011; Lai et al., 2013). A lot of literature focuses on the relationship between environmentally responsible firm and its financial performance (Viana et al., 2009). How to be profitable and reduce the adverse effect on environment at the same time has been a key challenge to most shipping firms (Guide and Van Wassenhove, 2009; Cheng and Tsai, 2009). McConnell (2002) accentuates the importance of promoting education for human resource in the shipping industry to maintain sustainable development. Strategy formation and implementation cannot be separated from people that are related (Snell, 2005).

From the above review, we can see that the literature covers mainly concepts and practices from the perspectives of environment and society subject to economic profitability. There is a lack of systematic study of sustainable strategies in shipping and thus a quantitative approach to tackle sustainability in shipping is needed to enhance this area.

2.3 Shipping Alliance

There are various forms of alliance in liner shipping. The most prominent one is strategic or global alliances, a relatively new type of co-operative agreement in shipping (Midoro&Pitto, 2000). In addition to this, various types of collaborative agreements have been developed between carriers (Panayides and Wiedmer 2011). These include vessel sharing and slot sharing agreement. Carriers share cost as well as profit based on the demand information sharing (Heaver et al., 2005). One of the recent new alliances is the P3 which is formed by Maersk Line, Mediterranean Shipping Co. and CMA CGM. They agreed to pool their biggest vessels in a giant vessel-sharing alliance in the main east-west trades. To match P3's market size and power, many competitors have also formed new alliances. The most recent example is that Evergreen Line joined CKYH alliance to share ships on trades between Asia and North Europe and the Mediterranean.

Many scholars have addressed the objective of alliance which is basically for accomplishing corporate objectives (Fossey, 1994; Gardiner, 1997; Midoro&Pitto, 2000; Yang et al., 2011). The general objectives contain financial (profit maximization, increase in shareholder wealth, and financial risk reduction), economic (cost reduction, economies of scale), strategic (entry in new markets, wider geographical scope), marketing (satisfy customers with higher quality) and operational objectives (increase in frequency of services, vessel planning and coordination in global scale) (Panayides&Wiedmer, 2011).

Judging from the analysis above, we can barely see any literature that analyses liner alliance from the social and environmental aspects of sustainability. This remains to be an unknown area which is worth researching on.

3. Mathematical Modelling

This model considers two shipping companies: A and B, both of which operate among the same series of ports. We assume there are N ports and each company has G voyages annually between port i and port j . D_{ijg}^A and D_{ijg}^B containers are ordered from port i to j at the g th voyage from company A and B respectively. The objective is to maximize the total system revenue by choosing the mix of containers from different ports along the voyage. Hence the decision variable is n_{ijg} , the number of containers transported from port i to port j at the g^{th} voyage. In the following subsections, we will develop mixed integer programming models for two scenarios: with and without VSA.

The notations in the models are given in Table 1.

Table 1. Parameters and variables used for modeling different scenarios

<i>Parameters</i>	
N	The total number of ports in our operating routes
G	The total annual voyages for a company/companies
R_{ijg}^A	The revenue generated in company A for a container to be transported from port i to port j at the g^{th} voyage
R_{ijg}^B	The revenue generated in company B for a container to be transported from port i to port j at the g^{th} voyage
S_{ijg}^A	The slots available in ships of company A from port i to port j at the g^{th} voyage
S_{ijg}^B	The slots available in ships of company B from port i to port j at the g^{th} voyage
S_{ijg}	The slots available in ships from port i to port j at gth voyage under VSA scenario
D_{ijg}^A	The number of container supplied by a company A from port i to port j at the g^{th} voyage
D_{ijg}^B	The number of containers supplied by company B from port i to port j at the g^{th} voyage
M^{AB}	Total revenue generated under non-VSA scenario
M	Total revenue generated under VSA scenario
<i>Decision Variables</i>	
n_{ijg}^A	The number of company A's container transported from port i to port j at the g^{th} voyage
n_{ijg}^B	The number of company B's container transported from port i to port j at the g^{th} voyage

3.1 Modelling the Non-VSA Scenario

Under the non-VSA scenario, each individual carrier will operate by their own ships. The objective function is formulated as

$$M^{AB} = M^A + M^B \quad (1)$$

$$\text{where } M^A = \sum_{g=1}^G \sum_{j=1}^N \sum_{i=1}^N (R_{ijg}^A \cdot n_{ijg}^A)$$

and

$$M^B = \sum_{g=1}^G \sum_{j=1}^N \sum_{i=1}^N (R_{ijg}^B \cdot n_{ijg}^B)$$

$$\sum_{g=1}^G \sum_{i=1}^N \sum_{j=1}^N R_{ijg}^A * n_{ijg}^A \sum_{g=1}^G \sum_{i=1}^N \sum_{j=1}^N R_{ijg}^B * n_{ijg}^B$$

Subject to:

$$n_{ijg}^A \leq S_{ijg}^A \quad (4)$$

$$n_{ijg}^B \leq S_{ijg}^B \quad (5)$$

$$n_{ijg}^A \leq D_{ijg}^A \quad (6)$$

$$n_{ijg}^B \leq D_{ijg}^B \quad (7)$$

$$n_{ijg}^A, n_{ijg}^B \in \text{integer}$$

Eq. (4) and Eq. (5) are capacity constraints, ensuring that the containers loaded on board cannot exceed the available slots in the ships. Eq. (6) and Eq. (7) guarantee that the containers loaded cannot exceed the available containers in that port.

In this study, the optimal revenue for each company depending on the optimal combination of containers in different ports is obtained by using Excel-Solver to solve the respective mixed integer programming model: M^A and M^B , for $i, j = 1, 2 \dots N$.

3.2 Modelling the VSA Scenario

Under VSA, company A and company B will cooperate with each other by deploying the containers belonging to both of them in different ports to maximize the total revenue. The objective function is formulated as:

$$M = \sum_{g=1}^G \sum_{j=1}^N \sum_{i=1}^N (R_{ijg}^A \cdot n_{ijg}^A + R_{ijg}^B \cdot n_{ijg}^B) \sum_{g=1}^G \sum_{i=1}^N \sum_{j=1}^N (R_{ijg}^A \cdot n_{ijg}^A + R_{ijg}^B \cdot n_{ijg}^B) \quad (8)$$

The containers from port i to port j will also be subject to the following condition due to limited slots in ships available:

$$n_{ijg}^A + n_{ijg}^B \leq S_{ijg} \quad (9)$$

$$n_{ijg}^A + n_{ijg}^B \leq D_{ijg} \quad (10)$$

$$n_{ijg}^A, n_{ijg}^B \in \text{integer}$$

Here, company A and company B share the vessels and S_{ijg} refers to the total available slots from both company A and company B. D_{ijg} refers to the available containers in corresponding ports. Similarly the optimal total revenue for them can be solved by using the Excel-Solver to solve the mixed integer programming model: M, for $i, j = 1, 2, \dots, N$.

4. A Numerical Study

This section presents an illustrative example for three purposes: (1) to demonstrate the application of the proposed mathematical formulations; (2) to compare the performance of companies in two scenarios: with and without vessel sharing; and (3) to examine the environmental impact of sharing vessel capacity.

The data on the amount of supplied containers in different ports and the ship sizes deployed is set according to the general industry practice in order to calculate the coefficient for the optimization model. The liner freight rate is set based on the distance between the loading port and discharging port as well as the presentation by Drewry (2012) which is shown in Appendix I. For the simplicity of calculation, only one week's voyages will be considered.

4.1 Parameter Settings

Table 2. Potential amount of laden containers by company A and B in all six ports

Company A/B(Blue Area) Inputs-Supply(TEUs)						
Starting/Supplies	Hong Kong	Kaohsiung	Busan	Kobe	Tokyo	New York
Hong Kong	0	1200	1600	400	600	1400
Kaohsiung	0	0	400	1000	1400	600
Busan	0	0	0	200	400	600
Kobe	0	0	0	0	600	400
Tokyo	0	0	0	0	0	690
New York	0	0	0	0	0	0
Hong Kong	0	1400	2000	600	400	1000
Kaohsiung	0	0	800	468	400	640
Busan	0	0	0	400	460	1000
Kobe	0	0	0	0	1300	400
Tokyo	0	0	0	0	0	1120
New York	0	0	0	0	0	0

Source: Authors

Company A and company B operate through the six candidate ports in the Trans-Pacific route: Hong Kong, Kaohsiung, Busan, Kobe, Tokyo and New York. In the Non-VSA scenario, both companies provide weekly services; while in the VSA scenario, the service frequency will be increased to semi-weekly service. The

amount of containers supplied by these two companies is assumed to spread out evenly during the week, which means half of a week's containers of each company will be shipped when there is vessel sharing each time. Each company deploys one 5,000-TEU containership in the route.

Table 1 shows the weekly supply of containers by company A and company B in different ports. The column represents the origin ports and the row shows the destinations. For example, company A has 1,200 TEUs to be shipped from Hong Kong to Kaohsiung. The upper part represents the supply of containers by company A and the lower part represents the supply of containers by company B respectively. Table 2 shows the liner freight rate (USD/TEU) that is charged by company A and company B corresponding to the routes in Table 1. For example, company B charges 200 USD for a container shipped from Hong Kong to Kaohsiung.

Table 3. Liner freight rate charged by company A and B.

Company A/B(Blue Area) Output-Liner freight rate(USD)						
Starting/Revenue USD/TEU	Hong Kong	Kaohsiung	Busan	Kobe	Tokyo	New York
Hong Kong	0	180	187	190	200	486
Kaohsiung	0	0	240	270	290	463
Busan	0	0	0	230	270	441
Kobe	0	0	0	0	245	420
Tokyo	0	0	0	0	0	400
New York	0	0	0	0	0	0
Hong Kong	0	200	210	230	250	500
Kaohsiung	0	0	200	240	245	465
Busan	0	0	0	180	190	432
Kobe	0	0	0	0	230	402
Tokyo	0	0	0	0	0	400
New York	0	0	0	0	0	0

Source: Authors

4.2 The Value of Vessel Sharing

According to the decision variables and constraints stated above, the optimal revenues for company A and company B can be solved using Excel Solver. The results are presented in Tables 3-4.

Table 3 displays the amounts of containers that are loaded and unloaded at different ports based on the ultimate target, optimizing the revenues for company A and company B under Non-VSA. In this scenario both companies have a weekly service. It can be observed that for the voyage from Hong Kong to Kaohsiung the vessel of company A is not fully loaded even though there are many more containers in Hong Kong. The reason for this observation is that the vessel should be used to take the containers that will generate the maximized revenue for the company. If the vessel was fully loaded in Hong Kong, it will only be able to load 1,200 TEUs in Kaohsiung; however, if the vessel was loaded according to Table 1 in Hong Kong, then it can be fully loaded in Kaohsiung and it turns out to maximize the revenue for company A. It is suggested that when there are lots of containers needed to be shipped, liner companies should choose those that will bring the most benefits to the companies even though the vessels may not be fully loaded. As can be seen from Table 3, the total revenue for company A and company B is \$6,249,920.

Similarly, Table 4 shows the optimal results under VSA. Under this context, where both companies cooperate with each other, the service frequency is increased to twice a week and as a result the supply of containers from company A and B will be halved for individual shipment. It can be observed that the voyage from Hong Kong to Kaohsiung is also not fully loaded and the combinations of containers in different ports are not exactly half of those in Table 3. The reason is that if company A and company B cooperate; there are a different set of supplies to choose from and vessel sharing enable better vessel utilisation such that the available scarce source can be offered to those that have higher value to the companies. The total revenue here is \$6,283,320 for two voyages, which is higher than the total revenue for the scenario in Table 3. This implies

that liner companies should cooperate with each other in order to generate better revenue by choosing from a more diversified range of container supplies. It can also be observed that there is no fixed ratio for the vessel sharing between company A and company B. This actually helps to realize the benefit of vessel sharing without any comprising. Thus, it is advised for liner companies to adopt this flexible vessel sharing policy to optimize the revenue for both.

Table 4. Optimized slots allocations and maximized revenue for non-vessel sharing

Company A/B(Blue Area) Inputs-Supplies	Maximized Revenue for Company A and Company B as Individuals					
Starting/Supplies	Hong Kong	Kaohsiung	Busan	Kobe	Tokyo	New York
Hong Kong	0	1200	800	0	0	1400
Kaohsiung	0	0	400	800	1000	600
Busan	0	0	0	200	400	600
Kobe	0	0	0	0	600	400
Tokyo	0	0	0	0	0	690
New York	0	0	0	0	0	0
Maximized Revenue(company A)	\$2,935,400					
Hong Kong	0	1400	2000	600	0	1000
Kaohsiung	0	0	92	468	200	640
Busan	0	0	0	400	460	1000
Kobe	0	0	0	0	1300	400
Tokyo	0	0	0	0	0	1120
New York	0	0	0	0	0	0
Maximized Revenue(company B)	\$3,314,520					
Total Revenue	\$6,249,920					

It can be observed that vessel sharing will also increase the frequency of service, which will increase customers' satisfaction over the service quality and in turn bring many immeasurable benefits to the companies. All in all, a flexible vessel sharing policy will benefit liner companies and thus should be adopted.

Table 5. Optimized container slots allocations and maximized revenue for Vessel Sharing

Company A/B(Blue Area) Inputs-Supplies (TEUs)	Maximized Revenue for Company A and B as a Whole					
Starting/Supplies	Hong Kong	Kaohsiung	Busan	Kobe	Tokyo	New York
Hong Kong	0	600	0	0	0	700
Kaohsiung	0	0	200	500	600	300
Busan	0	0	0	100	200	300
Kobe	0	0	0	0	300	200
Tokyo	0	0	0	0	0	345
New York	0	0	0	0	0	0
Hong Kong	0	700	1000	300	0	500
Kaohsiung	0	0	346	234	0	320
Busan	0	0	0	200	230	500
Kobe	0	0	0	0	650	200
Tokyo	0	0	0	0	0	560
New York	0	0	0	0	0	0
Total Revenue	\$6,283,320					

4.3 The Impact of Vessel Sharing on CO₂ Emissions

To examine the influence of vessel sharing on the environment, the CO₂ emission differences under two proposed scenarios are calculated. The CO₂ emission is estimated based on the level of transportation activity (McKinnon & Piecyk, 2010). The equation can be expressed as following:

$$\text{CO}_2 = \text{TEUs transported} \times \text{average distance travelled} \times \text{CO}_2 \text{ emissions factor per TEUs-nm} \quad (11)$$

The amounts of transported TEUs from one port to another are calculated as follows. For example, the amount of containers from Kobe to Tokyo shipped by company A is 5,000 TEUs, which is the sum of the highlighted numbers in Table 3. Using the same method of calculation we can get the total amount of containers shipped by these two companies under the two scenarios. They are shown in the following Table 5.

Table 6. Containers shipped from port to port and the difference of containers shipped between two scenarios.

Shipping amount Routes TEUs	Without Vessel Sharing-Total Amount(TEUs)	With Vessel Sharing-Total Amount(TEUs)	Difference (TEUs)
Hong Kong-Kaohsiung	8400	7600	+800
Kaohsiung-Busan	10000	10000	0
Busan-Kobe	9768	9968	-200
Kobe-Tokyo	10000	10000	0
Tokyo-New York	7850	7850	0

Table 7. CO₂ Emission in two scenarios and the difference amount

CO ₂ Emission Routes TEUs*nm	Without Vessel Sharing-Total Amount(TEUs*nm)	With Vessel Sharing-Total Amount(TEUs*nm)	Difference of CO ₂ (TEUs*nm)
Hong Kong-Kaohsiung	8400C*D ₁	7600C*D ₁	+800 C*D ₁
Kaohsiung-Busan	10000C*D ₂	10000C*D ₂	0
Busan-Kobe	9768C*D ₃	9968C*D ₃	-200 C*D ₃
Kobe-Tokyo	10000C*D ₄	10000C*D ₄	0
Tokyo-New York	7850C*D ₅	7850C*D ₅	0

Table 5 shows the amount of containers shipped from port to port within one week under those two scenarios. In Table 6, we use C to denote the CO₂ emissions factor per TEUs-nm and apply Eq. (8) to those voyages. D₁ to D₅ denote the corresponding distances between different ports. Comparing the amount of CO₂ emission under vessel sharing and non-vessel sharing, the differences exist in the voyage from Hong Kong to Kaohsiung and the voyage from Busan to Kobe. The distance between Hong Kong and Kaohsiung is 414 nautical miles and the distance from Busan to Kobe is 406 nautical miles. After calculation the difference amount can be shown as:

$$\Delta\text{CO}_2 = 250,000 \times C \times \text{TEUs} \times \text{nm} \quad (12)$$

It can be concluded that when there is vessel sharing there will be less environmental harm. As can be seen from Table 5, the scenario without vessel sharing actually shipped more containers than the scenario with vessel sharing. This amount difference directly contributes to the difference in CO₂ emission.

Above all, these outcomes indicate that vessel sharing is a sustainable, i.e., economically efficient and environmentally friendly, shipping management strategy.

5. Conclusion

This paper studies a sustainable management strategy for shipping companies, based on which a mathematical model is formulated for two scenarios respectively: with and without vessel sharing. There is almost no paper that addressed the environmental aspect and economic aspect of vessel sharing, as far as the authors know; this paper successfully fulfilled this gap. A numerical study is then carried out to investigate the value of vessel sharing from economical and environmental perspectives. We have observed several managerial implications. First, vessel sharing is a sustainable policy, and the benefits of it will be more significant when more liner companies cooperate to better utilize their vessels. Second, vessel sharing could boost up the

service quality due to higher service frequency. Third, although quite a few companies have signed vessel sharing agreement, the existing VSAs in practice are based on a fixed ratio for contractual parties and it sometimes hampers the efficiency of vessel sharing. This paper shows that a flexible ratio will be more efficient as there are fewer constraints. Those companies who are under the existing VSA are advised to employ this flexible ratio policy to get the best out of it, even though there are many other factors, like operation, profit splitting, etc., that may affect their decisions.

This paper works as a good reference for liner shipping management; however, it also raises many challenges for liner shipping operation. First, in real business the operation of containerships is more complicated. Bunkering consumption cost is a big portion of the operation cost and it affects the profitability together with the revenue generated. This cost is coherently connected with the steaming speed which is a major concern for liner companies when making decisions. Second, different companies may have different business interests and strategies, which contribute to the difficulties of collaborating with one another and may offset the benefit brought by vessel sharing. In addition, there might be many management and execution issues for vessel sharing, which is beyond the scope of this mathematical model presented in this paper but may add challenges to the vessel sharing process. All these challenges discussed are worthy of research in the future.

Acknowledgement

We wish to acknowledge the funding support for this project from Nanyang Technological University under the Undergraduate Research Experience on CAmpus (URECA) programme.

References

- Amit, R. and Zott, C. (2012), Creating value through business model innovation, *MIT Sloan Management Review* 53 (3): 41-49.
- Beattie, V. and Smith, S. J. (2013), Value creation and business models: refocusing the intellectual capital debate. *The British Accounting Review* 45(4): 243-254.
- Bocken, N. M. P., Short, S. W., Rana, P. and Evans, S. (2013), A literature and practice review to develop sustainable business model archetypes, *Journal of Cleaner Production*, <http://dx.doi.org/10.1016/j.jclepro.2013.11.039>.
- Buhaug, Ø., Corbett, J.J., Endresen, Ø., Eyring, V., Faber, J., Hanayama, S., Lee, D.S., Lee, D., Lindstad, H., Markowska, A.Z., Mjelde, A., Nelissen, D., Nilsen, J., P ° alsson, C., Winebrake, J.J., Wu, W.-Q., Yoshida, K. (2009), Second IMO GHG study, 2009, International Maritime Organization (IMO) London, UK.
- Cheng, Y. H. and Tsai, Y. L. (2009), Factors influencing shippers to use multiple country consolidation services in international distribution centers, *International Journal of Production Economics* 122(1): 78-88.
- Cotgrove, S. (1982), *Catastrophe or cornucopia: The environment, politics, and the future*, Chichester, UK: Wiley.
- Crane, A. (2000), Corporate greening as amoralization, *Organization Studies* 21(4): 673-696.
- Fossey, J. (1994), Birth of the global alliance, *Containerisation International* 49-55, October.
- Damas, P. (2012), Container shipping market outlook, freight rates and index-linked contracts. Multimodal 2012, Lecture conducted from Drewry Supply Chain Advisors, Birmingham.
- Gardiner, P. (1997), *The liner market*. London: Lloyd's of London Press.
- Gladwin, T. N., Kennelly, J. J. and Krause, T.S. (1995), Shifting paradigms for sustainable development: Implications for management theory and research, *Academy of Management Review* 20(4): 874-907.
- Guide V.D.R. and Van Wassenhove L.N. (2009), The evolution of closed-loop supply chain research. *Operations Research* 57(1): 10-21.
- Handelman, J. M. and Arnold, S. J. (1999), The role of marketing actions with a social dimension: Appeals to the institutional environment, *Journal of Marketing* 63(3): 33-48.
- Heaver, T. D., Meersman, H. and Vande Voorde, E. (2005), Co-operation and competition in international container transport. In H. Laggate, J. McConville, & A. Morvillo (Eds.), *International maritime transport* (pp. 145-159). New York: Routledge.
- Hoffman, K. D., Czinkota, M., Dickson, P., Dunne, P., Griffin, A., Hutt, M., (2003), *Marketing: Best Practices*, Ohio: Thomson.

- Johnson, M. and Suskewicz, J. (2009), How to Jump-Start the Clean-Tech Economy, Harvard Business Review on Greening Your Business Profitably, (November): 41-62.
- Lai, K. H., Lun, V. Y., Wong, C. W. and Cheng, T. C. E. (2011), Green shipping practices in the shipping industry: Conceptualization, adoption, and implications. *Resources, Conservation and Recycling* 55(6): 631-638.
- Lai, K. H., Wong, C. W. Y., Lun, Y. H. V. and Cheng, T. C. E. (2013), Shipping design for compliance and the performance contingencies for shipping firms, *Transportation Research Part E-Logistics and Transportation Review* 55: 74-83.
- Lee, C.K.M. and Lam, J.S.L. (2012), Managing reverse logistics to enhance sustainability of industrial marketing, *Industrial Marketing Management*, 41(4): 589-598.
- Lüdeke-Freund, F. (2010), Towards a conceptual framework of business models for sustainability. In: *ERSCP-EMU Conference*, Delft, The Netherlands, pp. 1-28.
- Magretta, J. (2002), Why business models matter, *Harvard Business Review* 80(5): 86-92.
- McConnell, M. (2002), Capacity building for a sustainable shipping industry: a key ingredient in improving coastal and ocean and management, *Ocean & Coastal Management* 45(9): 617-632.
- McKinnon, A. and Piecyk, M. (2010), Measuring and Managing CO2 emissions, Report prepared for Cefic.
- Midoro, R. and Pitto, A. (2000), A critical evaluation of strategic alliances in liner shipping, *Maritime Policy and Management* 27(1): 31-40.
- O'Riordan, T. (1991), The new environmentalism and sustainable development, *Science of the Total Environment* 108 (1-2): 5-15.
- Panayides, P. M. and Wiedmer, R. (2011), Strategic alliances in container liner shipping, *Research in Transportation Economics* 32(1): 25-38.
- Porter, M. and Kramer, M. (2011), Creating shared value, *Harvard Business Review* 89(1/2): 62-77.
- Schaltegger, S., Lüdeke-Freund, F. and Hansen, E. (2012), Business cases for sustainability: the role of business model innovation for corporate sustainability, *International Journal of Innovation and Sustainable Development* 6 (2): 95-119.
- Snell, S.A., Shadur, M. and Wright, P.M. (2005), Human resources strategy: the era of our ways. In: Hitt MA, Freeman R.E., Harrison J.S., editors, *Handbook of strategic management*. Blackwell Publishing 627-649.
- Stubbs, W. and Cocklin, C. (2008), Conceptualizing a "Sustainability Business Model", *Organization Environment* 21(2): 103-127.
- Teece, D. (2010), Business Models, Business Strategy and Innovation, *Long Range Planning* 43 (2-3): 172-194.
- Viana, M., Amato, F. and Querol, X. (2009), Chemical tracers of particulate emissions from commercial shipping. *Environmental Science & Technology* 43(19): 7472-7477.
- World Commission on Environment and Development. (1987), *Our common future*. Oxford, UK: Oxford University Press.
- Yang, D., Liu, M. and Shi, X. (2011), Verifying liner Shipping Alliance's stability by applying core theory. *Research in Transportation Economics* 32(1): 15-24.
- Zott, C. and Amit, R. (2010), Business model design: an activity system perspective, *Long Range Planning*. 43 (2-3): 216-226

Appendix I: Liner rates for different routes

Container freight rate outlook for 2012 Carriers have GRIs every week since March	
Asia outbound GRIs	Europe outbound GRIs
To Europe (1 st May) Maersk +\$400/TEU CMA CGA +\$385/TEU Cosco +\$425/TEU	To Asia (15 th April/1 st May) Maersk +\$300/TEU NYK +\$150/250 per 20ft/20ft MSC +\$300/TEU "no show charge"
To USWC (15 th April/1 st May) Maersk +\$500/40ft MSC +\$400/40ft...	To USWC (15 th April/1 st May) Maersk +\$160/200 per 20ft/40ft WTSA +\$50-100 per 40ft...

Source: Damas (2012)

An Evaluation of the Success Factors for Ship Management Companies using Experts' Knowledge

Jun-woo Jeon¹, Gi-Tae Yeo¹, Vinh V. Thai² and Tsz Leung Yip³

¹Graduate School of Logistics, Incheon National University, South Korea.

²Division of Infrastructure Systems and Maritime Studies, Nanyang Technological University, Singapore.

³Department of Logistics and Maritime Studies, The Hong Kong Polytechnic University, Hong Kong.

Abstract

In recent years, efficiency and competitiveness have become increasingly important in the shipping industry. The outsourcing of shipping operations to ship management companies (SMCs) is therefore regarded as an efficient way for shipping companies to focus on their core functions. However, the evaluation of the success factors for SMCs is a relatively difficult task. Ship owners and SMCs inevitably need to know each other's characteristics. The aim of this research is to identify the success factors for SMCs, to evaluate the weights of these factors, and finally to determine the differences in perceptions between ship owners and SMCs using the fuzzy evaluation method. The fuzzy method is capable of overcoming evaluation difficulties by accommodating both tangible and intangible variables using experts' knowledge. As a result of our analysis, the ship owners and SMCs' perception differences were established. The results show that SMCs rank "Quick responses to ship owners" first, followed by "Ship management fees" and "The efficient management of ships' operational costs." On the other hand, ship owners perceive "The efficient management of ships' operational costs," "The ability to recruit the full required manpower," and "The potential for high-quality management" as most important.

Keywords: Ship management companies (SMCs); Ship owner; Expert knowledge; Fuzzy evaluation method; Success factors.

1. Introduction

Modern companies need high-quality management to overcome the increasingly harsh business environment. Management can be defined as an activity that aims to achieve organizational objectives, and consists of various tangible and/or intangible variables. The tangible variables include company size, technologies, and machinery while the intangible variables are represented by knowledge, human resources, and service ability, etc. Executives with the ability to harmonize the various resources are needed in order for management to succeed (Panayides and Gray, 1999).

There is fierce competition across many sectors in the maritime industries. Moreover due to the introduction of various new elements to the shipping industry, such as flags of convenience, the entry of developing nations, and the business activities of multinational or transnational companies, more effective performance monitoring and diagnosis are required (Frankel, 1982). Given this context, efficiency and competitiveness are imperative for the entire shipping industry.

Shipping companies experience high operating costs, such as excessive crew expenses, and the limitations of national registries. Ships are shipping companies' basic profit-making units, and require different management and organizational systems compared to land-based structures (Ant and Alen, 2011). According to Frankel (1982), "ships are becoming more and more integral parts of transportation systems, and are subject to a variety of jurisdictions, controls, and interfaces." Given the complexities involved in ship operations, ship management teams can hardly be expected to have sole control for the various diverse functions, which leaves shipping companies in a difficult position. In this respect, the outsourcing of shipping operations to ship management companies (SMCs) can be regarded as an efficient approach (Asuquo et al., 2013). By employing the services of SMCs, which are equipped with emerging technologies and versatile operations,

shipping companies can focus on their core businesses. SMCs originated due to the expansion and concomitant growing needs of oil majors, charterers, investors, and banks. The scope of ship management has however been greatly extended and thus has become increasingly complex due to environmental regulations, widening jurisdictions over coastal waters, and offshore resource development (Frankel, 1982).

Intangible resources within organizations can be managed effectively and efficiently by SMCs, thus allowing shipping companies to compete in the industry. Stable relationships between SMCs and owner clients are considered intangible resources. Panayides and Gray (1999) further maintained that the services of SMCs are essentially intangible. Overall, the evaluation variables in the shipping management industry are intangible, immobile, and heterogeneous. However, the evaluation of service quality is a relatively difficult task for clients. Moreover, clients are quite often faced with uncertainty regarding the expected service performance levels of SMCs. Inevitably, ship owners and SMCs need to determine each other's characteristics. The fuzzy method is capable of fulfilling these evaluation difficulties by accommodating both tangible and intangible variables. In this respect, the aim of this research is to identify the success factors for SMCs, to evaluate the weights of these factors, and finally to find out the differences in perceptions between ship owners and SMCs using the fuzzy evaluation method.

The balance of this paper is organized as follows: Section 2 defines ship management companies and reviews the relevant literature. In Section 3, we measure the concentration ratio of the ship management industry in Korea using the concentration ratio, Herfindahl-Hirschman Index (HHI), and the Gini coefficient. Section 4 evaluates the success factors of ship management companies using fuzzy theory while Section 5 comprises the conclusion and suggestions for further research.

2. Literature Review

Frankel (1982) defined ship management as “a complex sequence of decisions required to ensure the effective operations and performance of a ship, as part of the transportation system or, as part of a fleet of ships.” He noted that ship management involved functions such as ship navigation, ship condition control, crewing, inventory control, maintenance, repair, ordering, and accounting. In addition, he argued that changes in the ship management industry are essential so that the industry can keep pace with the development of information technology (IT) and changes in the general shipping environment. According to Panayides (1997), ship management comprises the services provided in relation to the systematic organization of the economic resources required for the ship to maintain its revenue earning ability. Bisticic et al. (2011) also explored the role of ship management in the business activities of shipping companies. In order to achieve the goals set by shipping companies, SMCs use theoretical assumptions and practical experience. In addition, the success of SMCs is affected by the management process of the mid-level executives of shipping companies. Overall, a ship management company can be defined as a party that signs a management contract with a ship owner to manage a ship (or ships) on behalf of the ship owner. In return, the ship owner pays a fixed rental rate, and the SMC earns the fee for the services it provides to its client, the ship owner.

Panayides (1997) studied the application of the relationship marketing concept to SMCs. He found that SMCs focused primarily on improving their quality of service, but he suggested that building and maintaining customer relationships is of fundamental importance. In particular, he argued that establishing long-term customer contracts assures customer possession, brings down business costs, and achieves competitive advantage. Panayides and Gray (1999) maintained that SMCs are able to achieve a competitive edge through the establishment and maintenance of good relationships with their customers. Thus, long-term client relationships increase competitive advantage in ship management. Ship management companies should co-operate closely with ship owners.

Panayides (2003) determined there is a positive correlation between the pursuit of competitive strategy and the performance of SMCs. In other words, SMCs that apply competitive strategies are more likely to perform well. King and Mitroussi (2004) studied the factors taken into consideration by ship owners when they wish to select a ship management company. Quality of service was found to be more important to most ship owners than cost. Furthermore, it was ascertained that ship management companies' brands also affect ship owners'

selections. The authors explained that special services that suit a particular type of ship can also influence the choice of ship management company.

An analysis by Panayides and Hung (2003) found that the performance measurement factors of SMCs comprise reactivity, integrity, reliability, and technical capability. Cariou and Wolff (2011) determined that the two main factor groups for SMC selection are the characteristics of the vessels, including age, type, and size, and the characteristics of the ship owner, i.e., country of domicile and the number of vessels. However, this research did not identify or confirm such links between ship owners and SMCs. In addition, these intangible variables were not included and can therefore be considered research limitations.

Previous studies have suggested that the success factors of the ship management industry are the relationships with the ship owners, reduced operational costs, and ship management fees, among others. In addition, earlier studies have mainly focused on the opinions of the SMCs only. However, Asuquo et al. (2013) argued that the mission of SMCs is to satisfy the needs and expectations of ship owners. In order to evaluate the success factors of SMCs, it is therefore important to determine the opinions of ship owners. The opinions of ship owners are important to enhance the competitiveness of SMCs because ship owners are their true customers. Thus, to evaluate the differences between the perceptions of ship owners and SMCs regarding the success factors of SMCs via a comparative analysis, an accurate methodology needs to be established.

To solve the selection problem of third-party ship management companies, Asuquo et al. (2013) utilized six criteria, i.e., price, reputation, location, experience, technical expertise, and relationships, using the analytic hierarchy process (AHP) method. However, Yeo et al. (2010) insisted that AHP methods have some limitations in finding the rankings of research targets due to the existing uncertainty in the evaluations by experts. The evaluation of the success factors of SMCs is recognized as a complex problem, and involves various quantitative and qualitative factors. To calculate the qualitative factors, expert knowledge is needed. To solve this problem, Yeo et al. (2010) applied the fuzzy methodology to investigate expert evaluations. This method embraces the linguistic expression of expert perceptions using the fuzzy number concept. The fuzzy methodology, which can accommodate experts' knowledge, was introduced in recent studies on shipping and ship management industries, such as integrated process management systems in ship management companies (Celik, 2009), the selection of third-party ship management services (Asuquo et al., 2013), and risk management in ship management (Karahalios, 2014). Indeed, using the fuzzy method, Karahalios (2014) discusses ship management within the context of the financial field when ship collisions occur.

3. Case Study of Korean SMCs

3.1 Service types of SMCs

According to Asuquo et al. (2014), there are three types of SMCs: in-house management companies for vessel owners, third-party management companies, and hybrid companies, which are a combination of the previous two. In-house companies are established by ship owners and handle the owners' vessels while third-party management companies provide outsourced management services for the owners of vessels. There are no shareholding ties in third-party management companies.

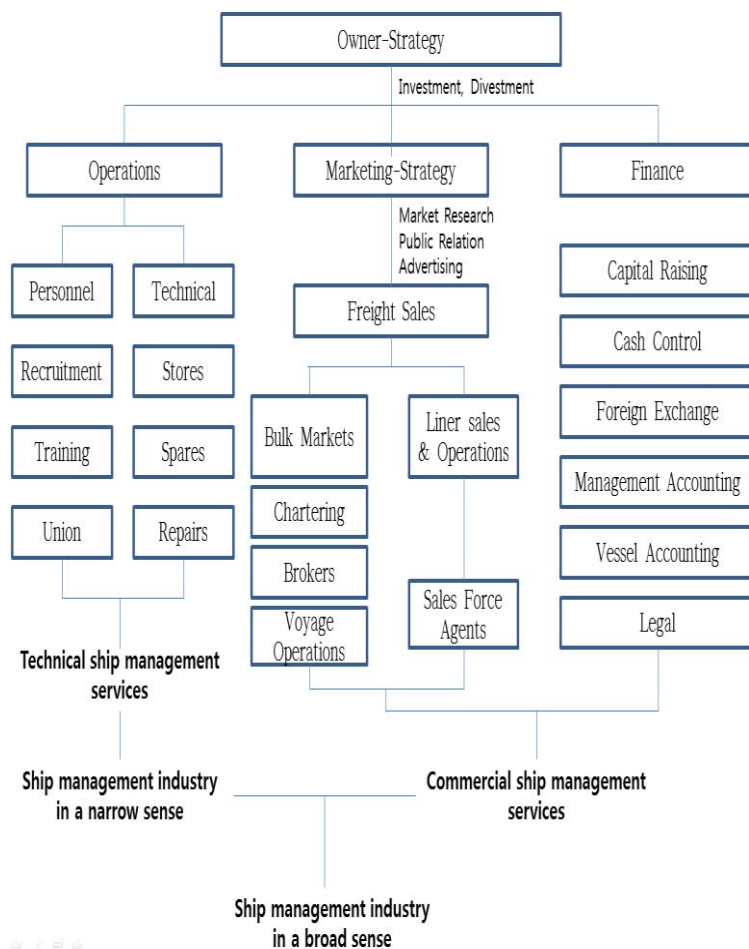
SMC service types are divided into two main classes: ship management industry in a narrow sense and ship management industry in a broad sense. In the former, only technical ship management services are provided, while the ship management industry in a broad sense includes technical and commercial ship management services.

The "narrow" ship management industry focuses on management activities, such as crew supply, insurance services, ship repairs, and the supply of articles for ships, with targets aimed at cost-cutting and efficiency improvement. The main task of the ship management industry in a broad sense is to carry out comprehensive management functions to optimize business performance and improve competitiveness through, for example, liner sales and operations, technical services, legal services, and cash control.

Ship management companies do not include ship owners in their structures even though ship management

companies conduct many business activities on behalf of ship owners. While SMCs are responsible for services such as consulting and the analysis of market conditions, decision-making regarding investment is the role of ship owners. The critical difference between SMCs and ship owners is that ship owners gain the benefits and risks of the assets associated with their investment, but SMCs are satisfied with their management fees.

Fig 1. Range of ship management services



Source: *Advancement of the ship management industry, Ministry of Land in Korea, 2010*

3.2 Analysis of concentration of Korean SMCs

The entrance barriers to the ship management industry are relatively low due to the small amount of initial capital investment required. There are various sizes of SMCs in the open market, and this leads to great rivalry amongst SMCs (Panayides and Gray, 1999). The number of SMCs in the Korean market is increasing, with a concomitant rise in the intensity of the rivalry in the ship management sector.

To analyze the level of concentration of Korean SMCs, we calculated an index of concentration. In this section, we apply three methods for measuring the concentration of SMCs in Korea, namely the applied concentration ratio, Herfindahl-Hirschman index, and Gini coefficient to measure. The reason for applying the analysis of concentration is that, if the result of the degree of concentration shows an oligopoly, then the success factors presented in this research would not be of much value. Thus, in this paper we attempt to understand the current state of SMCs in Korea through the analysis of concentration.

3.2.1 Data

The essential data for calculating the Korean ship management industry's concentration were obtained from

the Korea Ship Management Companies' Association. The concentration ratios were calculated for the period of 2010–2012 using the data of the top 50 companies. Although there are approximately 100 ship management companies in Korea, the lower-ranked companies were eliminated because the market share of these companies is less than 0.5%.

3.2.2 Concentration ratio

The concentration ratio calculates the market share of the k ($k = 1, 2, \dots, n$), the largest firms in a specific industry. The simplest measure of industry concentration involves the market share of the largest company. The three-company concentration ratio, known as CR3, is the most archetypal concentration ratio for the analysis of the level of concentration in a specific industry. The equation for the concentration ratio is as follows:

$$CR(k) = \sum_{i=1}^k s_i \quad (1)$$

in which

s_i = percentage ship management market share of company i .

As the value of the index increases, so the market power increases. The market share of the 3, 4, or 8 largest companies are CR3, CR4, and CR8, respectively. If CR1 and CR3 are calculated as 50% and 75%, respectively, the market is regarded as an oligopoly. In this study, we applied CR3 to analyze the degree of market concentration of the ship management company in Korea.

3.2.3 Herfindahl-Hirschman index (HHI)

The Herfindahl-Hirschman index takes into account both the number of ship management companies and the unfairness of their market share. The Herfindahl-Hirschman index analyzes the concentration of Korea's ship management industry by applying the following mathematical formula:

$$H = \sum_{i=1}^n s_i^2 \times 10,000 \quad (2)$$

in which

n = the number of ship management companies

s_i = the market share of the companies i .

The Herfindahl-Hirschman index gives the relative weights of the concentration of ship management companies. If the HHI is calculated as 0, it means that there is the condition of perfect competition in the industry, while 10,000 indicates a monopoly. An industry with an HHI below 1000 is deemed to have low concentration. An index of 1000–1800 usually means moderate concentration, and an index greater than 1800 means a very concentrated industry.

3.2.4 Gini coefficient

The Gini coefficient is used to analyze not only market concentration, but also income concentration. The index shows the summary status of the Lorenz curve, indicating unfairness among respective businesses. The values of the Gini coefficient range from “0” to “1,” where “0” shows complete equality and “1” reveals complete inequality. The equation of the Gini coefficient is as follows:

$$G = 1 - \frac{\sum_{i=1}^n (s_{ij} + s_i)}{n} \quad (3)$$

in which

n = the number of ship management companies

s_{ij} = the cumulative market share in terms of the sales of SMCs from the lowest to highest.

s_i = ship management market share of companies i .

3.2.5 Results of the degree of concentration of Korean SMCs

The results of the concentration degree using CR3, HHI, and the Gini coefficient are shown in Table 1. The Herfindahl-Hirschman index and Gini coefficient are represented as 1321 and 0.290, respectively, in year 2012 in the Korean market. This means that the Korean shipping management market has moderate concentration. Moreover, the CR3 ratio is 52%, which is under 75%, meaning that an oligopoly does not exist in the Korean market.

Table 1. Concentration results of the shipping management market in Korea (Korean shipping liners)

	2010	2011	2012
Top 50	98%	97%	97%
Top 40	96%	95%	95%
Top 30	93%	91%	91%
Top 20	87%	86%	85%
Top 10	74%	71%	70%
CR3	52%	53%	52%
HHI	1381	1326	1321
Gini coefficient	0.328	0.304	0.290

Synthetically, there is not an oligopoly situation in the ship management industry in Korea, so there is a slim chance of unfair trade practices, such as combination sales, competitor exclusion, and transaction rejections. Healthy competition is a favorable condition for the development of the ship management industry. Thus, in the next section, we propose the success factors for ship management companies using the fuzzy method.

4. Empirical Analysis

4.1 Fuzzy method

To measure experts' perceptions (judgements), we employed the fuzzy method introduced by Zadeh (1965). This method utilizes linguistic expressions to determine the judgements of experts. The membership of factors in a classical set is evaluated in binary conditions by bivalent terms; that is, a factor either belongs in a set or it doesn't. In contrast, fuzzy theory progressively evaluates the membership of the factors in a set. This is shown with the assistance of membership ability, which is assessed in the unit interval of real $[0, 1]$ (Fig. 2). Fuzzy sets extend classical sets as the index functions of classical sets are special cases of the membership ability of fuzzy sets if the latter only have the values 0 or 1. A classic value set is typically called crisp sets in fuzzy theory. A triangular fuzzy number is composed of three parameters, i.e., a_1 , a_2 , and a_3 , and the membership function can be indicated as shown in Equation 4.

Fig 2. Function of the triangular fuzzy number



Source: Zadeh (1965)

$$\mu A(\chi) = \begin{cases} 0, & \chi < a_1 \\ \frac{\chi - a_1}{a_2 - a_1}, & a_1 \leq \chi \leq a_2 \\ \frac{a_3 - \chi}{a_3 - a_2}, & a_2 \leq \chi \leq a_3 \\ 0, & \chi > a_3 \end{cases} \quad (4)$$

Triangular fuzzy numbers between the membership function “n” are defined as shown in Equation 5:

$$[\bar{A} = (a_1^{(i)}, a_2^{(i)}, a_3^{(i)}, i = 1, 2, 3, \dots, n)] \quad (5)$$

Fuzzy number \bar{A} is defined as follows:

$$[\bar{A} = A_{ave} = \frac{\bar{A}_1 + \bar{A}_2 + \dots + \bar{A}_n}{n} = \frac{(\sum_{i=1}^n a_1^{(i)}, \sum_{i=1}^n a_2^{(i)}, \sum_{i=1}^n a_3^{(i)})}{n} = (a_1, a_2, a_3)] \quad (6)$$

Language variables measured in the form of words and sentences can be quantified using the fuzzy method. Figure 2 is the triangular membership function that values the language assessment as very bad, bad, medium, good, and very good. The value of the triangular membership function is defined in Table 2.

Table 2. Value of the triangular membership function

Very bad (VB)	(0, 0, 0.3)
Bad (B)	(0, 0.3, 0.5)
Medium (M)	(0.2, 0.5, 0.8)
Good (G)	(0.5, 0.7, 1)
Very good (VG)	(0.7, 1, 1)

The last step in the fuzzy method is defuzzification. The purpose of defuzzification is to convert the results of the whole fuzzy set obtained in the previous step to the actual numbers. The most common method of defuzzification is the center of gravity. This method solves the center of the area of the binding membership function.

$$y^* = \frac{\sum \mu(y_i) x_i}{\sum \mu(y_i)} \quad (7)$$

4.2 Application of the fuzzy method

The fuzzy method is selected to evaluate the success factors of SMCs in Korea because it can handle the nature of complexity and ambiguity. In fact, it would be otherwise difficult to analyze the qualitative factors within the success factors for SMCs. For these reasons, this study evaluates the success factors of ship management by applying the fuzzy method using the results from a survey of experts. The success factors for SMCs are derived from literature reviews and in-depth interviews with members of the ship management industry. To confirm the success factors, 10 in-depth interviews were carried out with senior executives who had knowledge in this area, careers that had spanned over 15 years, and clearly had valuable knowledge about the ship management industry. All 10 interviewees were asked to indicate their perceptions and knowledge of the ship management industry.

The success factors perceived by ship management companies are shown in Table 3. In particular, we conducted a survey among ship owners and engaged with the ship management industry to evaluate the success factors of SMCs. In this survey, we analyzed the differences in the perceived success factors between the SMCs and ship owners. The survey was conducted from January 1, 2013, to March 15, 2013. Of 100 SMCs, 70 replied, and 60 of 100 ship owners replied.

Table 3. Success factors for SMCs

Factors	Definition	Authors (year)
The efficient management of ships' operational costs	Cost-efficient management of ship operations	Asuquo et al. (2013)
Ship management fees	Level of ship management fees	Asuquo et al. (2013)
The ability to recruit the full required manpower	The ability to maintain a smooth, regular staff complement, as needed	Frankel (1982), Celik (2004)
The ability to recruit superintendents (SIs)	The ability to recruit the right SIs to the right ships	Celik (2004), Mitroussi (2013)
The number of ships managed by each SI	Increasing the number of ships managed by SIs can result in decreased service quality	Celik (2004)
Length of experience in ship management	Period engaged in the ship management industry	King and Mitroussi (2003), Mitroussi (2004), Cariou and Wolff (2011), Asuquo et al. (2013)
Total SMC fleet size	The number of ships managed, represented by their reputations and maintenance levels	Mitroussi (2004), Cariou (2010), Cariou and Wolff (2011)
The caliber of the ship verification report	Ship owners want to receive information regarding the condition of their ships in the form of verification reports on regular basis	Celik (2009), Asuquo et al. (2013)
Quick response times to ship owners	Quick responses are needed if ship owners have queries	Panayides (1997), Celik (2009)
The potential for high-quality management	If SMCs provide high-quality management, the satisfaction of the owners increases	Panayides (2002), Celik (2004, 2009), Mitroussi (2013)
The ability to follow the ship owners' policies	Whether or not the SMCs comply with the policies established by the ship owners	Panayides (1997, 1999), Mitroussi (2013)
Real-time management using IT systems	Effective ship management through IT systems	King and Mitroussi (2003), Panayides (1999), Celik (2009)
The ability to form long-term relationships	The ability to communicate with the ship owners and to honor long-term contracts	Panayides (1997), Asuquo et al. (2013)

4.3 *Experimental results and implications*

The importance weights of the success factors using the fuzzy method, which is based on the experts' survey, are shown in Table 4. The differences in perceptions between the ship owners and SMCs are clearly represented for each factor.

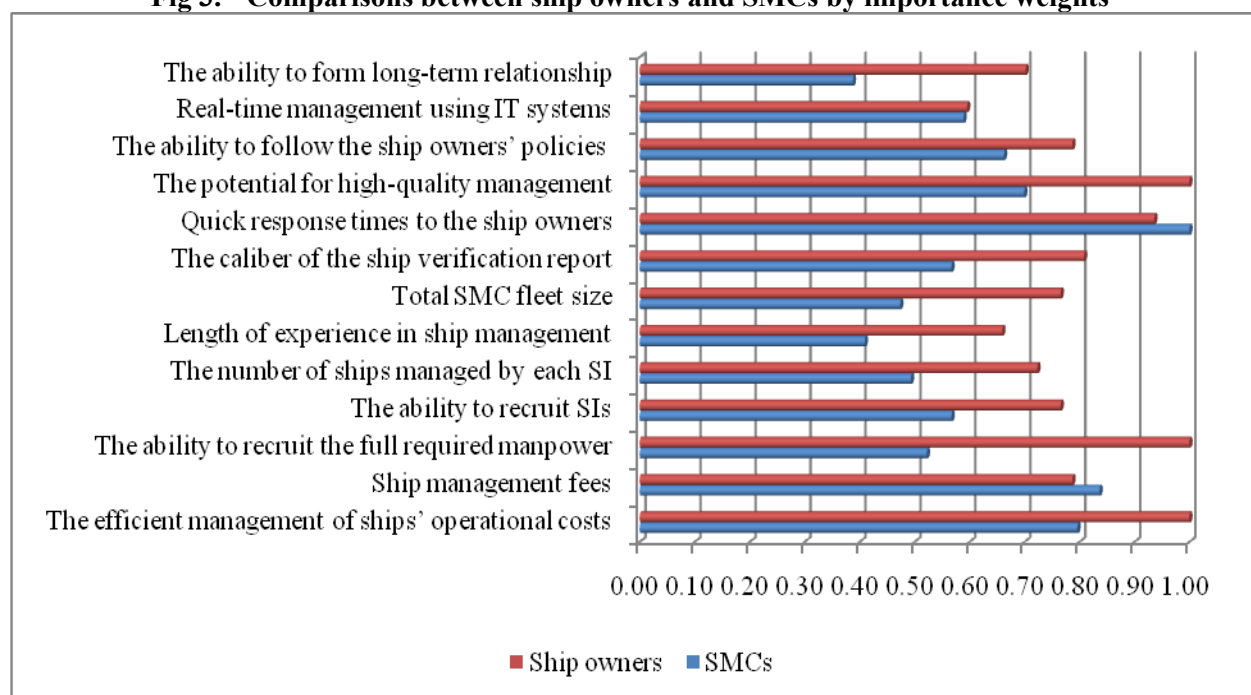
Table 4. Importance weights of the success factors

Factors	SMCs			Ship owners		
	IW	Averaged IW	Rankings	IW	Averaged IW	Rankings
The efficient management of ships' operational costs	0.692	0.80	3	0.94	1.00	1
Ship management fees	0.727	0.84	2	0.74	0.79	6
The ability to recruit the full required manpower	0.454	0.52	9	0.94	1.00	1
The ability to recruit SIs	0.493	0.57	7	0.72	0.77	8
The number of ships managed by each SI	0.429	0.49	10	0.68	0.72	10
Length of experience in ship management	0.356	0.41	12	0.62	0.66	12
Total SMC fleet size	0.412	0.47	11	0.72	0.77	8

The caliber of the ship verification report	0.493	0.57	7	0.76	0.81	5
Quick response times to the ship owners	0.869	1.00	1	0.88	0.94	4
The potential for high-quality management	0.608	0.70	4	0.94	1.00	1
The ability to follow the ship owners' policies	0.576	0.66	5	0.74	0.79	6
Real-time management using IT systems	0.512	0.59	6	0.56	0.60	13
The ability to form long-term relationship	0.337	0.39	13	0.66	0.70	11

Notes: *IW* = importance weight. The average importance weights of the SMCs were obtained by dividing each *IW* by the maximum value *IW*.

Fig 3. Comparisons between ship owners and SMCs by importance weights



According to SMCs, the relationship between SMCs and their client segments will improve when the SMCs adopt the appropriate technologies. SMCs are often compelled to introduce real-time management of ships using IT systems (Panayides and Gray, 1999). However, ship owners do not place much stress much on this factor. On the contrary, ship owners emphasize intangible variables, like “The potential for high-quality management.” The factor, “Total SMC fleet size” had a low importance weight. This result is in agreement with the analysis of Mitroussi (2004), which suggested that fleet size has no direct influence on the use of a particular SMC. Panayides and Gray (1999) stated that, for effective and efficient service delivery, stable long-term client relationships are an inevitable requirement. However due to the recent intense competition between SMCs, forming long-term contracts is difficult, and this factor received a comparatively low weight.

As a result of the analysis, it is evident that there are differences in the perceptions of the success factors between SMCs and ship owners. From the perspective of SMCs, top priority is given to the factor “Quick response times to ship owners” followed by “Ship management fees” and “The efficient management of ships’ operational costs.” According to Mitroussi (2004), to build trust, SMCs’ infrequent and ad-hoc approach to communication needs to be eliminated. In support of this, SMCs generally consider that “Quick response times to ship owners” is the most important factor. In addition, SMCs placed considerable emphasis on the cost factor, which is a tangible variable.

Table 5. Ranking comparison based on SMCs' perceptions

Factors	Rankings	
	SMCs	Ship owners
Quick response times to ship owners	1	4
Ship management fees	2	6
The efficient management of ships' operational costs	3	1

However, ship owners prioritized the success factors differently. The factor “The efficient management of ships' operational costs” was ranked first, followed by “The ability to recruit the full required manpower” and “The potential for high-quality management.”

Table 6. Ranking comparison based on ship owners' perceptions

Factors	Rankings	
	SMCs	Ship owners
The ability to recruit the full required manpower	9	1
The efficient management of the ships' operational costs	3	1
The potential for high-quality management	5	1

Asuquo et al. (2013) noted that effective and efficient ship operations rely solely on the practical experience of the ship operators. To improve operational efficiencies, a methodical approach combined with managerial knowledge and experience is critical. They also insisted that low prices are not always considered the most important factor in the ship management industry.

As noted in Table 3, “The ability to recruit the full required manpower” means the ability to maintain a smooth, regular staff complement, as and when they are needed. In addition, when SMCs provide a high-quality management service, the satisfaction of the ship owners increases. This is categorized as the factor “The potential for high-quality management,” which is an intangible variable. Ship owners thus tend to give priority to these intangible variables.

In the ship management industry, the main focus for SMCs is the ship owners, and they therefore need to understand ship owners' preferences and perceptions. Ship owners are able to evaluate the claims of rival sellers and select them as their partners; as a result, the competition between SMCs is becoming increasingly tough. Understanding ship owners' perceptions and expectations is therefore highly advantageous to SMCs. However, according to the comparison of success factor perceptions between ship owners and SMCs (Fig. 3), there is some level of misunderstanding on the SMCs' side of what ship owners actually want. For instance, SMCs stressed the factor “Ship management fees” as an important factor while ship owners selected “Quick response times to ship owners”. Essentially, SMCs focus on tangible variables while ship owners want to receive quality service, which is an intangible variable.

5. Conclusion

Shipping companies are continuously exposed to risk due to changes in the global market, and consequently they cannot succeed without efficient and effective management. Shipping companies require an abundance of different resources, and according to the literature, many factors have to be taken into account in order to succeed in the ship management industry. However, the evaluation of the success factors of SMCs is not a simple task because some factors can be quantified while others cannot. Overall, the evaluation is mixed with tangible and intangible variables. In this respect, the aim of this research is to analyze the important factors for SMCs' success.

The results of the evaluation of these success factors using the fuzzy method revealed a difference in opinions between SMCs and ship owners. This study's results therefore have the potential to provide theoretical and managerial insights for SMCs. Ship owners selected the “The ability to recruit the full required manpower” as

an important factor, but the surveyed ship management companies did not recognize its importance. Ship owners selected “The efficient management of ships’ operational costs” and “The potential for high-quality management” as important factors, but ship management companies stressed other factors, like “Ship management fees.” SMCs mistakenly think that ship owners are only focused on the cost of the management of the ship. In addition, SCMs do not fully appreciate the importance of the intangible variables of service. Indeed, high-quality management was selected as the most important factor to ship owners while this was of mid-level importance to SMCs.

References

- Asuquo, M., Coward, I. and Yang, Z. (2014), Modeling selection of third party ship management services, *Case Studies on Transport Policy* 2(1): 28-35.
- Bisticic, A., Jugovic, A. and Kuzman, Z. (2011), The role of ship management in business activities of shipping companies, *Scientific Journal of Maritime Research* 25(1): 29–44.
- Cariou, P. and Wolff, F.C. (2011), Ship-owners’ decisions to outsource vessel management, *Transport Reviews* 31(6): 709–724.
- Celik, M. (2009), Establishing an Integrated Process Management System (IPMS) in ship management companies, *Expert Systems with Applications* 36: 8152–8171.
- Celik, M., Kahraman, C., Cebi, S. and Er, I. D. (2009), Fuzzy axiomatic design-based performance evaluation model for docking facilities in shipbuilding industry: The case of Turkish shipyards, *Expert systems with Applications* 36: 599–615.
- Chien, C.J. and Tsai, H.H. (2000), Using fuzzy numbers to evaluate perceived service quality, *Fuzzy Sets and Systems* 116: 289–300.
- Christa Sys. (2009), Is the container liner shipping industry an oligopoly?, *Transport Policy* 16: 259-270.
- Eulaia, S. and Janusz, K. (2000), Distances between intuitionistic fuzzy sets, *Fuzzy Sets and Systems* 114: 505–518.
- Frankel, E. (1982), Ship management systems developments, *Maritime Policy & Management* 9(2): 135-143.
- King, J. and Mitroussi. (2003), Third-party Ship Management: A Greek Perspective, *Maritime Economics & Logistics* 5: 301–310.
- Mitroussi, K. (2004), The role of organisational characteristics of ship owning firms in the use of third party ship management, *Marine Policy* 28: 325–333.
- Mitroussi, K. (2013), Ship management: contemporary developments and implications, *The Asian Journal of Shipping and Logistics*, 29(2): 229–248.
- Moore, R. and Lodwick, W. (2003), Interval analysis and fuzzy set theory, *Fuzzy Sets and Systems* 135: 5–9.
- Nilesh, N. K. and Jerry, M. M. (2001), Centroid of a type-2 fuzzy set, *Information Sciences* 132: 195–220.
- Park, J.Y. and Yeo, G.T. (2010), An Evaluation of Greenness of major Korean ports: A Fuzzy Set Approach, *The Asian Journal of shipping and Logistics* 28(1): 67–82.
- Pavic, I., Galetic, F., and Kramaric, T.P. (2012), Level of concentration in banking markets and length of EU membership, *World Academy of Science, Engineering and Technology* 61: 869–874.
- Panayides, P.M. and Hung, M. (2003), Competitive strategies and organizational performance in ship management, *Maritime Policy & Management* 30(2): 123–140.
- Panayides, P.M. and Gray, R. (1997), Marketing the professional ship management service, *Maritime Policy & Management* 24(3): 233–244.
- Panayides, P.M. and Gray, R. (1999), An empirical assessment of relational competitive advantage in professional ship management, *Maritime Policy & Management* 26(2): 111–125.
- Spruyt, J. (1990), *Ship Management*, Lloyd's of London.
- Stephen, A.R. (1995), Market share inequality, the HHI, and other measures of the firm-composition of a market, *Review of Industrial Organization* 10: 657–674.
- Yeo, G.T., Song, D.W., Dinwoodie, J. and Roe, M. (2010), Weighting the competitiveness factors for container ports under conflicting interests, *Journal of the Operational Research Society* 61: 1249–1257.
- Zadeh, L.A. (1965), Fuzzy sets, *Information and Control* 8: 338–353.
- Zadeh, L.A. (1999), Fuzzy sets as a basis for a theory of possibility, *Fuzzy Sets and Systems* 100 Supplement: 9-34.

The Antecedents and Consequences of Supply Chain Service Capabilities in the Context of Container Shipping

Chung-Shan Yang

Assistant Professor, Department of Aviation and Maritime Transportation Management, Chang Jung Christian University, Tainan City, Taiwan, ROC. Email: r58951022@yahoo.com.tw.

Abstract

This study empirically examines the relationships among supply chain integration, supply chain service capabilities, market performance, and financial performance in the container shipping context. We collect data from a survey of 133 container shipping operators and agencies in Taiwan, and apply structural equation modeling (SEM) to test the research hypotheses. We confirm that supply chain integration has a positive impact on supply chain service capabilities, which in turn helps to enhance market and financial performance. The findings show that supply chain service capabilities act as fully mediating variable between supply chain integration and market performance. We also discuss the managerial implications for container shipping firms to improve their supply chain integration, supply chain service capabilities, and firm performance.

Keywords: Container shipping, Supply chain integration, Supply chain service capabilities, Market performance, Financial performance.

1. Introduction

Ocean liner shipping companies play a prominent role in facilitating international trade, not just by enabling the physical transport of cargoes, but also through their involvement in the commercial and marketing aspects of global trade. Competition now is largely between supply chains, rather than the individual players within these, and this situation also exists in the container shipping industry (Lam et al., 2011). In the maritime transport industry, cooperation or integration is becoming even more critical than competition in determining efficiency (Midoro et al. 2005). In terms of horizontal integration, liner shipping alliances and cooperation continue to play a central role in the operation and long-term viability of liner shipping companies. On the other hand, many shipping lines have undertaken vertical integration, in which they diversify their operations and services into various components along a multimodal supply chain system (Heaver, 2002; Panayides and Cullinane, 2002).

Panayides and Cullinane (2002) suggest that more empirical investigations of the strategy-performance relationships related to such integrations are needed. According to an empirical study carried out by Franc and Van der Horst (2010), Maersk, MSC and CMA CGM, which are the three main liner shipping companies in the world, controlling 33.4% of the global TEU-capacity in 2007, are also the main liner shipping companies involved in the hinterland. Consequently, an emerging trend in liner shipping is integration and diversification into inland transport, terminal operation and logistics (Panayides and Cullinane 2002). Since the main drivers of the development of such container shipping supply chains is usually container shipping liners, further studies need to explore the critical factors of container shipping supply chain integration, as well as supply chain service capabilities, and uncover their relationships with firm performance. To this end, an empirically validated measurement instrument is needed that will enable researchers and practitioners to assess the extent to which a container shipping company is integrated within a supply chain.

This study thus endeavors to examine the importance of supply chain integration and service capabilities (i.e. service efficiency, service reliability, service flexibility, and value-added service) in order to explain market performance and financial performance in the container shipping context. To the best of our knowledge, the present study is the first to empirically investigate the ways that supply chain service capabilities mediate the relationship between supply chain integration and multiple measures of firm performance, thereby

contributing to the literature on capabilities-based competition. There are five sections in this paper. Following this introduction, the next section is a review of previous research on supply chain integration, supply chain service capabilities, and firm performance. The third section discusses the research methodology, including the measures used in the survey, sampling techniques, and research methods. Section four presents the analytical results of the descriptive statistics, exploratory factor analysis, confirmatory factor analysis, and structural equation modeling. Conclusions drawn from the research findings and the implications for container shipping are then discussed in the final section.

2. Theoretical Background and Research Hypotheses

2.1. Resource-based view (RBV)

The resource-based contends that the idiosyncratic resources and capabilities of firms are the key sources of sustained competitive advantage (Lynch et al, 2000). Capabilities can be defined as the skills a firm needs to take full advantage of its assets. Capabilities are complex bundles of individual skills, assets and accumulated knowledge exercised through organizational processes that enable firms to coordinate activities and make use of their resources (Olavarrieta and Ellinger, 1997). Without such capabilities, assets are of little value. Competitive advantages arise from firm specific skills and teamwork, not from the performance of single practice or individual (Barney and Wright, 1998). Supply chain integration (SCI) has emerged as an important new archetype that encourages enterprises to work more closely with partners to achieve profit and market share objectives by lowering the level of risk related to uncertainty, while raising service efficiency, reliability, flexibility, and added-value. Supply chain integration may thus serve as part of the enabler that supports the improvement and intensification of supply chain service capabilities.

2.2. Supply chain integration (SCI) dimensions

2.2.1. Top management support

Andraski (1998) argued that collaboration among partners requires the leadership of the top management, because top management realizes that the development of future competitive advantages stems from tightly integrated partnerships and synchronized activities with suppliers, partners, and customers, in order to build mutually beneficial relationships. As Kahn (1996) noted, it is important for top managers to implement programs which encourage departments to achieve their goals collectively, foster mutual understanding, work informally together, and share the same visions, ideas, and resources.

2.2.2. Cross-functional cooperation

With respect to the fostering of integration, the most frequently cited approach in the literature is the use of cross-functional cooperation (Cohen and Bailey, 1997). Cross-functional cooperation brings ideas, knowledge, expertise and innovation to internal integration. Dawe (1994) asserted that comprehensive efforts for the improvement of all of supply chain functions within a firm should be made, and first of all, the utilization focus of supply chain activities should shift from the functional and independent dimensions to the general and integrative ones.

2.2.3. Information technology

An essential ingredient for an effective and efficiently integrated container shipping supply chain is accurate, real-time information about the cargos within the chain. This can be achieved with the use of information technology, and the provision of integrated information systems and electronic data exchanges (Vickery et al., 2003). With real-time data and information integration systems, container shipping companies can increase cargo visibility, eliminate service errors, reduce theft and shrinkage, and allow companies to regularly update their logistics databases. Sheu et al. (2006) concluded that better use of information technology contributes to better supply chain integration, and this can be achieved with the adoption of sophisticated software, electronic data interchange networks, internet/intranet connections, and so on.

2.2.4. *Goal Congruence*

In order to compete effectively, it is important that trading partners move smoothly and in synchrony with each other. In the literature, congruence is also referred to as similarity, compatibility, or fit. Goal congruence between supply chain partners is the extent to which supply chain partners perceive their own objectives are satisfied by accomplishing the aims of the overall supply chain (Angeles and Nath, 2001; Cao and Zhang, 2011). Goal congruence, one of the benefits of which is a reduction in the incentives to engage in opportunism, is also considered a key component in maintaining good relationships among supply chain partners (Lejeune and Yakova, 2005). Goal congruence among partners, customers, and suppliers is thus the degree of agreement on issues apposite to the supply chain, and this should be used as a criterion when selecting supply chain partners, in order to reduce uncertainty and risk.

2.2.5. *Collaborative communication*

Communication has been described as the glue that holds together a channel of distribution (Mohr and Nevin, 1990). Collaborative communication is the contact and message transmission process among supply chain partners, in terms of frequency, direction, mode, and influence. The existence of open, frequent, balanced, two-way, and multilevel communication is generally an indication of close inter-organizational relationships (Cao and Zhang, 2011). The specific forms that communication takes depend on the conditions of the supply chain, but the goal should always be to provide more complete knowledge to enable better decision-making (Boyle and Dwyer, 1995), improve delivery services and customer satisfaction (Mohr et al., 1996).

2.3. *Supply chain service capabilities*

Service capabilities result from the combined efforts of all functions or segments of the supply chain, both internal and external to the firm. The benefits of SC integration should be translated into service capabilities that are valued by customers - such as service reliability (Lu, 2007), service flexibility (Rosenzweig et al., 2003; Holweg et al., 2005), service efficiency (Kogut and Zander, 2003), and value-added service (Notteboom, 2004; Wang and Cullinane, 2006) - as these can then help develop valuable and unique competitive advantages (Wernerfelt, 1984; Barney et al., 2001).

2.3.1. *Supply chain service reliability*

Supply chain service reliability depends upon a consistent and accurate sailing schedule, as well as good practices with regard to booking space offers, documentation, and cargo safety. By developing a high level of SC integration, firms are able to identify and eliminate non-value-added activities, and subsequently strengthen delivery service reliability, thereby providing a foundation for sales growth (Rosenzweig et al., 2003). This study defines service reliability as the capability of fulfilling the container shipping service that the shipping liners initially proposed to their customers, and thus the maintenance of effective operations under conditions of uncertainty within supply chain networks.

2.3.2. *Supply chain service efficiency*

Service efficiency refers to the extent to which a firm's collaboration with its supply chain partners is cost competitive in comparison with its primary competitors (Bagchi and Skjoett-Larsen, 2005). Especially in the growing research field of supply chain management, where greater efficiency is the objective, it is important to explore the concept of efficiency to better understand the various supply chain management strategies that are in use. Service efficiency is the capability of a container shipping liner to work with its supply chain partners to meet the varied demands of shippers and consignees (e.g., lower unit costs, better operational productivity standards, on-time deliveries, and shorter lead-times) in ways that are better, or at least no worse, than industry norms.

2.3.3. *Supply chain value-added service*

Value-added logistics is a widely-used strategy that has given rise to dramatic changes in global supply chains.

Shipping lines need to take appropriate actions to improve their services in order to satisfy the needs of more sophisticated shippers (Bergin, 1997), and as a means of securing faster growth and better profitability than possible with more traditional practices (Heaver, 2002). Container shipping companies work to improve their logistics and offer more value-added services because they believe that this can lead to higher profits (Koo et al., 2009), and thus they offer warehousing services, labeling, packing, consolidation, preparation of the necessary paperwork, customs clearance services, multimodal services, and door-to-door services.

2.3.4. Supply chain service flexibility

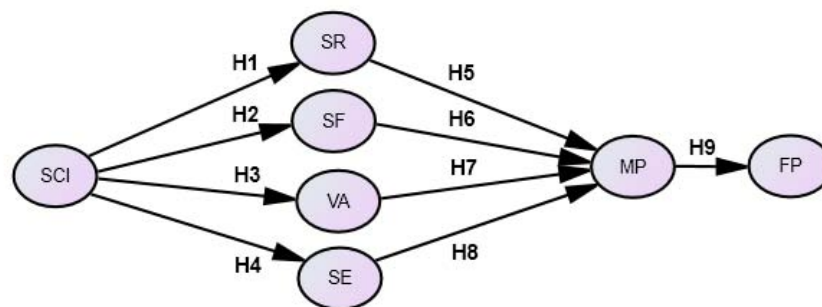
Flexibility is seen as a reaction to environmental uncertainty and an important competitive capability that helps firms enhance their performance and manage worldwide resources and markets. Severe SC disruptions have created a new appreciation of supply chain flexibility (Gosain et al., 2004). Supply chain service flexibility is increasingly important in hypercompetitive environments, in which frequent changes in volume, product/service mix, and schedules occur. Dyer (1996) proposed that highly integrated organizations are better able to obtain competitive advantages compared to more independent firms due to the greater flexibility of an integrated supply chain.

3. Methodology

3.1. Conceptual model and hypotheses

Based on the previous literature, this research proposes the conceptual model shown in Fig. 1, as well as the following nine hypotheses:

Fig 1. The conceptual model



- H1: Supply chain integration is positively related to supply chain service reliability.
- H2: Supply chain integration is positively related to supply chain service flexibility.
- H3: Supply chain integration is positively related to supply chain value-added service.
- H4: Supply chain integration is positively related to supply chain service efficiency.
- H5: Supply chain service reliability is positively related to market performance.
- H6: Supply chain service flexibility is positively related to market performance.
- H7: Supply chain value-added service is positively related to market performance.
- H8: Supply chain service efficiency is positively related to market performance.
- H9: Market performance is positively related to financial performance.

3.2. Sample

The Directory of the National Association of Shipping Agencies and Companies in Taiwan (2010) was used as the survey source for this study. The survey was administered by mail with a postage-paid return envelope sent to 260 container shipping operators and agencies on 15th June 2013, and they were also contacted by telephone to identify their willingness to participate in the survey. The initial mailing elicited 81 usable responses. A follow-up mailing was sent six weeks after the initial mailing, and an additional 52 usable responses were returned after this. The total number of usable responses number is thus 133, giving an overall response rate of 51.2%.

3.3. Measures

The measurement items for evaluating supply chain integration, service capabilities, and firm performance were mainly taken from prior research (see Table 1). We developed and refined all of the scales according to inputs from experienced shipping practitioners, in addition, we validated the resulting scales with field pilot tests to ascertain their content validity, as well as construct reliability and validity. Tables 2, 3, and 4 present the final measurement items. These items were scored using a five-point Likert scale, where 1 corresponds to “strongly disagree” and 5 to “strongly agree.”

3.4. Data analysis methods

An exploratory factor analysis was first employed to identify the key dimensions for supply chain integration, supply chain service capabilities, market performance and financial performance. A structural equation modeling approach was subsequently used to test the research hypotheses. A two-step approach suggested by Anderson and Gerbing (1988) was employed to analyze the data. In the first step, confirmatory factor analysis was performed to assess the validity of the measurement model. Once it was validated, the second step estimated the structural model based on the latent variables. All analyses were carried out using the SPSS 18.0 for Windows and AMOS 18.0 statistical packages.

Table 1. Prior research on measurement scales

Supply chain integration	Prior studies
Top management's support	Le Meunier-FitzHugh et al. (2011); Mentzer et al. (2000)
Cross-functional cooperation	Zhao et al. (2011) Antonio et al. (2009)
Information technology	Prajogo and Olhager (2012)
Goal congruence	Angeles and Nath (2001); Lejeune and Yakova (2005); Simatupang and Sridharan (2005); Cao and Zhang (2011)
Collaborative communication	Cao and Zhang (2011); Prahinski and Benton (2004); Paulraj et al. (2008)
Service capabilities	
Service reliability	Lu (2003); Liang et al. (2006); Lu (2007); Yang et al. (2009)
Service flexibility	Holweg et al. (2005); Stevenson and Spring, 2007; Narasimhan and Jayaram (1998); Chen and Paulraj (2004); Deveraj et al. (2007); Cao and Zhang (2011)
Value-added service	Lu (2000); Notteboom (2004); Wang and Cullinane (2006); Yang et al. (2009)
Service efficiency	Bagchi and Skjoett-Larsen (2005); Lee et al. (1997); Simatupang and Sridharan (2005); Chen and Paulraj (2004); Frohlich and Westbrook (2001); Li et al. (2006); Cao and Zhang (2011)
Firm performance	
Market performance	Moorman and Rust, 1999; Vorhies and Morgan, 2005; Zhou et al., 2009; Leonidou et al. (2013); Koufteros et al., 2005;
Financial performance	Moorman and Rust, 1999; Vorhies and Morgan, 2005; Zhou et al., 2009; Leonidou et al. (2013)

Note: Please evaluate your company's performance in the following areas relative to your primary/major competitors (1-Much worse; 5-Much better).

4. Results of empirical analyses

4.1. Participants' demographics

The profiles of were vice presidents or above (18.1%), managers/assistant managers (42.9%), directors/vice directors (15.8%), and clerks (23.2%). Almost 80% of the responses came from directors/vice directors or above, thus supporting the reliability of the survey findings. Almost 70% of the respondents had worked in the industry for more than 10 years, which implies that they had sufficient practical experience to answer the questions. With regard to ownership, more than 78% of the respondents worked at local Taiwanese firms,

while 13.6% and 7.5% were foreign-owned firms and foreign-local firms, respectively. Around 57.9% of the responding firms had fewer than 100 employees, while 20.3% had more than 1,000. The results indicate that 34.6% of respondents were from operations department, 32.3% from the management department, and 33.1% from the sales department.

Table 2. EFA of supply chain integration

Supply chain integration attributes	F1	F2	F3	F4	F5
TMS1. Our senior managers identify synergy between supply chain partners				<u>0.811</u>	
TMS2. Our senior managers carefully select our supply chain partners				<u>0.843</u>	
TMS3. Our senior managers support collaboration between supply chain partners				<u>0.675</u>	
TMS4. Our senior managers encourage parties in the container shipping supply chain to be closely aligned				<u>0.700</u>	
CFC1. There are close coordinating activities among internal functions.	<u>0.827</u>				
CFC2. We have a systematic interaction system among internal functions.	<u>0.825</u>				
CFC3. We have data and information integration among internal functions	<u>0.814</u>				
CFC4. We are able to search for real-time data on the inventory (booking space) level	<u>0.588</u>				
IT1. Inter-organizational collaboration in our supply chain is achieved using electronic links			<u>0.767</u>		
IT2. We use information technology-enabled transaction processing in our supply chain			<u>0.846</u>		
IT3. We use electronic transfer of purchase orders, invoices, and/or funds in our supply chain			<u>0.832</u>		
IT4. We use advanced information systems to track and/or expedite shipments in our supply chain			<u>0.732</u>		
GC1. Our firm and supply chain partners have agreement on the goals of the supply chain	<u>0.807</u>				
GC2. Our firm and supply chain partners have agreement on the importance of collaboration across the supply chain	<u>0.776</u>				
GC3. Our firm and supply chain partners have agreement on the importance of improvements that benefit the supply chain as a whole	<u>0.746</u>				
GC4. Our firm and supply chain partners agree that our own goals can be achieved through working toward the goals of the supply chain	<u>0.684</u>				
CC1. Our firm and its supply chain partners have frequent contacts on a regular basis					<u>0.768</u>
CC2. Our firm and its supply chain partners have open and two-way communication					<u>0.805</u>
CC3. Our firm and its supply chain partners influence each other's decisions through discussion					<u>0.634</u>
Eigenvalues	8.258	2.019	1.488	1.323	1.002
Percentage variance	43.46	10.62	7.831	6.961	5.273
Cumulative variance	43.46	54.09	61.92	68.88	74.15

4.2. Exploratory factor analysis(EFA) results

Principal component analysis with VARIMAX rotation was employed to identify the dimensions of supply chain integration, supply chain service capabilities, market performance and financial performance. The results of exploratory factor analysis for these dimensions are given in Table 2, 3, and 4. According to Hair et

al. (2006), when factor loadings are 0.50 or greater they can be considered significant. In Table 2, the exploratory factor analysis yielded a five-factor solution, with eigenvalues greater than one (Churchill and Iacobucci, 2002), which accounted for 74.15% of the variance. The five supply chain integration factors (dimensions) that were extracted are described below: goal congruence (GC), cross-functional cooperation (CFC), information technology (IT), top management support (TMS), and collaborative communication (CC).

Table 3. EFA of supply chain service capabilities

Supply chain service capability attributes	F6	F7	F8	F9
SR1. Our firm and its supply chain partners offer reliability with regard to booking space		<u>0.875</u>		
SR2. Our firm and its supply chain partners offers reliability with regard to the advertised sailing schedules		<u>0.866</u>		
SR3. Our firm and its supply chain partners offer accurate documentation		<u>0.865</u>		
SR4. Our firm and its supply chain partners offer cargo safety.		<u>0.843</u>		
SF1. Our firm and its supply chain partners offer a variety of shipping services in comparison with industry norms				<u>0.704</u>
SF2. Our firm and its supply chain partners meet different customer volume requirements more flexibly in comparison with industry norms				<u>0.737</u>
SF3. Our firm and its supply chain partners have good customer responsiveness in comparison with industry norms				<u>0.823</u>
SF4. Our firm and its supply chain partners are able to make adjustments in their relationships to cope with the changing market environment.				<u>0.779</u>
VA1. Our firm and its supply chain partners have the capability to provide warehousing services	<u>0.808</u>			
VA2. Our firm and its supply chain partners have the capability to provide customs clearance services	<u>0.787</u>			
VA3. Our firm and its supply chain partners have the capability to provide multimodal service s	<u>0.832</u>			
VA4. Our firm and its supply chain partners have the capability to provide door-to-door services	<u>0.842</u>			
SE1. Our firm and its supply chain partners better meet the agreed upon unit costs in comparison with industry norms			<u>0.810</u>	
SE2. Our firm and its supply chain partners better meet productivity standards in comparison with industry norms			<u>0.819</u>	
SE3. Our firm and its supply chain partners better meet on-time delivery requirements in comparison with industry norms			<u>0.844</u>	
SE4. Our firm and its supply chain partners better meet shorter lead-time requirements in comparison with industry norms			<u>0.680</u>	
Eigenvalues	7.025	2.201	1.608	1.313
Percentage variance	43.90	13.75	10.05	8.207
Cumulative variance	43.90	57.66	67.71	75.92

Table 4. EFA of firm performance

Firm performance attributes	F10	F11
MP1. Service quality offered to customers		<u>0.919</u>
MP2. Customer satisfaction		<u>0.920</u>
MP3. Customer loyalty		<u>0.846</u>
FP1. Return on investment	<u>0.938</u>	
FP2. Return on assets	<u>0.953</u>	
FP4. Operating profits	<u>0.951</u>	
Eigenvalues	3.525	1.738
Percentage variance	58.74	28.97
Cumulative variance	58.74	87.71

Table 3 shows the results of the exploratory factor analysis of service capability attributes and factors (dimensions), and these are labeled below: value-added service (VA), service reliability (SR), service efficiency (SE), and service flexibility (SF). Table 4 reports the results of exploratory factor analysis of firm performance attributes and factors (dimensions), as explained below: financial performance (FP) and market performance (MP). The results revealed that these items all had strong loadings on the construct.

Table 5. Results of reliability testing

Measures	Mean	Cronbach's α	CITC range
1. Top management's support (TMS)	4.13	0.84	0.79 — 0.81
2. Cross-functional cooperation (CFC)	4.05	0.87	0.80 — 0.88
3. Information technology (IT)	4.05	0.89	0.86 — 0.88
4. Goal congruence (GC)	3.91	0.87	0.81 — 0.86
5. Collaborative communication (CC)	4.00	0.78	0.63 — 0.83
6. Service reliability (SR)	4.16	0.92	0.89 — 0.91
7. Service flexibility (SF)	4.00	0.85	0.81 — 0.83
8. Value-added service (VA)	3.92	0.88	0.83 — 0.86
9. Service efficiency (SE)	3.81	0.88	0.82 — 0.88
10. Market performance (MP)	4.11	0.89	0.81 — 0.90
11. Financial performance (FP)	3.57	0.96	0.94 — 0.95

4.3. Confirmatory factor analysis

We employed confirmatory factor analysis (CFA) to assess the validity of the scales. Following the standard used in Hu and Bentler (1999), the results showed a good fit with the model fit indices of $\chi^2/\text{d.f.}=1.766$, GFI=0.882, AGFI=0.851, CFI=0.907, IFI=0.908, TLI=0.902, RMR=0.041, and RMSEA=0.076. We also assessed Cronbach's alpha, composite reliability of constructs, and average variance extracted (AVE) to test convergent validity. As Table 5 reports, Cronbach's alpha ranged from 0.78 to 0.96, well above the benchmark value of 0.70. The values of composite reliability ranged from 0.848 to 0.958 and were above the benchmark value of 0.70. The AVE scores ranged from 0.528 to 0.883 and were above the benchmark value of 0.50 (Fornell and Larcker, 1981). These results indicated that the measurement model had satisfactory convergent validity. Following Koufteros (1999), models are constructed for all possible pairs of latent variables within each instrument. These models are then run under the following conditions: (1) with the correlation between the latent variables fixed at 1.0, and (2) with the correlation between the latent variables free to assume any value. The difference in χ^2 values for the fixed (for constrained) and free solution indicates whether a uni-dimensional model will be sufficient to account for the inter-correlations among the variables observed in each pair. Table 7 shows that the difference in χ^2 for the fixed and free solutions is very significant (i.e., the minimum χ^2 difference = 59.4, $P < 0.01$, d.f. = 1), providing evidence of discriminant validity.

4.4. Test of hypotheses

The supply chain integration, supply chain service capabilities, market performance, and financial performance variables are analyzed simultaneously in SEM. The results of hypotheses tests 1-9 are shown in Table 8. The standardized coefficients indicate that out of the nine hypotheses, H5, H6, H7 and H8 are significant at the 0.05 level, while H1, H2, H3, H4, and H9 are significant at the 0.001 level. As a result, all nine hypotheses are supported (as shown in Figure 2).

Table 6. Results of confirmatory factor analysis

Latent variables	Unstandardized factor loading	Completely standardized factor loading	Standard error ^a	Critical ratio ^b
ξ_1 : Supply chain integration (CR: 0.848, AVE: 0.528)				
TMS	1.000	0.705	-- ^c	--
CFC	1.234	0.729	0.180	6.859
IT	1.326	0.751	0.197	6.727
GC	1.247	0.731	0.173	7.221

CC	1.144	0.716	0.177	6.460
ξ2: Service reliability (CR: 0.921, AVE: 0.745)				
SR1	1.000	0.877	-- ^c	--
SR2	1.043	0.911	0.071	14.748
SR3	1.043	0.829	0.084	12.373
SR4	0.934	0.832	0.075	12.482
ξ3: Service flexibility (CR: 0.855, AVE: 0.596)				
SF1	1.000	0.778	-- ^c	--
SF2	0.989	0.761	0.113	8.749
SF3	0.883	0.723	0.107	8.272
SF4	1.128	0.823	0.119	9.489
ξ4: Value-added service (CR: 0.887, AVE: 0.665)				
VA1	1.000	0.856	-- ^c	--
VA2	1.053	0.901	0.081	13.076
VA3	0.838	0.679	0.097	8.677
VA4	0.850	0.809	0.076	11.206
ξ5: Service efficiency (CR: 0.877, AVE: 0.640)				
SE1	1.000	0.797	-- ^c	--
SE2	1.011	0.838	0.098	10.311
SE3	1.047	0.807	0.106	9.866
SE4	0.987	0.756	0.108	9.125
ξ6: Market performance (CR: 0.895, AVE: 0.741)				
MP1	1.000	0.888	-- ^c	--
MP2	0.990	0.912	0.071	14.020
MP3	0.912	0.777	0.083	11.023
ξ7: Financial performance (CR: 0.958, AVE: 0.883)				
FP1	1.000	0.932	-- ^c	--
FP2	0.974	0.950	0.046	21.082
FP3	0.962	0.937	0.048	20.214

Fit indices: $\chi^2=556.235$, d.f.=315, $\chi^2/\text{d.f.}=1.766$, GFI=0.882, AGFI=0.851, CFI=0.907, IFI=0.908, TLI=0.902, RMR=0.041, RMSEA=0.076

Note: a. S.E. is an estimate of the standard error of the covariance

b. C.R. is the critical ratio obtained by dividing the estimate of the covariance by its standard error. A value exceeding 1.96 represents a level of significance of 0.05.

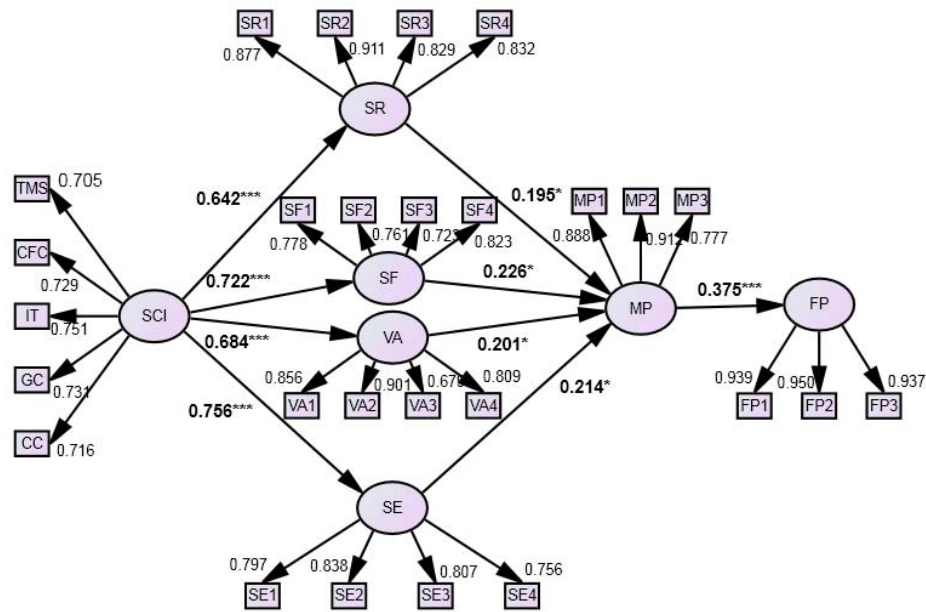
c. Indicates a parameter fixed at 1.0 in the original solution.

Table 7. Discriminant validity checks: χ^2 differences

Latent variables	ξ1	ξ2	ξ3	ξ4	ξ5	ξ6
ξ1: Supply chain integration						
ξ2: Service reliability	76.9					
ξ3: Service flexibility	73.3	172.5				
ξ4: Value-added service	71.7	69.8	66.9			
ξ5: Service efficiency	62.8	73.2	59.4	60.5		
ξ6: Market performance	73.3	68.4	61.5	65.1	62.9	
ξ7: Financial performance	87.9	70.9	64.6	62.5	66.4	68.1

Note: All of the χ^2 differences between fixed and free two-factor confirmatory measurement models (all tests=1 df) are significant at $p < 0.01$.

Fig 2. Estimated structural equation model



Note: *Correlation is significant at the 0.05 level, ***correlation is significant at the 0.001 level.

Table 8. Results (standardized) for hypotheses 1– 9 tests using SEM

Hypotheses	Estimate (\hat{a})	P	Outcome
H1: Supply chain integration → Service reliability	0.642 (\hat{a}_1)	0.000	Supported
H2: Supply chain integration → Service flexibility	0.722 (\hat{a}_2)	0.000	Supported
H3: Supply chain integration → Value-added service	0.684 (\hat{a}_3)	0.000	Supported
H4: Supply chain integration → Service efficiency	0.756 (\hat{a}_4)	0.000	Supported
H5: Service reliability → Market performance	0.195 (\hat{a}_5)	0.038	Supported
H6: Service flexibility → Market performance	0.226 (\hat{a}_6)	0.035	Supported
H7: Value-added service → Market performance	0.201 (\hat{a}_7)	0.043	Supported
H8: Service efficiency → Market performance	0.214 (\hat{a}_8)	0.048	Supported
H9: Market performance → Financial performance	0.375 (\hat{a}_9)	0.000	Supported

4.5. Analyses of direct, indirect and total effects

This study also examines the measured effects of all relationships, as shown in Table 9. With regard to the direct effects, supply chain integration (SCI) is positively related to service reliability ($\hat{a}_1=0.642$), service flexibility ($\hat{a}_2=0.722$), value-added service ($\hat{a}_3=0.684$), and service efficiency ($\hat{a}_4=0.756$). Supply chain service capabilities (i.e., service reliability, service flexibility, value-added service, and service efficiency) all have significantly positive relationships with market performance. Service reliability (SR) is positively related to market performance ($\hat{a}_5=0.195$), as is service flexibility (SF) ($\hat{a}_6=0.226$), value-added service (VA) ($\hat{a}_7=0.201$), and service efficiency (SE) ($\hat{a}_8=0.214$). Market performance (MP) is positively related to financial performance ($\hat{a}_9=0.375$).

With regard to indirect effects, the effect of service reliability on financial performance, as mediated by market performance, is 0.073, the effect of service flexibility on financial performance, as mediated by market performance, is 0.085, the effect of value-added service on financial performance, as mediated by market performance, is 0.075, and the effect of service efficiency on financial performance, as mediated by market performance, is 0.080. Supply chain integration is mostly positively related to supply chain service capabilities in container shipping industry (direct effect $\hat{a}_1, \hat{a}_2, \hat{a}_3$, and \hat{a}_4), and has an indirect positive effect (0.588) on market performance, as fully mediated by supply chain service capabilities, as well as an indirect positive effect (0.220) on financial performance, fully mediated by supply chain service capabilities and market performance.

Table 9. Direct, indirect and total effects

Paths	Direct effect	Indirect effect	Total effect
H1: Supply chain integration → Service reliability (SR)	0.642		
H2: Supply chain integration → Service flexibility (SF)	0.722		
H3: Supply chain integration → Value-added service (VA)	0.684		
H4: Supply chain integration → Service efficiency (SE)	0.756		
H5: Service reliability → Market performance	0.195		
H6: Service flexibility → Market performance	0.226		
H7: Value-added service → Market performance	0.201		
H8: Service efficiency → Market performance	0.214		
H9: Market performance → Financial performance	0.375		
Service reliability → Financial performance		0.073	
Service flexibility → Financial performance		0.085	
Value-added service → Financial performance		0.075	
Service efficiency → Financial performance		0.080	
Supply chain integration → Market performance		0.588	0.588
Supply chain integration → Financial performance		0.220	0.220

5. Conclusions and Contributions

This research has provided a more accurate and comprehensive model of supply chain integration with supply chain service capabilities and firm performance in a container shipping supply chain context. In doing so, it has identified a set of five dimensions that can enable effective supply chain integration: top management support (TMS), cross-functional cooperation (CFC), information technology (IT), goal congruence (GC), and collaborative communication (CC), and highlighted the critical mediating role of supply chain service capabilities (i.e. service efficiency, service reliability, service flexibility, and value-added service) in improving firms' market and financial performance. The current literature provides limited evidence with regard to the relationship between supply chain integration, supply chain service capabilities, market performance, and financial performance. The research results strongly support the claim that supply chain integration increases supply chain service capabilities (H1, H2, H3, and H4). Due to internal cross-functional cooperation and external inter-organizational collaboration synergy, better integration among supply chain partners provides a good context for better container shipping service capabilities, which can then improve return on investment, return on asset, and operating profit through greater customer satisfaction and loyalty. The results empirically confirm that supply chain service capabilities can directly and significantly increase market performance (H5, H6, H7, and H8), that market performance is positively and significantly related to financial performance (H9), and that well-executed supply chain integration indirectly improves financial performance through the mediation of supply chain service capabilities and market performance.

This study makes several contributions to both the theory and practice of supply chain integration and service capability. First, it provides a theoretical framework to link supply chain integration, supply chain service capabilities, market performance and financial performance for the container shipping service supply chain context. Second, it develops valid and reliable instruments for supply chain integration, supply chain service capabilities, and firm performance. All the scales have been tested through rigorous statistical methodologies, including content validity, reliability, and the validation of confirmatory factor analysis, and all of these met the necessary requirements, and can thus be used in future research. Third, the service capabilities and improved firm performance associated with supply chain integration will be realized when all partners in the supply chain, from upstream (shipping-related materials) suppliers, midstream (freight forwarders and terminal operators) partners to downstream (shippers and consignees) customers, integrate well in the container shipping context. Jointly developing the supply chain service capabilities in a container shipping service supply chain can thus enhance both market performance (i.e., quality, customer satisfaction and loyalty) and financial performance. Fourth, this study answers the call for more empirical research that examines the outcomes of supply chain integration (Panayides and Cullinane, 2002) and firm performance in a container shipping context. Finally, the model development and empirical testing presented in this study have extended our understanding of supply chain integration and the related service capabilities, and can thus serve

as a valuable reference for managers to achieve better supply chain integration formation and performance. The measurements presented in this work can also serve as a powerful tool that can help managers to develop more effective collaborative relationships, and thus minimize the chance of supply chain integration failure by addressing these key dimensions before entering into any closer associations with partner firms (Cao and Zhang, 2011).

6. Limitations and Future Research

While the objectives of this study have been accomplished, as outlined above, it has several limitations that should be noted, and which provide some directions for future work. First, the data collection was restricted to container shipping companies and agencies in Taiwan, and so the conclusions of this work may not be generalizable to other industries or countries, and more work should thus be done to verify the findings. It would also be interesting to compare the influence of supply chain integration on the related service capabilities and firm performance in various other industries. Second, the use of cross-sectional data limited the discussion of causality in this work, and future studies might be conducted using a longitudinal approach to investigate the short- and long-term effects of supply chain integration on service capabilities and firm performance in the container shipping context, in order to further test the pathways proposed in this study. Finally, the results of this study do not imply that these are the only valid models for the development of SC integration on SC service capabilities and firm performance in the container shipping industry, although the ones hypothesized in this study provide a good fit with the data.

Acknowledgement

This research was sponsored by the National Science Council, Taiwan, R.O.C. under NSC 101-2410-H-309-018.

References

- Andraski, J.C. (1998), Leadership and the realization of supply chain collaboration, *Journal of Business Logistics* 19 (2): 9-11.
- Angeles, R., and R. Nath. (2001), Partner congruence in electronic data interchange (EDI)-enabled relationships, *Journal of Business Logistics* 22 (2): 109-27.
- Antonio, K.W.L., C.M.Y. Richard, and E. Tang. (2009), The complementarity of internal integration and product modularity: an empirical study of their interaction effect on competitive capabilities, *Journal of Engineering and Technology Management* 26: 305–326.
- Armstrong, J. S., and T.S. Overton. (1977), Estimating non-response bias in mail surveys, *Journal of Marketing Research* 14: 396–402.
- Bagchi, P.K., and T. Skjoett-Skjoett-Larsen. (2005), Supply Chain Integration: a European Survey, *The International Journal of Logistics Management* 16 (2): 275-294.
- Barney J. B. (1991), Firm Resources and Sustained Competitive Advantage, *Journal of Management* 17 (1), 99-120.
- Barney J.B., and P.M. Wright. (1998), On becoming a strategic partner: the role of human resource in gaining competitive advantage, *Human Resource Management* 37 (1): 31-46.
- Barney, J.B. (1986), Strategic factor markets: expectations, luck, and business strategy, *Management Science* 32 (10): 1231-1241.
- Barney, J.B., M. Wright, and D.J., Jr. Ketchen. (2001), The resource-based view of the firm: Ten years after 1991, *Journal of Management* 27: 625-641.
- Bergin, S. (1997), How ocean carriers are staying afloat, *Transportation and Distribution* 38 (2): 45-47.
- Cao, M., and Q. Zhang. (2011), Supply chain collaboration: impact on collaborative advantage and firm performance, *Journal of Operations Management* 29 (3): 163-180.
- Chen, I.J., and A. Paulraj. (2004), Towards a theory of supply chain management: the constructs and measurements, *Journal of Operations Management* 22: 119-150.
- Churchill, G.A., and D. Iacobucci. (2002), *Marketing Research: Methodological Foundation*, 8th edition, South-Western, USA.
- Cohen, S.G., and D.E. Bailey. (1997), What makes teams work: group effectiveness research from the shop

- floor to the executive suite, *Journal of Management* 23 (3): 239-290.
- Daugherty, P.J., T.P. Stank, and A.E. Ellinger. (1998), Leveraging logistics distribution capabilities: the impact of logistics service on market share, *Journal of Business Logistics* 19 (2): 36-51.
- Dawe, R.L. (1994), An investigation of the pace and determination of information technology use in the manufacturing materials logistics system, *Journal of Business Logistics* 15 (1): 229-260.
- Deveraj, S., L. Krajewski, and J. Wei. (2007), Impact of e-Business technologies on operational performance: the role of production information integration in the supply chain, *Journal of Operations Management* 25: 1199-1216.
- Dyer, J.H. (1996), Specialized supplier networks as a source of competitive advantage: evidence from the auto industry, *Strategic Management Journal* 17: 271-291.
- Fornell, C., Larcker, D.F. (1981), Evaluating structural equation models with unobservable variables and measurement error, *Journal of Marketing Research* 18 (1), 39-50.
- Franc, P., and M. Van der Horst. (2010), Understanding hinterland service integration by shipping lines and terminal operators: a theoretical and empirical analysis, *Journal of Transport Geography* 18 (4): 557-566.
- Frohlich, M.T., and R. Westbrook. (2001), Arcs of integration: an international study of supply chain strategies, *Journal of Operations Management* 19: 185-200.
- Golob, T.F. (2003), Structural equation modeling for travel behavior research, *Transportation Research Part B* 37: 1-25.
- Gosain, S., A. Malhotra, and O.A. El Sawy. (2004), Coordinating for flexibility in e-business supply chains, *Journal of Management Information Systems* 21 (3): 7-45.
- Hair Jr., J.F., W.C. Black, B.J. Babin, R. Anderson, and R. Tatham. (2006), *Multivariate data analysis*, 6th Edition, Prentice Hall, Upper Saddle River.
- Heaver, T.D. (2002), The evolving roles of shipping lines in international logistics, *International Journal of Maritime Economics* 4 (3): 210-230.
- Holweg, M., S. Disney, J. Holmström, and J. Smaron. (2005), Supply Chain collaboration: Making Sense of the Strategy Continuum, *European Management Journal* 23 (2): 170-181.
- Hu, L., and P.M. Bentler. (1999), Cutoff criteria for fit indexes in covariance structure analysis: conventional criteria versus new alternatives, *Structural Equation Modeling* 6 (1): 1-55.
- Kahn, Kenneth B. (1996), Interdepartmental Integration: A Definition with Implications for Product Development Performance, *Journal of Product Innovation Management* 13 (2): 137-151.
- Kerlinger, F.N. (1986), *Foundations of behavioural research* (3rd ed), Holt, Rinehart and Winston, New York.
- Kogut, B., and U. Zander. (2003), Knowledge of the firm and the evolutionary theory of the multinational corporation, *Journal of International Business Studies* 34: 516-529.
- Koo, J.S., K.S. Hwang, and H.J. Yeo. (2009), Are Shippers satisfied with the diversified Provision of Logistics Service by Shipping Companies?-A Study between the UK and South Korea, *The Asian Journal of Shipping and Logistics* 25 (2): 237-251.
- Koufteros, X., M. Van Vonderembse, and J. Jayaram. (2005), Internal and external integration for product development: the contingency effects of uncertainty, equivocality, and platform strategy, *Decision Sciences* 36 (1): 97-133.
- Koufteros, X.A. (1999), Testing a model of pull production: a paradigm for manufacturing research using structural equation modeling, *Journal of Operations Management* 17: 467-488.
- Lam, J.S.L., and E. van der Voorde. (2011), Scenario analysis for supply chain integration in container shipping, *Maritime Policy and Management* 38 (7): 705-725.
- Le Meunier-FitzHugh, K., G.R. Massey, and N.F. Piercy. (2011), The impact of aligned rewards and senior manager attitudes on conflict and collaboration between sales and marketing, *Industrial Marketing Management* 40: 1161-1171.
- Lee, H.L., V. Padmanabhan, and S. Whang. (1997), Information distortion in a supply chain: the bullwhip effect, *Management Science* 43 (4): 546-558.
- Lejeune, M. A., and N. Yakova. (2005), On characterizing the 4 C's in supply chain management, *Journal of Operations Management* 23 (1): 81-100.
- Leonidou, L.C., C.N. Leonidou, T. Fotiadis, and A. Zeriti. (2013), Resources and capabilities as drivers of hotel green marketing strategy: Implications on competitive advantage and performance, *Tourism Management* 35 (2): 94-110.
- Liang, T.P., H.J. Lai, and Y.C. Ku. (2006), Personalized content recommendation and user satisfaction: theoretical synthesis and empirical findings, *Journal of Management Information Systems* 23 (3): 45-70.

- Lu, C.S. (2000), Logistics services in Taiwanese maritime firms, *Transportation Research Part E: Logistics and Transportation Review* 36 (2): 79-96.
- Lu, C.S. (2003), The impact of carrier service attributes on shipper-carrier partnering relationships: a shipper's perspective, *Transportation Research Part E: Logistics and Transportation Review* 39 (5): 399-415.
- Lu, C.S. (2007), Evaluating key resources and capabilities for liner shipping services, *Transport Reviews* 27 (3): 285-310.
- Lynch, D.F., S.B. Keller, and J. Ozment. (2000), The effects of logistics capabilities and strategy on firm performance, *Journal of Business Logistics* 21 (2): 47-67.
- Mentzer, J.T., S. Min, and Z.G. Zacharia. (2000), The nature of inter-firm partnering in supply chain management, *Journal of Retailing* 76 (4): 549-568.
- Midoro, R., E. Musso, and F. Parola. (2005), Maritime liner shipping and the stevedoring industry: Market structure and competition strategies, *Maritime Policy and Management* 32: 89-106.
- Mohr, J., and J.R. Nevin. (1990), Communication strategies in marketing channels: a theoretical perspective, *Journal of Marketing* 54 (4): 36-51.
- Mohr, J., R.J. Fisher, and J.R. Nevin. (1996), Collaborative communication in inter-firm relationships: moderating effects of integration and control, *Journal of Marketing* 60 (3): 103-115.
- Moorman, C., and R.T. Rust. (1999), The role of marketing, *Journal of Marketing* 63 (Special Issue): 180-197.
- Narasimhan, R., and J. Jayaram. (1998), Causal linkage in supply chain management: an exploratory study of North American manufacturing firms, *Decision Science* 29 (3): 579-605.
- Notteboom, T. (2004), Container Shipping and Ports: An Overview, *Review of Network Economics* 3 (2): 86-106.
- Olavarrieta, S., and A.E. Ellinger. (1997), Resource-based theory and strategic logistics research, *International Journal of Physical Distribution & Logistics Management* 27 (9/10): 559-587.
- Panayides, P.M., and K. Cullinane. (2002), Competitive advantage in liner shipping: a review and research agenda, *International Journal of Maritime Economics* 4: 189-209.
- Paulraj, A., A.A. Lado, and I.J. Chen. (2008), Inter-organizational communication as a relational competency: antecedents and performance outcomes in collaborative buyer-supplier relationships, *Journal of Operations Management* 26 (1): 45-64.
- Prahinski, C., and W.C. Benton. (2004), Supplier Evaluation: Communication Strategies to Improve Supplier Performance, *Journal of Operations Management* 22 (1): 39-62.
- Prajogo, D., and J. Olhager. (2012), Supply chain integration and performance: the effects of long-term relationships, information technology and sharing, and logistics integration, *International Journal of Production Economics* 135 (1): 514-522.
- Rosenzweig, E.D., A.V. Roth, and J.W. Dean. (2003), The influence of an integration strategy on competitive capabilities and business performance: an exploratory study of consumer products manufacturers, *Journal of Operations Management* 21 (4): 437-456.
- Sheu, C., H.R. Yen, and B. Chae. (2006), Determinants of supplier-retailer collaboration: evidence from an international study, *International Journal of Operations and Production Management* 26(1): 24-49.
- Simatupang, T. M., and R. Sridharan. (2005), An integrative framework for supply chain collaboration, *The International Journal of Logistics Management* 16 (2): 257-274.
- Stevenson, M., and M. Spring. (2007), Flexibility from a supply chain perspective: definition and review, *International Journal of Operations & Production Management* 27 (7): 685-713.
- Teece, D., G. Pisano, and A. Shuen. (1994), *Dynamic Capabilities and Strategic Management*, Working Paper, Center for Research in Management, University of California, Berkeley.
- Teece, D.J. (1988), Technological change and the nature of the firm, In: Dosi, G., Freeman, C., Nelson, R., Silverberg, G., Soete, L. _Eds., *Technical Change and Economic Theory*. Frances Pinter, London.
- Tidd, J., J. Bessant, and K. Pavitt. (2001), *Managing Innovation: Integrating technological, market and organisational change*, John Wiley & sons, Chichester.
- Vickery, S.K., J. Jayaram, C. Droge, and R. Calantone. (2003), The effects of an integrative supply chain strategy on customer service and financial performance: an analysis of direct versus indirect relationships, *Journal of Operations Management* 21: 523-540.
- Vorhies, D.W., and N.A. Morgan. (2005), Benchmarking marketing capabilities for sustainable competitive advantage, *Journal of Marketing* 69 (January): 80-94.
- Wang, T.F., and K. Cullinane. (2006), The efficiency of European container terminals and implications for supply chain management, *Maritime Economics & Logistics* 8: 82-99.

- Wernerfelt, B. (1984), A resource based view of the firm, *Strategic Management Journal* 5 (2): 171-180.
- Yang, C.C., P.B. Marlow, and C.S. Lu. (2009), Assessing resources, logistics service capabilities, innovation capabilities and the performance of container shipping service in Taiwan, *International Journal of Production Economics* 122 (1): 4-20.
- Zhao, X., B. Huo, W. Selen, and J. H. Y. Yeung. (2011), The impact of internal integration and relationship commitment on external integration, *Journal of Operations Management* 29: 17-32.
- Zhou, K., J. Brown, and C. Dev. (2009), Marketing orientation, competitive advantage, and performance: a demand-based perspective, *Journal of Business Research* 62: 1063–1070.

The Link between Corporate Social Responsibility, Corporate Reputation, and Organisational Performance: Evidence from the Liner Shipping Industry

Kuo-Chung Shang^{a*}, Chin-Shan Lu^b, J-R Lin^c, Chih-Ching Chang^d and Kung-Don Yu^e

^{a,c} Department of Transportation Science, National Taiwan Ocean University, Keelung, Taiwan

^{d,e} Department of Shipping and Transportation Management, National Taiwan Ocean University, Keelung, Taiwan.

^b Department of Logistics and Maritime Studies, The Hong Kong Polytechnic University, Hong Kong.

*Corresponding author

Abstract

This study, based on a survey of 246 liner shipping companies in Taiwan, uses structural equation modelling to examine the relationships among corporate social responsibility (CSR), corporate reputation, and organisational performance. Confirmatory factor analysis is conducted to identify three critical CSR dimensions, namely, environmental responsibility, social responsibility, and economic responsibility. The results indicate that environmental responsibility, social responsibility, and economic responsibility each indirectly and positively influence organisational performance through corporate reputation. Accordingly, this study suggests that liner shipping managers could enhance their CSR to improve their corporate reputation, and organisational performance. The theoretical and practical implications of the findings for liner shipping firms are also discussed.

Keywords: Corporate Social Responsibility; Corporate Reputation; Organisational Performance; Liner Shipping Company.

1. Introduction

In recent years, with the international popularization of environmental awareness, green concepts, and renewable consumption, corporate social responsibility (CSR) has become highly valued. Under this framework, companies not only pursue profits for stakeholders and investors; they also devote themselves to environmental protection, labour rights, charity work, and community participation.

Several internationally recognizable brands have adopted CSR as a useful tool for market segmentation from competitors. For instance, the biggest retailer in the world, Wal-Mart, requires suppliers to provide energy consumption information in order to calculate total greenhouse gas emissions.

Under the tendency toward globalization, world standards have become increasingly consistent. Consequently, Taiwan's businesses must remain internationally competitive. In addition, both international clients and Taiwanese consumers have increased their demands and expectations for Taiwanese businesses. In particular, liner container shipping companies, which primarily provide shipping consignment services that transport container ships to various world locations, encounter differing national, ethnic, legal, and international covenants. Compared to domestic industries, topics regarding the CSR of container shipping companies are significantly more crucial. For example, Taiwan's Yang Ming Marine Transport Corporation and Evergreen Marine Transport corporations have joined the Europe-based Business for Social Responsibility (BSR) organisation and its efforts for reducing oil consumption and carbon dioxide emissions, ballast water and antifouling paint management, the promotion of environmental measures, and improving employee rights and benefits. Additional BSR corporate members, including Wal-Mart, IKEA and Nike, offer priority commissions for cargo carriage to shipping companies that are BSR members.

In recent years, corporate reputation has received wide attention in the strategic management field. This is

because, according to resource-based theories, corporate reputation is an intangible resource that is difficult to imitate and that establishes a lasting competitive advantage for a company (Hall, 1992; Deephouse, 2000). Therefore, the U.S. magazine *Fortune* has been publishing corporate reputation reports since 1983, including one limited to the U.S. companies and one comprising international companies. Similarly, *Common Wealth*, a domestic magazine, adopted *Fortune*'s methods and has been conducting the top 100 "Benchmarking Enterprises Reputation Survey" since 1994. Extant academic studies investigating the correlation between corporate reputation and financial performance mostly obtained positive results (Antunovich et al., 2000).

Previous research has shown that corporate strategies related to CSR have gradually become a key element for business success (Donald et al., 2004). In addition, many studies have highlighted that a successful CSR strategy entails benefits such as a decreasing employee turnover rate, increasing sales, and reduced operational risks (Griffin & Mahon, 1997). Furthermore, researchers have asserted that organisational performance is affected by CSR. Orlitzky et al. (2003) verified that CSR is positively correlated with organisational and financial performance. This shows that the implementation of relevant strategies regarding CSR enhances financial performance (Luo & Bhattacharya, 2006). However, from another perspective, fulfilling CSR requires increased costs, and can cause losses in business benefits or shareholders' rights and interests (Davidson & Worrell, 1988). Thus, this study endeavours to understand whether executing CSR positively enhances or curtails the corporate performance of liner container shipping companies, which is a topic worthy of in-depth research and examination.

In addition to investigating the relationship between CSR and financial performance, many studies have targeted correlation unrelated to financial performance between employees and consumers as the subject of research (Brown & Dacin, 1997). However, few researchers have addressed the relationship between CSR and reputation, which is an area that lacks research and to which this study is directed.

CSR is a cultural phenomenon. A diversity of CSR and social performance can be observed in various countries (Quazi & O'Brien, 2000; Gao, 2009). Most related research has targeted developed countries, such as those in North America and Europe and Japan (Lindgreen et al., 2009; Okamoto, 2009). Because of the scarcity of relevant literature regarding developing countries, this study investigates Taiwan's container shipping companies to assist in compensating for the deficiencies of international research.

To sum up, CSR and corporate reputation have become increasingly crucial to the significance of businesses in modern-day competitive markets. However, there is insufficient domestic research on CSR that targets liner container shipping companies (Lu et al., 2009). Therefore, a study investigating the relationships among the CSR, reputation, and the organisational performance of container shipping companies can serve as a reference for liner container shipping company operators regarding operational strategies.

2. Theoretical Development

2.1 *Corporate Social Responsibility*

The concept of corporate social responsibility (CSR) originated in the 1950s, based on the belief that corporate entities are obligated to engage in activities that satisfy the needs of and are aligned with the values of society (Brown, 1953). The World Business Council for Sustainable Development (WBCSD) (1992) defined CSR as the commitment by corporations to consistently adhere to moral guidelines, contribute to economic development, and improve the living standards of employees and their families, as well as those of the entire community and society. In a recent study, Smith (2003) concluded by stating concisely that CSR is not merely the right thing to do but also the smart thing to do.

Scholars have in the past held different views regarding the attitude required of corporations toward society, and therefore a consensus has not been achieved. Neoclassical economists asserted that the primary concern of corporate managers was to maximize the long-term market value of their companies, and ensure that returns are generated for shareholders. Friedman (1970), for example, maintained that increasing profits is the sole CSR of any corporation, to the extent that administrators have no right to allocate shareholders' wealth to any other organisations. However, other scholars have countered the opinions of neoclassical economists with the

stakeholder theory. As Freeman (1984) indicated, administrators are required to allocate their company's resources not only to generate shareholder profits, but also benefit the stakeholders. In addition to these schools of thought, some economists have held relatively neutral opinions regarding the CSR concept. Jensen (2001) contended that a company should not be regarded as successful if it maximizes shareholders' interests at the expense of the interests of others; true success is demonstrated by a company that considers the interests of both the stakeholders and shareholders.

For container shipping companies, CSR has become a crucial corporate concern. For example, a CSR report released by Nippon Yusen Kaisha (NYK) contained the following seven CSR activities pertaining to the shipping industry: (1) organisational governance; (2) human rights; (3) labour practises; (4) environment; (5) fair operating practices; (6) consumer issues; and (7) community involvement and development (NYK Group, 2012). The Singapore-based Neptune Orient Lines (NOL) asserted that its CSR is concerned with its environment, community, and security (NOL, 2012). Similarly, Yang Ming Marine Transport Corporation's CSR report stated that economy, society, and environmental protection are three of the most pressing stakeholder concerns (Yang Ming Marine Transport Corporation, 2012). Therefore, this study asserts that container shipping companies are required to consider the interests of both the stakeholders and shareholders when fulfilling their CSR, and that the CSR concept can be classified into the following three categories: (1) economic responsibility; (2) social responsibility; and (3) environmental responsibility (NYK, 2012; Yang Ming Marine Transport Corporation, 2012). Economic responsibility issues include corporate governance, share prices, and financial status. Social responsibility issues consider topics such as staff development, workplace safety, community care, charity work, supply chain relationships, and security. Environmental responsibility issues involve the use of environmentally friendly vessels, green purchasing behaviour, pollution control, slow steaming, and management of resources (e.g., water, paper, electricity, and oil).

2.2 *Corporate Reputation*

Corporate reputation is regarded as an intangible asset to a company (Walsh & Beatty, 2007). Numerous researchers have asserted that companies can enhance their competitive advantage and attract more customers by maintaining a sound corporate reputation (Gardberg & Fombrun, 2002). Bromley (2001) held that a corporate reputation is created by internal members, associated organisations, and stakeholders. Rose and Thomsen (2004) defined corporate reputation as the stakeholders' perception toward the company in which they have a vested interest. Previous studies also identified corporate reputation as an intangible asset, one that can improve the competitiveness of a company's products and services if properly maintained (Barney, 2002). Other scholars asserted that corporate reputation contributes to a company's efforts in increasing competitive advantage and improving organisational performance (Hall, 1993). By taking all of the above assertions into consideration, this study acknowledges corporate reputation to be a key asset of a company (Dasgupta, 1988), and concurs with the view that reputation results from stakeholders' assessments after perceiving a company through the products or services offered (Fombrun & Shanley, 1990), and that reputation is a crucial factor for corporate success (Kay, 1993). For these reasons, not only are corporations required to maintain a sound reputation, but their supply chain firms must also behave in a manner that supports the company's reputation.

Various viewpoints exist regarding the corporate reputation dimension. Walsh and Beatty (2007), for example, asserted that corporate reputation should be measured based on customer satisfaction, loyalty, trust, and positive word of mouth. Chun (2005) maintained that a company's reputation is measured by six factors, namely, positive goodwill, quality products and services, excellent leadership, positive future prospects, retention of competent employees, and fulfilment of environmental and social obligations. Finally, Ewing et al. (1999) identified positive reputation, service quality, and leadership as the three factors for measuring corporate reputation. In this study, some of the aforementioned indicators are used to measure the corporate reputations of shipping companies.

2.3 *Organisational performance*

Performance has been viewed in a great variety of ways by logistics researchers (Chow et al., 1994; 1995; Bowersox et al., 1999). The definition and measurement of performance is often a challenge for researchers

because organisations have multiple and frequently conflicting goals (Chow et al., 1994; Rogers, 1996). Thus, the definition of performance is ‘ultimately up to the evaluator’ (Haytko, 1994, p.263).

Performance can be classified into financial performance and non-financial performance. Financial performance which reflects the fulfilment of the economic goals of the firm includes profit before tax. By contrast, non-financial performance includes customer satisfaction and customer loyalty.

3. Hypotheses Development

The relationship between CSR and organisational reputation has been brought to the notice of researchers. Carmeli and Cohen (2001) found that CSR will lead to a good corporate reputation and will thus enhance financial performance. Fombrun (2005) pointed out that the implementation of CSR can improve a company’s reputation. Lai et al. (2010) did extensive work on CSR and found that a supplier’s implementation of CSR will positively affect a firm’s corporate image.

Many studies have found CSR to have a positive impact on organisational reputation (Logsdon & Wood, 2002; Mahon, 2002; Mahon & Wartick, 2003; Brammer & Pavelin, 2004). The implementation of CSR is, therefore, essential for the successful performance of environmental responsibility, social responsibility, and economic responsibility, which, in turn, enhances organizational reputation. Accordingly, it is surmised that:

Hypothesis 1: The CSR aspect of environmental responsibility has a positive effect on organizational reputation in liner shipping.

Hypothesis 2: The CSR aspect of social responsibility has a positive effect on organisational reputation in liner shipping.

Hypothesis 3: The CSR aspect of economic responsibility has a positive effect on organisational reputation in liner shipping.

Various groups of researchers have worked with the relationship between CSR and organisational performance. For example, Freeman (1984) pointed out that when enterprises pay attention to CSR, it can enhance the relationship between stakeholder and business performance. Waddock and Graves (1997) also observed that business performance depends on good social responsibility. Orlitzky et al. (2003) found by using meta-analysis that a positive relationship exists between CSR and organisational performance.

To sum up, CSR can be regarded as a key strategic resource for acquiring superior performance (Margolis & Walsh, 2003; Beurden & Gossling, 2008). CSR, including three indices (i.e., environmental responsibility, social responsibility, and economic responsibility), has been found to be positively associated with organisational performance. Thus, the present research hypothesizes that:

Hypothesis 4: The CSR aspect of environmental responsibility has a positive effect on organisational performance in liner shipping.

Hypothesis 5: The CSR aspect of social responsibility has a positive effect on organisational performance in liner shipping.

Hypothesis 6: The CSR aspect of economic responsibility has a positive effect on organisational performance in liner shipping.

Corporate reputation, as an important intangible asset, has an important role to play in communicating with business customers. People can take advantage of the messages conveyed to accept the company’s products or services, and to enhance the company’s performance. Sanchez and Sotorrio (2007) have suggested that a good corporate reputation can provide companies with a competitive advantage in the marketplace. Sabate and Puente (2003) have done extensive work on reviewing the literature to examine the relationship between corporate reputation and organisational performance. Their results indicate that most of the literature shows

that a positive corporate reputation will affect organisational performance. Many studies have also found that for many enterprises a good reputation will affect the company's financial performance (Podolny, 1993; Fombrun, 1996; Roberts & Dowling, 1997). Thus, the present research hypothesises that:

Hypothesis 7: Organisational reputation has a positive effect on organisational performance in liner shipping.

4. Methodology

4.1 Sample

The sample of liner companies was selected from the *Directory of the National Association of Shipping Agencies and Companies* in Taiwan. A total of 246 shipping managers were identified. The initial mailing elicited 55 usable responses. A follow-up mailing was sent two weeks after the initial mailing and an additional 75 usable responses were returned. The total number of usable responses was 130 and the overall response rate for this study was approximately 55%.

A comparison of early (those responding to the first mailing) and late (those responding to the second mailing) respondents was carried out in this study to test for non-response bias (Armstrong & Overton, 1977). The 130 survey respondents were divided into two groups based on their response wave (first: n=55, 42.3% and second: n=75, 57.7%). T-tests were performed on the two groups' responses to the CSR dimensions and the results indicated that, at the 5% significance level, there were no significant differences in the two groups' perceptions of the agreement of the various items. The test results suggested that non-response bias was not a problem in this study since late respondents' responses were similar to those of the first wave of respondents.

With regard to the profiles of respondents, more than 60% of respondents were classified according to title as being either vice president or above or manager/assistant manager. In general, managers are actively involved in and anchor operations in the businesses. Thus, the high percentage of responses from managers or above reinforced the reliability of the survey findings. In order to ascertain whether respondents actually understood or appreciated the market in the liner shipping industry, respondents were asked to indicate how long they had worked in it. Approximately 30% of respondents had worked in the industry for less than 10 years, suggesting that they had abundant practical experience to answer questions. Nearly half of the respondents were from liner shipping companies (49.1%), with the remainder coming from shipping agencies (50.9%).

4.2 Measures

Among these CSR items, environmental factors, social factors, and economic factors are suggested as being important determinants of CSR and are incorporated into our research model. *Environmental responsibility* was assessed by six items adapted from the published environment or CSR reports of liner shipping companies (Yang Ming Marine Transport Corporation, 2012; MOL Group, 2011, K Line Group, 2011, NYK Line, 2012). *Social responsibility* was measured by six items adapted from Lai et al. (2010), Mishra and Suar (2010), Lu et al., (2009), Mijatovic and Stokic (2009), Gao (2009), and Lamberti and Lettieri (2009). *Economic responsibility* was measured by three items adapted from Jamali (2008).

Corporate reputation was measured by four items adapted from Cretu and Brodie (2007), Puncheva-Michelotti and Michelotti (2010), and Michaelis et al. (2008). *Organisational performance* was measured by three items covering improvements along dimensions including profit before tax, customer loyalty, and customer satisfaction. (Germain & Dröge, 1998; Lu et al, 2009; Shang et al., 2010).

In this study, each CSR and corporate reputation item was measured using a seven-point Likert scale, where 1 corresponds to "strongly disagree" and 7 to "strongly agree", while each variable for organisational performance was assessed using a seven-point Likert scale, ranging from "1= very poor" to "7= very good."

4.3 Research methods

This study aims to evaluate the effects among environmental responsibility, social responsibility, economic

responsibility, corporate reputation, and organisational performance in the liner shipping industry. This study has adopted the two-step SEM approach (Anderson & Gerbing, 1988; Garver & Mentzer, 1999). The researchers first assessed the validity of the measurement model, including (1) content validity, (2) unidimensionality, (3) reliability, (4) convergent validity, and (5) discriminant validity, by using confirmatory factor analysis (CFA). Following validation of the measurement model, SEM can be used to estimate the structural model (Wisner, 2003). The analysis is carried out using the *IBM SPSS 20.0 for Windows* and *Amos 18.0* statistical packages.

CFA was tested on all five constructs for path coefficients of the hypothesized structural model. In order to ensure the instrument's accuracy and the content validity of the questionnaire, a comprehensive review of the literature and interviews with practitioners were used in this study, i.e., the questions were based on previous studies and discussions with a number of executives and experts in liner shipping.

Unidimensionality and convergent validity were satisfactory (Garver & Mentzer, 1999; Koufteros, 1999), because (1) the three goodness-of-fit indexes (the comparative fit index, CFI=0.959>0.95; the Tucker-Lewis index, TLI=0.952>0.95; and the root mean square error of approximation, RMSEA=0.063<0.08) satisfied the cutoff criteria (Hu & Bentler, 1999; Baumgartner & Homburg, 1996); (2) no pair of standardised residual values, which represent 'the differences between the observed correlation or covariance and the estimated correlation or covariance matrix' (Hair et al., 1998: 615), was greater than ± 2.58 ; (3) no specifically larger modification indices (MI) values were expected to be modified; (4) all expected parameter change (EPC) values were smaller than ± 0.3 ; (5) all t-values of variables were significant (t-values $> \pm 1.96$); and (6) all factor loadings (λ) on each variable were greater than or equal to 0.7.

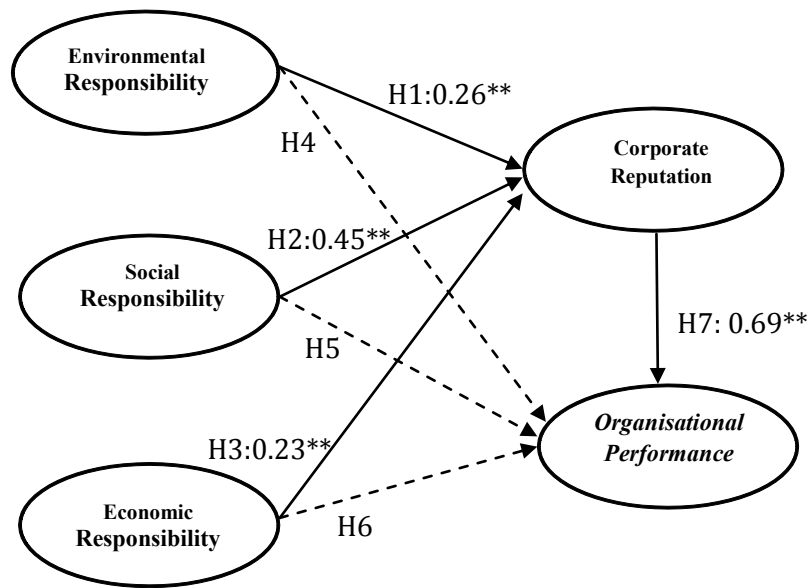
Reliability was assessed by Cronbach's alpha, composite reliability (CR), and average variance extracted (AVE). The Cronbach's alpha values as well as CR were greater than 0.80 (see the Appendix), suggesting that the theoretical constructs were reliable. In addition, the AVE values for all constructs exceeded the threshold value of 0.50. (Garver & Mentzer, 1999; Koufteros, 1999).

Discriminant validity, which was assessed using the $\chi^2_{\text{different}}$ test to compare the base model (unconstrained) and other pairs of constructs (constrained) (Ahire et al., 1996; Anderson & Gerbing, 1988), was satisfactory because all pairs of latent variables were statistically significant ($p < 0.05$).

4.4. Hypotheses testing

After verification of the validity and reliability of the constructs in the form of measurement scales, the full structural equation model was tested by using the maximum likelihood estimation with the sample covariance matrix as the input in AMOS 17.0. The results indicate that the research model provided a reasonable fit to the survey data with fit indices of Chi-square = 301.18, df = 199, TLI = 0.95, and CFI = 0.96. The results supported Hypotheses 1, 2, and 3 which predicted that environmental responsibility ($\lambda = 0.26, p < 0.05$), social responsibility ($\lambda = 0.45, p < 0.05$), and economic responsibility ($\lambda = 0.23, p < 0.05$) had positive impacts on organisational performance as shown in Figure 1. Moreover, the findings showed that corporate reputation has a significant positive influence on organisational performance, lending support for Hypothesis 7. Contrary to our theorization, environmental responsibility, social responsibility, and economic responsibility were not sufficiently significant to impact organisational performance at $p < 0.05$, and thus did not support Hypotheses 4, 5 and 6.

Fig 1. Model Results



*Note: Broken lines indicate no significant relationship. * $p < 0.05$; ** $p < 0.01$*

5. Discussions and Limitations

The earthquake in Japan and the flooding in Thailand reconfirmed the important role that shipping companies play in supporting people's lives by transporting goods and materials (NYK Group, 2012). Thus, the concept of CSR has become increasingly important in the shipping industry. This study aims to examine the effect among CSR, corporate reputation, and organisational performance using SEM analysis. The main findings derived from a survey conducted in the container shipping industry in Taiwan are summarized below.

The research findings reveal that CSR, comprising environmental responsibility, social responsibility and economic responsibility, plays a very critical role in enhancing firms' corporate reputation. This finding is consistent with previous studies (Lu et al., 2009). Success in terms of environmental responsibility depends on reducing emissions of greenhouse gases, using tin-free paint, adopting new CFC-free refrigerants, managing discharges of ballast water, and designing new energy-saving ships.

Likewise, success in relation to social responsibility depends on an emphasis on reserve staff development, skill training and on-the-job training, employing local personnel, taking part in community development and the inhabitants' welfare, not discriminating against employees with respect to employment or occupation, and not furthering business interests by cheating customers.

Success in regard to economic responsibility depends on a good long-term rate of return to shareholders, encouraging staff ownership of shares, and good management of corporate governance issues.

In our study, CSR included environmental responsibility, social responsibility, and economic responsibility, and was not found to directly impact organisational performance but rather to indirectly impact organisational performance through corporate reputation. In other words, environmental responsibility, social responsibility, and economic responsibility had an indirect effect on organisational performance.

In conclusion, top managers should always display a willingness to reinforce their environmental responsibility, social responsibility, and economic responsibility, thus contributing to the acquisition and maintenance of a long-term superior corporate reputation which can, in turn, lead to better organisational performance.

However, this research was limited to an evaluation of CSR, corporate reputation, and organisational

performance in liner shipping firms. In particular, different firms have distinct strategic goals in the short-term, such as customer satisfaction or profit, etc. Moreover, firms may enhance customer satisfaction by sacrificing short-term profit in order to acquire long-term profit. The performance items in this study could not reflect these varying situations. The research was limited to examining the CSR and corporate reputation within a particular national industry in the Taiwan area. However, the liner shipping industry is a global business and future studies could usefully embrace the same scope of investigation while including other countries in the research.

Acknowledgements

This research was partially sponsored by the National Science Council in Taiwan (R.O.C) under grant number NSC 99-2410-H-019-014.

References

- Ahire, S. L., Golhar, D. Y., & Waller, M. A. (1996), Development and validation of TQM implementation constructs, *Decision Sciences* 27(1): 23-56.
- Anderson, J. C. & Gerbing, D. W. (1988), Structural equation modelling in practice: a review and recommended two-step approach, *Psychological Bulletin* 103(3): 411-423.
- Antunovich, P., Laster, D. & Mitnick, S. (2000), Are high-quality firms also high-quality investments? *Current Issues in Economics and Finance* 6 (1): 1-6.
- Armstrong, S. J. & Overton, T. S. (1977), Estimating nonresponse bias in a mail survey, *Journal of Marketing Research* 14: 396-402.
- Barney, J. B. (2002), *Gaining and sustaining competitive advantage*. Reading: Addison Wesley.
- Baumgartner, H. & Homburg, C. (1996), Applications of structural equation modelling in marketing and consumer research: a review, *International Journal of Research in Marketing* 13(2): 139-161.
- Beurden, P. V. & Gossling, T. (2008), The worth of values – A literature review on the relation between corporate social and financial performance, *Journal of Business Ethics* 82(2): 69-82.
- Bowersox, D. J., Closs, D. J., & Stank, T. P. (1999), *21st Century Logistics: Making Supply Chain Integration a Reality*, Oak Book: Council of Logistics Management.
- Brammer, S. & Pavelin, S. (2004), Building a good reputation, *European Management Journal* 22 (6): 704-713.
- Bromley, D. B. (2001), Relationships between personal and corporate reputation. *European Journal of Marketing* 35(3/4): 316-334.
- Brown, T.J. & Dacin, P.A. (1997), The Company and the product: corporate associations and consumer product responses, *Journal of Marketing* 61: 68-84.
- Carmeli, A., & Cohen, A. (2001), Organizational reputation as a source of sustainable competitive advantage and above-normal performance: an empirical test among local authorities in Israel. *Public Administration & Management: An Interactive Journal* 6(4): 122-165
- Chow, G. Heaver, T. D. & Henriksson, L. E. (1994), Logistics performance: definition and measurement, *International Journal of Physical Distribution & Logistics Management* 24(1): 17-28.
- Chow, G., Heaver, T. D. & Henriksson, L. E. (1995), Strategy, structure and Performance: a framework for logistics research, *Logistics and Transportation Review* 31(4): 285-303.
- Chun, R. (2005), Corporate reputation: Meaning and Measurement, *International Journal of Management Reviews* 7(2): 91-109.
- Cretu, A. E. & Brodie, R. J. (2007), The influence of brand image and company reputation where manufacturers market to small firms: A customer value perspective, *Industrial Marketing Management* 36(2): 230-240.
- Dasgupta, P. (1988), This is a chapter. In D. Gambetta (Ed.), *Trust: Making and breaking cooperative relations* (pp. 47-72), New York: Blackwell.
- Davidson, W. N. & Worrell, D. L. (1990), A comparison and test of the use of accounting and stock market data in relating corporate social responsibility and financial performance, *Akron Business and Economic Review* 21, 7-19.
- Deephouse, D. L. (2000), Media reputation as a strategic resource: an integration of mass communication and resource-based theories. *Journal of Management* 26(6): 1091-1112.

- Donald R., L., Drumwright, M. E. & Braig, B. M. (2004), The effect of corporate social responsibility on customers' donation to corporate-supported non-profits, *Journal of Marketing* 68(4): 16-32.
- Dröge, C. & Germain, R. (1998), The Just-in-time inventory effect: does it hold under different contextual, environmental, and organizational conditions? *Journal of Business Logistics* 19 (2): 53-71.
- Ewing, M. T., Caruana, A. & Loy, E. R. (1999), Corporate reputation and perceived risk in professional engineering services, *Corporate Communications: An International Journal* 4(3): 121-128.
- Fombrun, C. J. & Shanley, M. (1990), What's in a name? Reputation-building and corporate strategy. *Academy of Management Journal* 33(2): 233-258.
- Fombrun, C. J. (2005), This is a chapter. In J. P. Doh & S. A. Stumpf (Eds.), *Handbook on Responsible Leadership and Governance in Global Business* (pp. 54-68). Cheltenham: Edward Elgar.
- Fombrun, C.J (1996), *Reputation: Realizing realizing value from the corporate image*, Cambridge. Boston: Harvard Business School Press.
- Freeman, R. E. (1984), *Strategic Management: A stakeholder Approach*. Massachusetts: Pitman Publishing Inc.
- Friedman, M. (1970), The social responsibility of business is to increase its profits, *New York Times Magazine*, 13 (September), 122-26.
- Gao, Y., (2009), Corporate social performance in china: Evidence from large companies. *Journal of Business Ethics* 89 (1): 23-35.
- Gardberg, N.A. & Fombrun, C.J. (2002), The global reputation quotient project: First steps towards a cross-Nationally nationally valid measure of corporate reputation, *Corporate Reputation Review* 4 (4): 303-307
- Garver, M. S. & Mentzer, J. T. (1999), Logistics research methods: employing structural equation modelling to test for construct validity, *Journal of Business Logistics* 20(1): 33-58.
- Griffin, J. J. & Mahon, J. F. (1997), The corporate social performance and corporate financial performance debate: twenty-five years of incomparable research, *Business & Society* 36(1): 5-31.
- Hair, J. F., Anderson, R. E., Tatham, R. L. & Black, W. C. (1998), *Multivariate Data Analysis* (5th ed.), New York: Prentice-Hall.
- Hall, R. (1992), The strategic analysis of intangible resource. *Strategic Management Journal* 13: 135-144.
- Hu, L. T. & Bentler, P. M. (1999), Cut off criteria for fit indexes in covariance structure analysis: conventional criteria versus new alternatives. *Structural Equation Modelling* 6(1): 1-31.
- Jamali, D. (2008), A stakeholder approach to corporate social responsibility: A fresh perspective into theory and practice, *Journal of Business Ethics* 82(1): 213-231.
- Jensen, M. C. (2001), Value maximization, stakeholder theory, and the corporate objective function. *Journal of Applied Corporate Finance* 14 (3): 8-21
- K Line Group (2011), *Social & Environment Report 2011: Toward Synergy for all and Sustainable Growth*. Retrieved from <http://www.kline.co.jp/> .
- Kay, J. (1993), The structure of strategy. *Business Strategy Review* 4(2): 17-37.
- Koufteros, X. A. (1999), Testing a model of pull production: a paradigm for manufacturing research using structural equation modelling, *Journal of Operations Management* 17(4): 467-488.
- Lai, C. H., Chiu, C. J., Yang, C. F. & Pai, D. C. (2010), The effects of corporate social responsibility on brand performance: The mediating effect of industrial brand equity and corporate reputation, *Journal of Business Ethics* 95(3): 457-469.
- Lai, K. H., Lun, Y. H.V., Wong, C. W. Y., & Cheng, T. C. E. (2011), Green shipping practices in the shipping industry: conceptualization, adoption and implications, *Resources, Conservation and Recycling* 55 (6): 559-566.
- Lamberti, L. & Lettieri, E. (2009), CSR practices and corporate strategy: Evidence from a longitudinal case study, *Journal of Business Ethics* 87(2): 153-168.
- Lindgreen, A., Swaen, V. & Johnston, W. J. (2009), Corporate social responsibility: an empirical investigation of U.S. organizations, *Journal of Business Ethics* 85: 303-323.
- Logsdon, J. M. & Wood, D. J. (2002), Reputation as an emerging construct in the business and society field: An introduction, *Business and Society* 41(4): 365-370.
- Lu, C. S., Lin, C. C., & Tu C. J. (2009), Corporate social responsibility and organisational performance in container shipping, *International Journal of Logistics Research and Applications* 12 (2): 119-132.
- Luo, X. & Bhattacharya, C. B. (2006), Corporate social responsibility, customer satisfaction, and market value, *Journal of Marketing* 70(4): 1-18.

- Mahon, J. and Wartick, S. (2003), Dealing with stakeholders: How reputation, credibility and framing influence the game, *Corporate Reputation Review* 6(1): 19–35.
- Mahon, J. (2002), Corporate reputation: A research agenda using strategy and stakeholder literature. *Business and Society* 41(4): 415–445.
- Margolis, J. & Walsh, J., J. (2003), Misery loves companies: Rethinking social initiatives by business. *Administrative Science Quarterly* 48(2): 268–305.
- Michaelis, M., Woisetschlager, D. M., Backhaus, C. & Ahlert, D. (2008), The effects of country of origin and corporate reputation on initial trust, *International Marketing Review* 25(4): 402–422.
- Mijatovic, I. S. & Stokic, D. (2009), The influence of internal and external codes on CSR practice: The case of companies operating in Serbia, *Journal of Business Ethics* 94(4): 533–552.
- Mishra, S. & Suar, D. (2010), Does corporate social responsibility influence firm performance of Indian companies? *Journal of Business Ethics* 95(4): 571–601.
- MOL group. (2011), Environmental and Social Report 2011: Bluer Oceans, Cleaner Environment and Sustainable Future, Retrieved from <http://www.mol.co.jp/>.
- NOL (2012), <http://www.nol.com.sg/>
- NYK Group (2012), CSR Report 2012: The corporate social responsibility policy and activities of the NYK Group, Retrieved from <http://www.nyk.com/english/>
- Okamoto, D. (2009), Social relationship of a firm and the CSP-CFP relationship in Japan: Using Artificial Neural Networks, *Journal of Business Ethics* 87: 117–132.
- Orlitzky, M., Schmidt, F. L. & Rynes, S. L. (2003), Corporate social and financial performance: a meta-analysis, *Organization Studies* 24(3): 403–441.
- Podolny, J. M. M. (1993), A status-based model of market competition, *American Journal of Sociology* 98(4): 829–872.
- Puncheva-Michelotti, P. & Michelotti, M. (2010), The role of the stakeholder perspective in measuring corporate reputation, *Marketing Intelligence & Planning* 28(3): 249–274.
- Quazi, A. M. & O'Brien, D. (2000), An empirical test of a cross-national model of corporate social responsibility, *Journal of Business Ethics* 29: 1–18.
- Roberts, P. W. & Dowling, G. R. (1997), The value of a firm's corporate reputation. *Corporate Reputation Review* 1(1): 72–76.
- Rogers, D. S., Daugherty, P. J. & Ellinger, A. E. (1996), The relationship between information technology and warehousing performance, *Logistics and Transportation Review* 32(4): 409–421.
- Rose, C. & Thomsen, S. (2004), The impact of corporate reputation on performance: Some Danish evidence. *European Management Journal* 22(2): 201–210.
- Sabate, J. M. & Puente, E. (2003), Empirical analysis of the relationship between reputation and financial performance: A survey of the literature. *Corporate Reputation Review* 6(2): 61–177.
- Sanchez, J. L. F. & Sotorrio, L. L. (2007), The creation of value through corporate reputation. *Journal of Business Ethics* 76(3): 335–346.
- Shang, K. C., Lu, C. S., and Li, S. (2010), A taxonomy of green supply chain management capability among electronics-related manufacturing firms in Taiwan, *Journal of Environmental Management* 91: 1218–1226.
- Smith, C. (2003), Corporate social responsibility: Whether or how? *California Management Review* 45(4): 52–76.
- Waddock, S. & Graves, S. (1997), The corporate social performance- financial performance link, *Strategic Management Journal* 18(4): 303–319.
- Walsh, G. & Beatty, S. E. (2007), Customer-based corporate reputation of a service firm: scale development and validation, *Journal of the Academy of Marketing Science* 35(1): 127–143.
- Wisner, J. D. (2003), A structural equation model of supply chain management strategies and firm performance, *Journal of Business Logistics* 24 (1): 1–26.
- Yang Ming Marine Transport Corporation (2012), Corporate social responsibility report, Retrieved from <http://www.yangming.tw/>.

Appendix-Indicators of CSR, Corporate Reputation, Organisational Performance

Indicator <i>(Cronbach's Alpha, Composite Reliability, Average Variance Extracted)</i>	λ	t-value	R²
<i>Environmental responsibility</i> ($\alpha = 0.93$; CR = 0.93; AVE = 0.70)			
Ship has been an effective solution to the improper discharge of ballast water or harmful substances, and its impact on marine ecology	0.88	-	0.78
Use tin-free paint on hulls to protect living organisms in the ocean	0.81	11.99	0.65
Reduce emissions of greenhouse gases or harmful gases (CO ₂ , SO _x , NO _x)	0.88	13.42	0.74
Use new CFC-free refrigerants (e.g., R134A or R404A) for reefer containers in order to preserve the earth's environment.	0.83	12.47	0.68
Our company undertakes initiatives to promote greater environmental responsibility	0.81	12.02	0.65
The building of new ships is geared towards energy saving and environmental protection concepts	0.79	11.53	0.62
<i>Social responsibility</i> ($\alpha = 0.91$; CR = 0.91; AVE = 0.63)			
Our company emphasises reserve staff development, skill training and on-the-job training	0.70	-	0.48
Our company, to the greatest extent practicable, employs local personnel and provides training with a view to improving skill levels	0.76	8.12	0.58
Our company provides transparent and effective procedures to address consumer complaints and contributes to the fair and timely resolution of consumer disputes without undue cost or burden	0.81	8.68	0.66
Our company does not further its business interests by cheating customers	0.87	9.21	0.75
Our company takes part in community development and inhabitants' welfare activities	0.80	8.58	0.65
Our company does not discriminate against employees with respect to employment or occupation on such grounds as race, colour, sex, religion, political opinion, national extraction or social region	0.80	8.54	0.64
<i>Economic responsibility</i> ($\alpha = 0.87$; CR = 0.88; AVE = 0.72)			
Good long-term rate of return to shareholders	0.90	-	0.80
Encourage staff ownership of shares	0.68	9.14	0.47
Corporate governance issues are well managed	0.94	15.04	0.88
<i>Corporate Reputation</i> ($\alpha = 0.87$; CR = 0.93; AVE = 0.77)			
My company provides good service quality	0.92	-	0.85
My company's employees have professional ability	0.90	17.00	0.81
In general, my company's reputation is good	0.93	18.72	0.87
My company is famous in Taiwan	0.77	11.91	0.60
<i>Organisational Performance</i> ($\alpha = 0.89$; CR = 0.90; AVE = 0.76)			
Profit before tax	0.69	-	0.45
Customer loyalty	0.95	9.42	0.90
Customer satisfaction	0.95	9.41	0.90
Chi-square = 301.18; Degrees of freedom = 199; Probability level = .000 Model Fit Indices: Comparative Fit Index (CFI)= 0.959; Tucker-Lewis Index (TLI)=0.952; Root Mean Square Error of Approximation (RMSEA)=0.063			

All t-values are significant at the $p < 0.01$ level

Bi-level Optimization Model for Last Mile Retail Cargo

Shao-Jian Qu^{1,2}, Mark Goh^{2,3} and Robert de Souza²

¹Academy of Fundamental & Interdisciplinary Sciences, Harbin Institute of Technology, China.

²The Logistics Institute-Asia Pacific, National University of Singapore, Singapore.

³NUS Business School, National University of Singapore, Singapore.

Abstract

This paper focuses on the consolidation of last mile retail cargo using an urban consolidation centre, placed strategically in close proximity to high demand traffic locations for a very dense supply chain configuration, which involves four receiving gateways, several hundred retail outlets of varying demand rates daily, and lumpy delivery schedules. We model this problem from the perspective of a Stackelberg game model involving the operator (leader) of the urban consolidation centre and the logistics service provider (follower) who manages the last mile delivery. The leader makes his operational decision by considering the derived demand from the follower and from the economic efficiency, environmental emissions, and constraints of highly dependent time windows with penalties for late deliveries. Simultaneously, the follower arranges his transportation plan by considering the cost of the delivery orders from the stores and the time window set by the operator at the upper level.

Keywords: Last mile retail cargo; Stackelberg game; Supply chain; Urban transport; Time window; Bi-level.

1. Introduction

Many capital cities in Asia are already very densely populated and face daily traffic gridlocks which can sometime paralyse the economic activity and the mobility of the residents and businesses active in those urban environs. There is an imperative as such for policy makers and service providers in the urban systems and cities to improve transport mobility, reduce unnecessary environmental emissions, and better organise or streamline asset utilization particularly those of the drivers and vehicles. In response, progressive cities such as Singapore, in their quest to reduce or manage the traffic congestion and improve the productivity of the workforce, have put forward the concept of the decentralization of urban development so that residents can 'live, work, and play' in new urban areas. In practice, however, this attempt to decentralize economic activity away from a central business district presents business with the constant operational challenges of traffic congestion near the key amenities such as shopping malls, hospitals, and office towers due to the limited capacity of the transport network, inadequate information and visibility of actual facility usage and space availability, and the lack of an integrated design of the facilities. In short, the problem of congestion continues to persist albeit on a small scale and with a wider geographical dispersion.

With the big cities in Asia growing in economic activity and strength, the retail malls are also growing in size and in the demand for efficient logistics delivery of the goods and services to consumers. In responding to the more sophisticated consumers, typically, the retail stores would forego operational efficiency as in better logistics utilization of the delivery vehicles and drivers in order to satisfy the customer and be paid accordingly. This, however, lowers worker productivity and asset utilization, and in addition damages the environment through unnecessary carbon emissions and traffic congestions.

To reduce the traffic congestion as well as to improve workforce productivity, in this paper, we propose a Stackelberg game model. This model involves two decision-makers as follows. The first player is the operator (leader) of an urban consolidation centre, and the other is the logistics service provider (follower) who manages the last mile delivery to the retail outlets. The leader makes his decision by considering the demand from the follower and the economic efficiency, environmental emissions, and the highly dependent delivery time windows with penalties for late delivery. At the same time, the follower arranges his transportation plan

by considering the cost of the delivery and transport orders from the retail stores and the time window set by the operator at the upper level. Adopting such a form of cargo aggregation, notably small parcels or packages, through an intermediary who has overview of the followers' cargo delivery patterns and available capacity, the operator and decision makers or urban planners should technically be able to mitigate the wastage in capital intensive assets such as vehicles, drivers and expensive storage space in the city.

Our motivation for this paper is as follows. The literature and popular press note that urban transportation plays a vital role in improving the mobility, sustainability, and liveability of cities in the future. The future of the urban transportation setup appeals for minimum congestion on the roads, minimum environmental affects in particular being carbon neutral, and a higher mobility of the logistics delivery providers. To achieve this goal, we consider this practical problem as one that involves multiple objectives with dynamic constraints such as consolidation, emissions management, and so on. Indeed, efficient urban logistics has become one of the most significant contributors to a sustainable city. The high density of urban functions in a metropolis, while having agglomerative effects, is also naturally prone and extremely sensitive to traffic congestion, especially when both cargo and people are channelled into the area simultaneously, causing negative externalities to all concerned. Therefore, we formulate an advanced mathematical model to help the operator of the urban logistics consolidation centre to arrange the last mile transportation for retail cargo into a shopping mall or a group of such malls thereof. In this paper, specifically, a bi-level optimization model is proposed, in which the operator of the urban logistics consolidation centre is at the upper level setting the delivery time window for the last mile transportation and the decision makers at the lower level then arrange their transportation by considering the set time window and the associated delivery costs to the malls.

Thus far, the extant literature has resulted in many papers published that put forward several methods to overcome the operational and tactical challenges for delivery routing and resource scheduling. For example, Quak and Koster (2009) recently presented a case study detailing how to deal with urban policy restrictions and the environment, and they highlight that the cost impact of using time windows is the largest factor for retailers who combine many deliveries into a single vehicle round-trip. A model for peak-hour urban freight movement is presented with limited data availability (Munuzuri et al., 2010). An application of this model to the city of Seville, in Spain, shows the efficiency of the model. Next, Friesz, Lee and Lin (2011) have also provided a game theoretic model to consider the effects of competition and disruption within a dynamic urban supply chain. Browne and Gomez (2011) similarly investigate and attempt to quantify the impact of delivery restrictions on cost and the environmental performance for a distribution operation. Larson et al. (2012) have found, using simulation techniques, that urban land use and transportation policies have dramatic effects on the density and spatial distribution of residences in large cities. Indeed, in the case of Singapore, the popular press has indicated that the amount of harmful sulphur emissions from all vehicles in Singapore is around 952 tons each year. The methods in the extant literature mainly focus on modelling urban logistics from the perspective of the operator of the urban logistics consolidation centre without considering the impact of the operators of the logistics delivery transportation. Clearly, there is a need to integrate both levels of operations, at the consolidation centre and the logistics service provider. While it is impossible to derive a sound transportation policy without considering the constraints of logistics transportation, it is also unrealistic to seek system optimization without including the constraints afforded at the consolidation centre. Different from the above methods, in this paper, we present a bi-level optimization model for urban transport and logistics management. Through this model, a better decision making perspective can be obtained through resource and information sharing in collaborative and cooperative efforts between the stakeholders in a highly built up urban setting. Doing so can benefit policy makers in urban planning and the business service providers in delivery, and finally to the urban consumers who desire for a cleaner and environmentally safer city.

The rest of this paper is organized as follows. Section 2 proposes the bi-level optimization model for last mile retail cargo consolidation. Section 3 presents the solution approach for the proposed bi-level model. Section 4 details the numerical test for the proposed model. The last section concludes the paper with some suggestions for future research.

2. Model Description

This section presents a bi-level optimization model for last mile retail cargo consolidation by involving economic efficiency, environmental emissions, and highly dependent time windows with penalties for late deliveries. In this model, the upper level decision-maker (in this case the consolidation centre operator) sets the decision variables for travel time and cost. The decision-makers at the lower level as in the logistics delivery service providers will then make their multi-objective decisions by considering the constraints of the travel time imposed by the decision-maker at the upper level and their own delivery capacities.

In the model, we assume that there are m retail stores and each store $i : i = 1, \dots, m$ orders products from a set of suppliers. In a typical mall, m can be as large as 250. Retailer i 's orders are sent by n_i trucks. The amount of indivisible cargo to be delivered to the mall by each truck $j : j = 1, \dots, n_i$ for retailer i is z_{ij} . The time taken by each delivery truck $j : j = 1, \dots, n_i$ for retailer i is t_{ij} . t_{ij} is related with the delivered amount z_{ij} and is defined as a function of z_{ij} . Typically, if z_{ij} is large, then t_{ij} is assumed to be larger as well, though not proportionately. $[x, \bar{x}]$ is the time window set by the leader. The unit cost under a given delivery time window is set as λ and the cost is set as $\bar{\lambda}$ if delivery is outside of the time window. Hence, the cost for the delivery can be expressed mathematically as

$$\max \left\{ c \sum_{i=1}^m \sum_{j=1}^{n_i} t_{ij} + h \left(\sum_{i=1}^m \sum_{j=1}^{n_i} t_{ij} - x \right), c \sum_{i=1}^m \sum_{j=1}^{n_i} t_{ij} \right\}. \quad (1)$$

The other costs besides this can be given by function $f(x)$. The unit management costs for the in-time window and out of the time window are λ and $\bar{\lambda}$ respectively.

The decision-maker at the upper level makes decisions by minimizing the time window for transportation, which can be described through the following optimization model, with μ set as an upper bound on the delivery slack and \underline{x} and \bar{x} are the lower and upper limits on the time windows set by the leader respectively,

$$\begin{aligned} \min_{(x, \mu), (\tau, t, z)} \quad & \lambda x + \bar{\lambda} \mu \\ \text{s.t.} \quad & \mu \geq \sum_{i=1}^m \sum_{j=1}^{n_i} t_{ij} - x \\ & \mu \geq 0, \underline{x} \leq x \leq \bar{x}, \end{aligned} \quad (2)$$

where $(\tau, t, z) \in S(x)$ and $S(x)$ is the solution set of the following optimization problem,

$$\begin{aligned} \min \quad & \tau + f(z) \\ \text{s.t.} \quad & \sum_{j=1}^{n_i} z_{ij} = d_i, \quad i = 1, \dots, m, \\ & \tau \geq c \sum_{i=1}^m \sum_{j=1}^{n_i} t_{ij}, \\ & \tau \geq c \sum_{i=1}^m \sum_{j=1}^{n_i} t_{ij} + h \left(\sum_{i=1}^m \sum_{j=1}^{n_i} t_{ij} - x \right), \\ & z_{ij} \geq 0, \quad t_{ij} \geq 0, \quad j = 1, \dots, n_i, \quad i = 1, \dots, m. \end{aligned} \quad (3)$$

The decision making process for this model can be described as follows. First, the operator of the urban logistics consolidation centre declares the time window by considering his cost and the demand of the decision makers at the lower level. Then, the decision makers at the lower level determine their delivery schedules by considering the time window set by the upper level operator and their own transport costs.

3. Solution Methods

The model presented in the above section is a bi-level optimization problem. Bi-level optimization has already attracted some attention in the literature. The interested reader is referred to Bard (1998) and Dempe (2002) for further theoretical properties on this class of problems. A general bi-level optimization problem can be described as follows:

$$\begin{aligned}
& \min_{x \in R^{n_1}, y \in R^{n_2}} \phi(x, y) \\
& \text{s.t. } g(x, y) \geq 0, \quad h(x, y) = 0 \\
& y \text{ solves } \begin{cases} \min_y F(x, y) \\ \text{s.t. } H(x, y) = 0 \\ G(x, y) \geq 0, \end{cases}
\end{aligned} \tag{4}$$

where ϕ and F are smooth scalar-valued functions, and g , h , H , and G are smooth vector functions of dimensions m_1 , m_2 , m_3 , and m_4 , respectively, with the dimensions being real numbers.

For solving the above bi-level problem, a commonly used approach is to replace the lower-level problem by its associated KKT (Karush-Kuhn-Tucker) system, resulting in the following mathematical programming problem with equilibrium constraints (MPEC),

$$\begin{aligned}
& \min_{x \in R^{n_1}, y \in R^{n_2}} \phi(x, y) \\
& \text{s.t. } g(x, y) \geq 0, \quad h(x, y) = 0 \\
& \quad \nabla_y F(x, y) - \nabla_y G(x, y)^T \lambda + \nabla_y H(x, y)^T \mu = 0, \\
& \quad H(x, y) = 0, \quad 0 \leq \lambda \perp G(x, y) \geq 0,
\end{aligned} \tag{5}$$

where \perp marks orthogonality: $\lambda^T G(x, y) = 0$. MPEC typically has a non-convex feasible set, which has been extensively studied and can be solved by the numerical solver Path (Ferris and Munson, 2000).

Another approach for solving the MPEC is the KKT approach which turns the MPEC into its KKT system and aims at obtaining its stationary point. It can be shown that under a linear independence constraint qualification, the solution obtained by the KKT approach is a local solution of the original MPEC (see e.g. Allende and Still, 2013 for further discussion on this technique).

4. Numerical Tests

We now present some numerical tests using the proposed solution methods with randomly generated data. The generated MPEC and KKT problems are solved by the numerical solver Path (Ferris and Munson, 2000). The tests are conducted on a DELL computer with Intel(R) Core(TM) i5-2400 processor (3.1 GHz) and 4GB of memory on a Windows 7 platform.

The parameters in the test are set as follows: $n_i = 2$, $d_i = 1$, $i = 1, \dots, m$; \underline{x} , c and λ are randomly generated from $[1, 2]$; \underline{p} , h and \bar{x} are randomly generated from $[10, 20]$. \bar{p} is a linear function of z_{ij} with a co-efficiency of 0.5. For simplicity, we assume $f(\bar{p}) = 0$. With different values of \bar{p} we solve the bi-level problem with the MPEC and KKT methods presented in the previous section respectively. The numerical results are given in Table 1. The column headings in Table 1, Iter and CPU, represent the computational iterations and the CPU time needed (in seconds) respectively. Table 1 shows that the method based on the MPEC outperforms the one based on the KKT approach.

The numerical results suggest that by solving a bi-level optimization model the operator of the urban logistics consolidation centre can optimally set the time windows for delivery by considering the lower-level decision makers' response effectively. Managerially, this effectively synchronizes the last mile retail delivery operations into the mall with the operations at the consolidation centre. This helps to then maximise the worker productivity, space utilization and truckload optimization. Further, we note that if the lower bound of the time window is large enough, then the decision maker at the lower level can arrange the deliver by only considering the demand constraints. Put simply, the logistics delivery service provider only needs to consider the demands set by the retail stores. Similarly, when the upper bound of the time window is sufficiently small, the costs to the decision makers on both levels will increase as the penalties are now higher.

Table 1: Numerical results

m	MPEC		KKT	
	Iteration	CPU time (s)	Iteration	CPU time (s)
5	3	0.002	4	0.012
10	5	0.141	5	0.754
20	8	0.208	10	0.866

5. Conclusion

In recent years, urban logistics management under the additional constraints of sustainability has attracted much attention from both research and industry since it has a significant impact on urban living. This paper proposes a bi-level optimization model for urban logistics practitioners and urban planning decision makers to consider including the operator of the urban logistics consolidation centre at the upper level and the logistics delivery operators at the lower level. Numerical examples of the two methods (MPEC and KKT) that attempt to find the local optimal points or stationary points of the randomly generated urban logistics bi-level models are given to highlight the efficiency of the proposed model. Moving forward, we trust that this paper is suitable for the academic community and for urban planners interested in tackling the operational challenges of mega-city management in a balanced way. We will test this on a precinct in a city to validate some of the theoretical properties.

Acknowledgements

This work was supported by the Science and Engineering Research Council (SERC) of the Agency for Science, Technology and Research (A*STAR) under Grant 1224200003. This work is also supported by the Natural Scientific Foundation of China (No. 71201040, No. 11201099) and by the Major Program of the National Natural Science Foundation of China (No. 71031003).

References

- Bard, J.F. (1998), Practical bilevel optimization: algorithms and applications, Nonconvex Optimization and Its Applications 30, Kluwer: Dordrecht.
- Browne, M. and Gomez, M. (2011), The impact on urban distribution operations of upstream supply chain constraints, International Journal of Physical Distribution and Logistics Management 41(9): 896-912.
- Dempe, S. (2002), Foundations of bilevel programming, Nonconvex Optimization and Its Applications 61, Kluwer: Dordrecht.
- Ferris, M.C. and Munson, T. (2000), Complementarity problems in GAMS and the PATH Solver. Journal of Economics and Dynamic Control 24(2): 165-188.
- Friesz, T.L., Lee, I. and Lin, C.C. (2011), Competition and disruption in a dynamic urban supply chain, Transportation Research Part B 45: 1212-1231.
- Larson, W., Liu, F. and Yezer, A. (2012), Energy footprint of the city: effects of urban land use and transportation policies, Journal of Urban Economics 72: 147-159.
- Munuzuri, J., Cortes, P., Onieva, L. and Guadix, J. (2010), Modelling peak-hour urban freight movements with limited data availability, Computers and Industrial Engineering 59: 34-44.
- Quak, H.J. and de Koster M.B.M. (2009), Delivering goods in urban areas: how to deal with urban policy restrictions and the environment, Transportation Science 43(2): 211-217.
- Allende, G.B. and Still, G. (2013), Solving bilevel programs with the KKT-approach, Mathematical Programming 138(1-2): 309-332.

Impact Factor Analysis of Container Terminal Shipline Operating Efficiency

Yi-Chih Yang^{a*} and Yao-Lang Hong^b

^aDepartment of Shipping and Transportation Management, National Kaohsiung Marine University, Kaohsiung City, Taiwan. Email: hgyang@mail.nkmu.edu.tw

^bManager, Kaohsiung Container Terminal of Wan Hai Lines, Taiwan.

*Corresponding Author

Abstract

This study seeks to determine factors influencing container terminals' shipline operating efficiency through a review of the literature and a case study, investigates key factors affecting container terminals' shipline operating efficiency using the Analytic Hierarchy Process, and finally provides some suggestions for shipping companies and terminal operating companies.

This paper's chief findings include the following: (1) The main assessment dimensions affecting the operating efficiency of shipline areas are container yard management, personnel qualifications, equipment and facilities, and ship status. (2) Workplace safety is of paramount importance, and automated equipment should be used to reduce manual loading and human error. (3) Shipping companies should be responsible for stowage planning, stress pre-job training and education for personnel, and use job performance appraisals to reward staff demonstrating high performance.

Keywords: Container terminal, operating efficiency, shipline, Analytic Hierarchy Process.

1. Introduction

Container terminals are a vital part of the transportation infrastructure. Container terminals have evolved from cargo handling points to distribution centers serving as transport hubs in container supply chains (Lu, 2011). Container terminals consist of three subsystems: the gate, container yard, and berths. Container handling equipment in these systems includes transfer cranes, gantry cranes, yard tractors, and trailers (Yun and Choi, 1999). The four main subsystems/operations in a container terminal system are ship to shore, transfer, storage, and delivery/receipt. Container terminal operations involve very complicated operating systems, which must be evaluated from the perspective of container terminal operating performance to assess a container terminal's competitiveness.

Yun and Choi (1999) proposed container terminal performance indicators and container equipment performance indicators, including gantry crane and transfer crane utilization and container yard occupancy rate. While larger container ships achieve better economies of scale at sea, they may incur diseconomies of scale in port. The greatest shipping costs occur at both ends of shipping routes, and cargo handling costs constitute a major portion of shipping expenses. Consequently, shipping companies and terminal operators must seek to increase operational efficiency, reduce operating costs, lessen berthing time, and improve the efficiency of container handling.

The goal of this study was to discover the chief factors affecting the operating efficiency of container terminals' shipline areas through the examination of academic and industry literature associated with container handling efficiency. After an overview of the shipline loading and unloading processes of a case company, the paper sought to determine impact factors affecting container terminal operating efficiency. The impact factors were then verified by a questionnaire survey aimed at container terminal operators and shipping companies. The paper used the AHP method to determine the ranking order of factors affecting container terminal shipline operating efficiency, and proposed some conclusions and recommendations.

concerning the improvement of container terminal operating efficiency for terminal operators and shipping companies.

The purpose of this study can be summarized as follows:

1. To investigate container terminal shipside operating efficiency through a review of the literature and expert interviews;
2. To rely on analysis of performance indicators to find factors influencing shipside operating efficiency and seek out methods of improvement;
3. To compare the stevedoring practices and procedures of the various container terminals at the port of Kaohsiung, and propose improvements.

This paper consists of five sections: This section is an introduction which states the motivations, goals, and framework of this study. The second section provides a review of the literature concerning determinants of container terminal performance and factors influencing the operating efficiency of container terminals' shipside areas. The third section consists of an overview of the AHP method, assessment criteria, questionnaire design, and data collection. The fourth section presents empirical analysis and results obtained using AHP. The final sections presents conclusions and implications for shipping companies and terminal operators, and suggests possible directions for future research.

2. Literature Review

2.1 Shipside operating efficiency

With regard to factors affecting container terminal operating efficiency, Song et al. (2003) listed wharf length, wharf size, number of gantry cranes, number of yard cranes, number of straddle carriers, and container throughput volume. Park and De (2004) listed berth capacity, cargo handling volume, cargo handling throughput, number of vessels entering and leaving port, revenue, and customer satisfaction. Barros and Athanassiou (2004) proposed labor and capital, vessel number, cargo, and container handling volume. Cullinane et al. (2004) listed wharf length, wharf size, number of gantry cranes, number of yard cranes, number of straddle carriers, and container handling throughput.

Barros (2006) considered number of employees, investment capital, operating cost, cargo handling volume, number of vessels entering and leaving port, and business income. Rio and Macaca (2006) listed number of gantry cranes, number of berths, number of employees, wharf size, number of container handling facility items, container handling volume, and average loading and unloading volume per ship per hour. Hsieh (2006) and Lu (2011) used various assessment variables, including number of gates, berths, area, length, storage area, reefer area, and number of containers, as a basis for analyzing the relative efficiency of the major container terminals in Asia. Choi and Ha (2006) and Lee (2012) proposed a port productivity index based on the operating performance of handling facilities and encompassing the factors of yard crane productivity, tractor productivity, combined productivity of different equipment, and distance of movement of tractors and equipment. Choi and Ha (2007) and Rodriguez-Molins et al. (2012) propose several assessment variables for simulated container terminal designs, including container handling volume, container terminal storage volume, tractor operating time, transport route and duration of vehicle motion, and distance from tractors to terminal.

Berry (1968) provides an optimization model to determine the dimensions of a container terminal layout that minimizes handling distance, handling time, space utilization, and cost. Yard cranes are the most commonly-used container handling facilities for moving containers on or off trucks in the container yards of land-scarce container terminals (Ng and Mak, 2005). Common container terminal productivity measures include crane utilization, crane productivity, berth utilization, service time, land utilization, storage productivity, gate throughput, truck turnaround time, and labor productivity (Beskovnik, 2008).

This article's research scope is limited to assessing the operating efficiency of cargo handling facilities in shipside areas, and does not include assessment of performance in such other areas as the container yard and gate areas. While there is a lack of literature concerning shipside operations, this study collected a number of shipside performance assessment factors as explained in the following.

Shipping companies have developed short-term fleet schedules in accordance with their past long-term planning practice and working experience; these schedules are constantly adjusted in light of changing cargo volume, container handling efficiency, container terminal storage capacity, and inland traffic access, etc. The majority of shipping companies seek to reduce ship berthing time and improve handling efficiency in the shipside area. Wang (2008) identified the chief factors influencing container terminal operating efficiency as container terminal dimensions, container handling equipment employment, full container volume, stowage planning, shipside gantry cranes and transport vehicles, tractor assignment, and traffic route planning. Hu (2008) suggested that the container terminal areas entailing the greatest risks include the shipside operating area, container stacking area, and empty container operation area. Even while pursuing of high loading and unloading efficiency, terminal operators must ensure the safety of personnel, ships, and cargo in shipside areas. Terng (2010) pointed out that container ship delays may result from poor shipside operating efficiency due to bad stowage planning.

2.2 Impact factors obtained from shipping companies

Total container handling volume and container moves per hour in the shipside area are important indicators of container terminal operating performance, and allow comparison with terminals at other harbors. The fact that many shipside operating efficiency indicators differ in the case of different shipping companies makes it difficult to perform comparative analysis. In order to employ unified methods of calculating shipside operating efficiency, this paper first collected literature concerning container terminal efficiency, and then collected shipside handling efficiency records from container shipping companies at the port of Kaohsiung.

Subsequent in-depth interviews with personnel at shipping companies and terminal operating companies allowed the assessment criteria listed in Table 2 to be compiled. Statistical analysis of the ABC company's operating efficiency in 2010 was performed to determine key impact factors affecting shipside operations, which were classified under four assessment dimensions, namely ship status, container terminal management, equipment and facilities, and personnel qualifications. There were 20 assessment criteria under these four dimensions.

3. Research Methodology

3.1 Analytic Hierarchy Process

With the actual operating processes of Kaohsiung Container Terminal, efficiency record collection of container handling at Kaohsiung container carriers, companies and terminal operators conducted in-depth expert interviews with shipping companies and terminal operators, and case studying company's operational efficiency record in 2010, the paper sorted out key impact factors of shipside operational efficiency and identify assessment criteria of operational efficiency in container terminal shipside by virtue of Analytic Hierarchy Process (AHP), finally we made some conclusions and proposed appropriate suggestions for shipping companies and terminal operators to improve operating inefficiency in the shipside area.

Table 1. Shipment failure factors at the ABC company

Dimension	Factor	Frequency	Percentage %	Rank	Minutes	Percentage %	Rank
Ship Status	Twist lock malfunction	227	4.33%	6	3075	3.15%	7
	Hold cell damage or deformation	58	1.11%	12	680	0.70%	14
	Ship repair work	62	1.19%	11	1155	1.18%	12
	Ship tilting or shifting	91	1.73%	8	1850	1.90%	9
	Stowage place discrepancies	18	0.34%	17	455	0.47%	15
Total		456	8.63%	3	7215	7.38%	3

C.T. Management	Containers have not entered gate	44	0.84%	14	1690	1.73%	8
	Risk label operation	33	0.61%	15	135	0.14%	17
	Container yard congestion	1127	21.48%	2	15370	15.76%	3
	Document revision or error	97	1.85%	7	4405	4.52%	6
	Container yard restowage	75	1.43%	9	1045	1.07%	13
	Total	1376	26.04%	2	22645	23.16%	2
Equipment & Facilities	Equipment breakdown	1022	19.48%	3	21535	22.08%	2
	Working space restrictions	517	9.86%	4	7100	7.28%	4
	Overheight container handling	1466	27.95%	1	29430	30.18%	1
	Container deformation	55	1.05%	13	1220	1.25%	11
	Lifting crane	284	5.42%	5	6240	6.40%	5
	Total	3344	63.29%	1	65525	67.00%	1
Personnel qualifications	Container misplaced or restowed	19	0.36%	16	285	0.29%	16
	Woodwork dismantling	6	0.11%	18	110	0.11%	19
	Revised stowage plan	73	1.39%	10	1815	1.86%	10
	Climate factors	5	0.10%	19	135	0.14%	18
	Shift change uncertainty	5	0.10%	20	65	0.07%	20
	Total	108	2.04%	4	2410	2.46%	4

Table 2. Summary of assessment criteria sources

Dimension	Assessment variable	Evergreen	Wan Hai	YML	Expert Opinion
Ship status	Hold cell guide damage or deformation	●	●	●	
	Twist lock malfunction	●	●	●	
	Hatch cover damage	●	●	●	
	Ship repair work	●	●	●	
	Ship tilting and shifting	●	●	●	
Container terminal management	Containers have not entered gate	●	●	●	
	Container yard congestion	●	●	●	
	Document revision or error	●	●	●	
	Computer and communication failure	●	●	●	
	Occupational accident	●	●	●	●
Equipment and facilities	Container yard restowage	●	●	●	
	Aging equipment			●	●
	Insufficient quantity of equipment			●	●
	Repair and maintenance	●	●		●
	Working space restrictions	●	●	●	
Personnel qualifications	Overheight container handling	●	●	●	
	Insufficient professional knowledge			●	●
	Shift change uncertainty			●	●
	Delay of work				●
	Overly long working hours				●

Table 3. Description of Assessment criteria

Category	Factor name	Description	Category	Factor name	Description
A Ship status	A1 Hold cell guide deformation or damage	Damage to the hold cell guides due to prolonged collisions or rust will affect the operating efficiency if not repaired in a timely manner.	C Equipment & facilities	C1 Aging equipment	Due to slow movement and handling speed, old equipment has difficulty coping with the increasing amounts of work, leading to container yard congestion and decline in operating efficiency.
	A2 Twist lock malfunction	Twist locks are used to connect different containers, and will prevent successful disassembly if in poor condition, which will delay loading and unloading operations.		C2 Insufficient quantity of equipment	Due to the tremendous container volume carried by large ships, insufficient container handling equipment will directly affect operating efficiency.
	A3 Hatch cover damage	The rubber seal components of hatch covers may no longer function due to prolonged water exposure, or require painting or maintenance due to corrosion, which may delay loading and unloading operations.		C3 Repair & maintenance	Insufficient equipment due to repair and maintenance work will affect container handling operating efficiency.
	A4 Ship repair work	If a bay requiring repair is near loading and unloading operations, this may necessitate slowing down or pausing loading or unloading work in order to avoid accidents.		C4 Working space restrictions	Because today's huge gantry cranes span several storage spaces, container handling equipment working in the same storage space may encounter restrictions on operating space, affecting operating efficiency.
	A5 Ship tilting or shifting	During the loading and unloading process, insufficient ballast water in a ship, a ship still on sea trials, or loose mooring ropes may lead to ship tilting or shifting.		C5 Overheight container handling	Out of gauge containers (such as containers holding large pieces of machinery) must use over-height spreaders or wire rope hangers, resulting in low operating efficiency.

B Container terminal management	B1 Containers have not entered gate	Transshipment containers have not been unloaded from another vessel or been transported from another customs area, preventing on-time shipment.	D Personnel qualifications	Planners' lack of professional knowledge or newcomers' unfamiliarity with operating procedures may lead to unnecessary restowage, delays in the working progress, and even on-the-job accidents.
	B2 Container yard congestion	Insufficient storage space or excessive container volume delivered by shippers will reduce digestion space and impact loading and unloading operations in the shipside area.	D1 Insufficient professional knowledge	Shift change uncertainty involving container yard equipment drivers and tractor drivers will result in ships waiting for loading or unloading, reducing operating efficiency.
	B3 Document revision or error	Incidents such as a request to change the stowage plan for the sake of navigational safety by a chief mate, a customs clearance staff error, a change in port of discharge by the cargo owner, or shut out of a ship in full and down status will disrupt operations and affect operating progress.	D2 Shift change uncertainty	As tallymen's salaries are calculated based on hours, tallymen tend to prolong their working time, affecting efficiency.
	B4 Computer & communications breakdown	Since vessels communicate by radio and computer, equipment failures will cause operating delays.	D3 Delay of work	
B5 Occupational accident	B6 Container yard restowage	Occupational accidents will seriously affect operating efficiency, and may even lead to dock downtime	D4 Overly long working hours	Since operating personnel are responsible for all loading and unloading processes, overwork may lead to low morale and poor efficiency

3.2 *Data collection and questionnaire design*

Since the purpose of this study was to identify the degree of importance of assessment criteria influencing the operating efficiency of shipside areas as perceived by shipping companies and terminal operating companies, the questionnaire survey focused on container shipping companies and port operating companies located near the port of Kaohsiung. The shipping companies were obtained from a list of registered companies issued by the International Shipowner Association, and the port operating companies were obtained from a list of companies issued by the Kaohsiung Harbor branches of the Taiwan International Ports Corporation. After recovering the questionnaires in May 2011, this study performed data processing employing the AHP method, and obtained the ranking order of impact factors based on their overall weight values.

3.3 *Assessment criteria*

The assessment factors obtained via the foregoing collection method were accepted and confirmed by five experts at shipping companies (including three business executives from the Wan Hai, Evergreen and Yang Ming lines, and two terminal operating company executives from Lien Hai and Kao Ming). As Table 3 shown that the assessment criteria were subsequently classified under the four dimensions of ship status, container terminal management, equipment and facilities, and personnel qualifications and the assessment criteria comprised 20 impact factors influencing shipside operational efficiency under the four dimensions based on previous literatures (Yun and Choi, 1999; Song et al, 2003; Park and De, 2004; Barros and Athanassiou, 2004; Cullinane et al. 2004; Beskovnik, 2008; Qang, 2008; Hu, 2008, Terng, 2010; Lee, 2012), Table 1 and Table 2.

This study identified the shipside operating efficiency assessment criteria using Analytic Hierarchy Process (AHP) and employing the actual operating processes at the Kaohsiung Container Terminal, container handling efficiency records of Kaohsiung container carriers and terminal operators, in-depth interviews with experts at shipping companies and terminal operators, and the case study company's operational efficiency records for 2010. We further provide conclusions and propose appropriate suggestions to help shipping companies and terminal operators improve operating efficiency in the shipside area.

4. **Empirical Analysis**

4.1 *Analysis of respondent attributes*

As shown in Table 5, a total of 36 questionnaires were distributed to 26 experts at shipping companies (American President line, OOCL, NYK, Hyun Dai, Han Jin, Evergreen, Yang Ming, Wan Hai) and 10 experts at terminal operating companies (Lian Hai, Gao Ming) by mail during April and May of 2011, and 26 questionnaires were returned, for a response rate of 72.22%. Among the respondents, in terms of type of work, 80.8% were affiliated with shipping companies and 19.2% with terminal operating companies. With regard to job title, 42.3% held the position of manager, and 15.4% held the position of director. In terms of working experience, 65.4% had 21 years or more, 15.4% had 16-20 years, and 19.2% had 15 years of experience or less. The respondents' professional affiliations, job titles, and working experience suggested that their opinions were competent and representative.

4.2 *AHP analysis*

This study used the AHP method to calculate the weights of the four assessment dimensions and 20 assessment criteria gathered from the respondents' opinions concerning the relative importance of the various assessment dimensions and assessment criteria. The weight of each dimension was then multiplied by the weights of the individual evaluation factors under that dimension to obtain the overall weight of that dimension. The example shown in Table 4 contains the overall weights of assessment criteria from the viewpoint of shipping companies and terminal operating companies. After determining the weight ranks of the assessment dimensions and variables from the viewpoint of all respondents, the former were found to have a ranking order of container terminal management (0.337), personnel qualifications (0.291), equipment and facilities (0.241) and ship Status (0.198). The ranking order of the top five assessment variables was occupational accident (0.113), insufficient professional knowledge (0.100), repair and maintenance (0.081),

insufficient quantity of equipment (0.079), and container yard congestion (0.065).

Table 4. Overall weights of assessment criteria influencing shipside operating efficiency

Dimension	Weight	Assessment Criteria	Weight	Overall weight
A Ship status	0.126 (4)	A1 Hold cell guide damaged and deformed	0.245 (2)	0.039 (12)
		A2 Twist lock malfunction	0.262 (1)	0.042 (10)
		A3 Hatch cover damage	0.159 (4)	0.025 (19)
		A4 Ship repair work	0.116 (5)	0.019 (20)
		A5 Ship tilting and shifting	0.217 (3)	0.035 (14)
B Container terminal management	0.337 (1)	B1 Containers have not entered gate	0.130 (4)	0.045 (9)
		B2 Container yard congestion	0.186 (2)	0.065 (5)
		B3 Document revision or error	0.095 (6)	0.033 (16)
		B4 Computer and communication failure	0.117 (5)	0.041 (11)
		B5 Occupational accident	0.324 (1)	0.113 (1)
		B6 Container yard restowage	0.148 (3)	0.052 (6)
C Equipment and facilities	0.241 (3)	C1 Aging equipment	0.123 (5)	0.033 (17)
		C2 Insufficient quantity of equipment	0.297 (2)	0.079 (4)
		C3 Repair and Maintenance	0.305 (1)	0.081 (3)
		C4 Working space restrictions	0.128 (4)	0.034 (15)
		C5 Overheight container handling	0.147 (3)	0.039 (13)
D Personnel qualifications	0.291 (2)	D1 Insufficient professional knowledge	0.443 (1)	0.100 (2)
		D2 Shift change uncertainty	0.205 (3)	0.046 (8)
		D3 Delay of work	0.209 (2)	0.047 (7)
		D4 Overly long working hours	0.142 (4)	0.032 (18)

4.3 Differential analysis

This section used differential analysis to compare the ranking order of shipside handling efficiency dimensions and assessment factors in the actual 2010 data for the case study company and the results of the questionnaire survey. The purpose of this analysis was to verify the accuracy of the survey and provide suggestions for improvement of shipside container handling.

It can be seen from Table 5 that differential analysis of shipside operating efficiency assessment dimensions yields very different results for the data from the questionnaire survey and case study company; the former had a ranking order of Container terminal management, Personnel qualifications, Equipment & facilities, and Ship Status. The latter had a ranking order of Equipment & facilities, Container terminal management, Ship status, and Personnel qualifications.

Furthermore, Table 6 shows results of differential analysis of shipside operating efficiency assessment factors. We found that there were significant differences between the data from the questionnaire survey and the results for the case study company; in the case of the questionnaire survey, the ranking order of the top five assessment factors was Occupational accidents, Insufficient professional knowledge, Repair and maintenance, Insufficient quantity of equipment, and container yard congestion; for the case study company, the ranking order of the top five assessment factors was Overheight container handling, Equipment breakdown, Container yard congestion, Working space restrictions, and Lifting boom restrictions.

Table 5. Differential analysis of ranking order of assessment dimensions

	Ship Status	Container terminal management	Equipment & facilities	Personnel qualifications
Questionnaire survey	4	1	3	2
Case study company	3	2	1	4

Table 6. Different analysis of ranking order of assessment factors

Rank No.	Question Survey	Weight Value	Case study company	Percent%
1	Occupational accident	0.113	Overheight container handling	30.18
2	Insufficient professional knowledge	0.100	Equipment breakdown	22.08
3	Repair and maintenance	0.081	Container yard congestion	15.76
4	Insufficient quantity of equipment	0.079	Working space restrictions	7.28
5	Container yard congestion	0.065	Lifting boom restrictions	6.40
6	Container yard restowage	0.052	Document revision or error	4.52
7	Delay of work	0.047	Locker breakdown or insufficient	3.15
8	Shift change uncertainty	0.046	Containers have not entered gate	1.73
9	Containers have not entered gate	0.045	Ship tilting or shifting	1.90
10	Locker breakdown or insufficient	0.042	Stowage plan revision	1.86
11	Computer & communication breakdown	0.041	Container deformation	1.25
12	Hold cell guide damage and deformation	0.039	Ship repair work	1.18
13	Overheight container handling	0.039	Container yard restowage	1.07
14	Ship tilting or shifting	0.035	Hatch cover damage	0.70
15	Working space restrictions	0.034	Unmatched storage space	0.47
16	Document revision or error	0.033	Containers misplaced or restowed	0.29
17	Aging equipment	0.033	Operation risk	0.14
18	Overtime working	0.032	Climate factors	0.14
19	Hatch cover damage	0.025	Woodwork dismantling	0.11
20	Ship repair work	0.019	Shift change uncertainty	0.07

This study found through empirical examination that the main assessment dimensions affecting the operating efficiency of shipside areas are, in order of perceived importance, container yard management, personnel qualifications, equipment and facilities, and ship status. This study's findings can be summarized as follows:

- a. Because loading and unloading containers in the shipside area demands the full cooperation of the entire container yard in order to achieve efficiency goals, container yard management plays the most crucial role in shipside operations. Container yard management comprises storage area planning, operating equipment job assignment, and arrangement of lines of operation. In limited container working areas, a suitable container stacking arrangement can reduce the need for unnecessary container restowing. The dispatching of mobile and evenly distributed equipment assignment should be based on the delineation of storage areas, and smooth lines of movement can reduce congestion and even lessen the chance of on-the-job accidents.
- b. Personnel constitute the foundation of loading and unloading work, and personnel such as equipment operators, stowage planners, gantry crane operators, truck drivers, tallymen, and dock workers are all associated with loading and unloading operating efficiency. Some container terminal operators employ performance assessment systems with the possibility of bonuses as a means of encouraging workers to boost operating performance. Some shipping companies have adopted responsibility systems in which workers are responsible for the entire loading and unloading process.
- c. The development of mega sized ship is having a dramatic impact on terminal operations. The use of old, slow equipment with high failure rates will reduce operating efficiency, and the size of huge gantry cranes spanning several bay spaces constrains the speed of other gantry cranes working in the same storage areas. Shipping companies and terminal operators should take advantage of the arrival of mega sized ships to replace old equipment, and the introduction of advanced equipment with improved span and operating approach can enhance operations and effectively solve the shortage of container yard storage space. New gantry crane spreader designs, which include twin-lift, tandem-lift, and triple-lift types, are expected to have a multiplier effect on container terminal shipside operating efficiency.

However, it should be noted that container terminals' workloads are expected to continue to increase.

- d. Ship status cannot be controlled by terminal operators. If a terminal operator can obtain relevant information concerning a ship before operations begin, it will be able to simultaneously implement both regular ship repair and cargo handling operations. Furthermore, if seafarers can cooperate with shipside operations, such as by adjusting ballast water to avoid tilting, and paying close attention to mooring lines in order to avoid shifting of the vessel, this will make a significant contribution to the safety and efficiency of shipside operations. Shipping companies and terminal operators should employ ship database specialists in order to gain an understanding of the current state of each ship.

5. Conclusions

The trend toward mega-size container ships has resulted in increasing container loading and unloading volume, and shipping companies have had to reduce operating costs and enhance their service quality in order to maintain fast, intensive, stable schedules. As a result, promoting container terminal shipside operating efficiency and thereby decreasing the turnaround time of ships in port has become a critical issue.

With regard to container ship loading and unloading operations, in addition to the requirements for improvement on handling efficiency, no industrial accidents and zero on-the-job accidents should be constant goals for shipping companies and container terminal operators. The survey respondents' emphasis on occupational safety was revealed in questionnaire. The top three shipside operation failure factors at the case company were overheight container handling (which accounted for 30.18% of lost time), equipment failure (22.08%), and working space congestion (15.76%); these three factors accounted for a combined total of 68.02% of time lost due to failures. We consequently make the following recommendations for the container terminal industry.

a. Occupational safety

Through labor safety education and training, shipping companies and terminal operations industry should establish the concept of zero on-the-job accidents, and implement standard operating procedures in compliance with safety norms to prevent industrial accidents.

b. Overheight container handling

The main cause of delay is in the handling of overheight containers the need to wait for the transport of the overheight container spreader, container, or rack to the shipside area. An insufficient number of spreaders can be remedied by adjusting operating sequence of gantry cranes and avoiding the simultaneous operation of multiple gantry cranes. When there are insufficient racks, empty racks should be arranged in advance. The purchase of an extra overheight spreader can relieve dispatching pressure, and an increase in the number of racks will lessen the overheight container replacement frequency and shorten the wait for empty racks.

c. Equipment failure

Container terminals can rely on assessment of the two stages of troubleshooting time, where the first stage constitutes the time from failure notification to the time maintenance and repair engineers arrive at the site, and the second stage lasts from the time maintenance and repair engineers reach the site to the time of recovery, to obtain a clearer understanding of the maintenance and repair department's mobility and troubleshooting capabilities. In addition, companies should compile equipment and facility breakdown and troubleshooting time databases in order to find ways of reducing failure time and improving the transmission of expertise.

d. Space congestion

Because the trend toward mega-sized ships has caused enormous growth in container terminal handling volume, companies must develop new operating software, increase stowage planning efficiency, and lessen human errors in the use of container yard storage areas. Furthermore, companies should adopt up-to-date handling equipment with larger spans, higher elevations, and faster movement if they wish to improve their spatial usage ratio and operational efficiency.

References

- Barros, C. P. (2003), The measurement of efficiency of Portuguese seaports with DEA, *International Journal of Transport Economics* 30: 335-354.
- Barros, C.P. (2006), A Benchmark Analysis of Italian Seaport Using Data Envelopment Analysis, *Maritime Economic & Logistics* 8: 347-365.
- Barros, C. P. and Athanassiou, M. (2004), Efficiency in European Seaport with DEA: Evidence from Greece and Portugal, *Maritime Economic & Logistics* 6: 122-140.
- Berry, J.R. (1968), Elements of warehouse layout, *International Journal of Production Research* 7(2): 105-121.
- Beskovnik, B. (2008), Measuring an increasing the productivity model on maritime container terminal, *Journal of Maritime Study* 22(2): 171-183.
- Choi, S. H. and Ha, T. Y. (2006), A study on the design of container terminal by knowledge-based simulation, *Korea maritime policy research* 20(1): 145-184.
- Choi, S. H. and Ha, T. Y. (2007), A study on productivity analysis by yard layout of container terminal, *Korea maritime policy research* 21(1): 151-183.
- Cullinane, K.P.B., Song, D.W., Ji, P., Wang, T.F. (2004), An application of DEA window analysis to container port production efficiency. *Review of Network Economics* 3(2): 186-208.
- Hu, Y. W. (2008), A study of risk management for container terminal loading and unloading operations -take Kaohsiung port as an Example, Master thesis, National Kaohsiung Marine University.
- Hsueh, S. Y. (2006), Performance Evaluation of the Top 20 International Container Ports by Data Envelopment Analysis, Master Thesis, National Taiwan Ocean University.
- Lee, D. H., Jin, J. G. and Chen, J. H. (2012), Terminal and yard allocation problem for a container transshipment hub with multiple terminals, *Transportation Research Part E* 48: 516-518.
- Lu, Y. H. V., Browne, M., Lai, K.H., Wong, C. W. Y and Cheng, T. C. E. (2011), Examining the influence of firm performance on business risk-taking and the mediation effect of scale of operations in the container terminal industry, *Research in Transportation Economics* 32: 64-70.
- Lu, Y. H. Venus (2011), Green management practices and firm performance: A case of container terminal operations. *Resources, Conservation and Recycling* 55: 559-566.
- Ng, W. C. and Mak, K. L. (2005), Yard crane scheduling in port container terminals, *Applied Mathematical Modeling* 29: 263-276.
- Park, R. and DE, P. (2004), An Alternative Approach to Efficiency Measurement of Seaport, *Maritime Economic & Logistics* 6: 53-60.
- Rio, L. R. and Macaca, A. C. G. (2006), Analyzing the Relative Efficiency of Container of Terminals of Macros Using DEA, *Maritime Economic & Logistics* 8(4): 331-346.
- Rodriguez-Molins, M., Salido, M. A. and Barber, F. (2012), Intelligent planning for allocation containers in maritime terminals, *Expert systems with applications* 39: 978-989.
- Saaty, T. L. (1980), *The Analytic Hierarchy Process*, McGraw-Hill: New York.
- Song, D. W., Cullinane, K. P. B. and Wang, T. (2003), An application of DEA window analysis to container port production efficiency. *Proceeding of International association of maritime economists annual conference*.
- Terng C. H. (2010), The analysis of influence for container ship's bads towage planning, Master thesis, National Kaohsiung Marine University.
- Wang, M. C. (2008), An analysis of Influential factors for container fleet demurrage in Kaohsiung port, Master thesis, National Kaohsiung Marine University.
- Yun, W. Y. and Choi, Y. S. (1999), A simulation model for container-terminal operation analysis using an object-oriented approach, *International Journal of Production Economics* 59: 221-230.

Green Port Performance Index for Sustainable Ports in Egypt: a Fuzzy AHP Approach

Sara Elzarka¹ and Sara Elgazzar¹

¹ College of International Transport & Logistics, Arab Academy for Science, Technology & Maritime Transport, Alexandria, Egypt.

Abstract

As today's competitiveness is highly rising in the global maritime sector paralleled with an increased concern on the sustainability of operations and the environment, the purpose of this research is to propose a performance measurement system to evaluate and improve ports' green performance. The proposed system would support ports' authorities in assessing their green performance, defining the areas that would need improvement and ultimately allocating the necessary fund to develop and improve its green performance.

The literature is reviewed and a survey is conducted to identify the key green port performance indicators. This survey targeted subject matter experts (SMEs) and academics in the maritime sector in Egypt, the United Kingdom and Singapore. A fuzzy analytic hierarchy process (FAHP) questionnaire is then carried to determine the relative importance weight (W) of the key selected indicators among the major container ports in Egypt namely; Alexandria, East Port Said and Sokhna. The indicators would then be quantified and a performance rate (R) would be assigned for each indicator based on a performance rating scale.

Finally, a green port performance index would be designed using a weighted averaging aggregation method in order to aggregate the indicators' weighted rates (WR) into a single index of overall performance from which a port can compare its performance with other competitive ports.

Keywords: Sustainability, Egypt, Green, Ports, Performance, Index.

1. Introduction

Container ports play a very significant role in the facilitation of global trade. Advances in shipping and sea transport allowed the movement of larger and faster container ships, which are well accommodated in similarly advanced container ports that ensure the fast turnaround of ships to continue its race against time and the fierce competition in the global market. Despite the fact that sea transport is considered one of the most environmentally friendly mode of transport, the extent and intensity of pollution and emissions resulting from the ports' activities, question the sustainability of this mode of transport. This issue became of prime importance as global supply chains (GSC) promoting sustainable operations are on the rise and are constantly seeking cleaner and greener networks. It is worth noting that the structure of GSC networks is no longer limited to achieve lower costs, but also to have a lower negative impact on the environment. Therefore, the choice of 'green' ports became inevitable since they are considered essential nodes within the sustainable/green GSC networks.

Egypt has a very distinct geographical location on the major trade routes between Europe and the Far East, bordered on the north by the Mediterranean Sea with three major ports namely Alexandria, Damietta and East Port Said, and on the east by the Red sea with Sokhna port. The Egyptian government policy since the year 2000 aimed at promoting exports and attracting a greater share of regional and international markets for container handling, transient and transshipment (Abbas and Mokhtar, 2003). Sustainability along efficiency and effectiveness of cargo and containers movement through the Egyptian ports would then be considered as a critical factor towards the attainment of the Egyptian government's goals.

This research would therefore aim at proposing a performance measurement system to evaluate and improve

the Egyptian ports' green performance. The proposed system would support the Egyptian ports' authorities in assessing their green performance, defining the areas that would need improvement and ultimately allocating the necessary fund to develop and improve its green performance.

2. Literature Review

Sustainable or green supply chain management (GSCM) is one of the topics that attracted many researchers over the past 13 years (Zhu and Sarkis, 2004; Carter and Rogers, 2008; Mudgal et al., 2010; Shang et al., 2010; Wooi and Zailani, 2010). Transportation has been recognized as one of the major logistics activities that negatively impact the environment and it is one of the prime elements in greening supply chains (Evangelista et al., 2010). Research in sustainable transportation, specifically sea transport, focused mainly on either the vessels' operations or the ports' operations. Research that addressed the sustainability in vessels' operations studied the different methods and models for optimizing low carbon shipping. Armstrong (2013) for instance, examined the impact of different performance optimization tools i.e. operational, technical and commercial to achieve low carbon shipping. Slow steaming or reducing the speed of vessels as an operational measure to reduce fuel consumption, Carbon Dioxide (CO₂) emissions and Green House Gases (GHG), was also studied by different researchers such as Kontovas and Psaraftis (2011), Lindstad et al. (2011), Cariou (2011), Tai and Lin (2013), and Woo and Moon (2013).

Before reviewing the literature in sustainable ports operations, it is important to define the concept of a sustainable port. According to Denktas-Sakar and Karatas-Cetin (2012), sustainable port operations refer to the 'business strategies and activities that meet the current and future needs of the port and its stakeholders while protecting and sustaining human and natural resources'. For this study, the researchers will use Dekker's (2008) more comprehensive definition of a sustainable port which is 'a port with an optimal balance between performance of business economics, utilizing the available capacity, limited use of space, minimal negative influence on the environment and a relation between port and hinterland' (Dekker, 2008 in Broesterhuizen et al. 2014). Research in sustainable ports operations, according to Lam and Van De Voorde (2012), was driven by the arising environmental legislations. But according to Esmer et al. (2010), the need for research in this area was driven by the new role of ports within the framework of sustainable supply chain, the changing expectations of shippers in terms of customer service and costs, and the challenging sustainable logistics initiatives. Research in sustainable ports operations, essentially focused on examining the environmental impact of ports' operations in European and Asian ports as well as developing indicators or frameworks to assess the ports' sustainability.

In terms of the environmental impact of ports operations, most studies have concluded that the major types of impact on the environment is on water and air quality. The severity of air pollution in ports' communities was shown in Corbett et al. (2007) who estimated that about 60,000 annual cardiopulmonary and lung cancer deaths along the European, East and South Asian coastlines are due to particulate matter (PM) emissions from vessels. Bailey and Solomon (2004) also stated that the health effects resulting from ports' pollution include asthma, other respiratory diseases, cardiovascular disease, and premature mortality.

Gupta et al. (2005) examined the environmental impacts generated from the ports activities in India, and found that the impact on water quality was in the form of the sewage generated by the port, bilge wastes, sludge waste, oil discharges and leakages of harmful materials both from the shore and ships, while the impact on air quality was from dust, site clearing, construction activities and emissions from vehicles, ships and on-shore equipment. Chin and Low (2010) also identified air and water pollutants in 13 major East Asian Ports that included Nitrogen Oxides (NO_x), CO₂, sulphur dioxide (SO₂), and oil spills that caused local damage to soil and wildlife around ports. In addition to the previously mentioned air pollutants, Bailey and Solomon (2004) who examined air pollution in American ports, added other major air pollutants related to ports activities that included volatile organic compounds (VOCs), ozone, carbon monoxide (CO), formaldehyde, heavy metals, dioxins, and pesticides used to fumigate produce. In their research Bailey and Solomon (2004) also detailed the impact of each pollutant to human health which demonstrates the severity of the issue.

In terms of research that focused on developing indicators or frameworks that assess the ports' sustainability, research is generally limited (Peris-Mora et al., 2005; Lirn et al., 2012; Park and Yeo, 2012).

Peris-Mora et al. (2005) proposed a system of sustainable environmental management indicators that can be used by any port authority, using the Port of Valencia in Spain as a case study. To create this system, the researchers examined all the activities performed within a port and analyzed the environmental impacts and risks of these activities. Based on the environmental impacts found, they consequently defined 17 indicators that can be used by port authorities to set environmental policies and action plans. It is worth noting however that the main limitation of this study was the application on only one port.

Using the procedures of ISO14001, Saengsupavanich et al. (2009) created port's environmental performance indicators by integrating port state control with ISO14001. The researchers used the Map Ta Phut industrial port in Thailand as a case study and developed fifteen indicators to assess five environmental management aspects which are success, awareness, determination, preparedness and environmental policy coverage. The unavailability of financial data and past incidents information due to confidentiality, led the researchers to reduce the indicators to be only twelve. This in return question the inclusion of similar indicators in other frameworks and whether such information would affect the validity of the set frameworks. Another limitation of this study is similar to that of Peris-Mora et al. (2005), which is presented on the application on only one port.

Park and Yeo (2012) evaluated the greenness of five major Korean ports namely In-cheon, Bu-san, Gwang-yang, Pyeong-taek and Ul-san, using the Green Criteria of a Seaport (GCS). They used factor analysis and the fuzzy approach to create the GCS which consists of a set of fifteen indicators grouped into five main categories: (1) Ease the environmental burden; (2) environment friendly method and technology development of construction; (3) utilization of resources and waste inside a port (4) efficient planning and management of port operation; and (5) port redevelopment with introduction of waterfront concept. Applying the fuzzy method to evaluate the greenness of a seaport proved to be a relevant method, because, according to Park and Yeo (2012) ‘..the green port analysis is characteristically complex and ambiguous.’

Lirn et al. (2012) measured the green performance of three major ports in Asia i.e. Shanghai, Hong Kong and Kaohsiung. The researchers classified seventeen indicators under five dimensions: (1) Air pollution management (2) Aesthetic and noise pollution management (3) Solid waste pollution management (4) Liquid pollution management (5) Marine biology preservation. Lirn et al. (2012) used the analytic hierarchy process (AHP) to get the weight and degree of performance of each of the seventeen indicators among the three ports to evaluate their greenness.

In conducting this literature review, the researchers did not find any study that attempted to examine or investigate the issue of sustainability or green performance of any Egyptian ports nevertheless, any ports located in the Middle East. This proved that there is a significant gap in literature and supported the aim of this study in proposing a performance measurement system to evaluate and improve the Egyptian ports' green performance.

3. Methodology

The research started by selecting the key green port performance indicators, then a FAHP approach was used to prioritize the key selected indicators among the container ports in Egypt. Finally, a green port performance index was proposed to assess the actual green port performance. Table 1 describes the steps followed in this research, the approaches and data collection methods used.

Table 1: Research Steps, Approaches and Data Collection Tools

Step Number	Description	Research Approach	Data Collection Tool
1	Selecting key green port performance indicators	Descriptive, based on the work of Lirn et al. (2012)	Online Survey
2	Prioritizing the selected key port performance indicators	Fuzzy Analytical Hierarchy Process	Focus Group
3	Designing the green port performance index	Applied	Focus Group

3.1. Selecting the key green port performance indicators

As discussed in the literature review, a critical review was conducted to identify the key green port performance indicators. The indicators provided by Lirn et al (2012) were reviewed by the researchers to ensure that they meet the general characteristics of Port Indicators as described in Peris-Mora et al. (2005). Following Lirn et al. (2012), 32 indicators were found to be the key green port performance indicators as illustrated in Table 2. An online survey was conducted to select the most important indicators among these 32 indicators. The survey targeted subject matter experts (SMEs) and academics in the maritime sector in Egypt, the United Kingdom and Singapore. The experts were asked to indicate the degree of importance of the 32 indicators based on a five-point Likert scale survey, where 1 indicates unimportant indicator, 2 for little of importance indicator, 3 for moderately important indicator, 4 for important indicator and 5 for very important indicator.

Table 2. The Key Green Port Performance Indicators and Their Average Degree of Importance

Indicator	Average Rating
1. Sediment of port entrance & coast erosion	1.82
2. Marine biology preservation & protection	2.77
3. Oil spill contingency plan	4.48
4. Solid waste dumping management	4.30
5. Liquid cargoes spilling contingency plan	4.32
6. Spill prevention during disconnection of cargo pipeline	3.95
7. Regulation on noise & vibration from unloading equipment	1.77
8. Avoid decreasing community real estate value due to the existence of cargo pipelines	1.61
9. Regulation on noise & vibration from discharging equipment	1.75
10. Ballast water pollutant prevention	4.02
11. Sewage processing and water resource control	3.86
12. Air pollution avoidance (toxic gas regulation)	4.14
13. Reducing vessel speed after landfall (reducing fuel consumption & pollution)	2.55
14. Cold ironing (on-dock power supply)	1.77
15. Use of electrically powered equipment (to replace diesel equipment)	4.14
16. Encouraging use of low-sulphur fuel	1.79
17. Using substitute energy and energy saving device	3.98
18. Aesthetic interference/visual impact/ improving city scenery	1.80
19. Avoiding the dust pollutant during loading & discharging	2.57
20. Biology impact avoidance/reducing infrastructure disturbance to marine biology density	2.45
21. Reducing road vehicles CO ₂ emission	4.18
22. Ecology preservation & environment protection training	2.81
23. Port maintenance & pollution avoidance	4.25
24. Flood impact & control	1.82
25. Improving willingness to reuse recyclable resources	3.82
26. Avoiding disturbance to community during infrastructure construction & demolition	1.75
27. Infrastructure impact avoidance	1.77
28. Encouraging public transport mode development	3.95
29. Dredging sediment disposal	1.89
30. Ship bilge discharge management	1.89
31. Hazardous cargo management	4.14
32. Using recyclable resource, and reduce energy consumption	4.34

52 responses were collected, 8 were incomplete and excluded. The completed surveys (44 replies) were analyzed using a descriptive statistics technique, based on which the average degree of importance of each indicator was calculated. The indicators with average degree of importance less than 3 were removed from the list. While indicators with average degree of importance equal to or greater than 3 were identified as the most

important key green port performance indicators to be incorporated in the second phase of the study (see table 2). The five-point Likert scale survey allowed the researchers to exclude the unimportant indicators from the list resulting in a more precise list of 15 performance indicators for the prioritization phase.

3.2. *Prioritizing the selected key green port performance indicators*

The multi-criteria decision-making process (MCDM) is one of the most critical challenges facing decision makers in different industries and businesses. Deciding towards multiple criteria to determine their relative importance weights with respect to overall objective is a relatively subjective process depending on the preferences of the evaluators which makes MCDM rather complex and challenging (Abdul Moneim, 2008).

The analytic hierarchy process (AHP) method is one of the most widely used approaches to deal with MCDM problems. In the AHP, the complex decision problem is broken down into sub-elements structured hierarchically at different levels. Then, the relative importance of the decision elements (weights of the criteria) at different levels are determined based on pairwise comparison judgments. Finally, the weights of elements are aggregated into global scores of alternatives by applying the principle of hierarchic composition in order to establish the final decision (Chan, 2003; Mikhailov, 2004).

However, decision makers could be uncertain about their level of preferences as it depends on whether they adopted a conservative or optimistic attitude when determining their preferences. Also the preferences could differ depending on the degree of environmental uncertainty which makes the classical AHP technique is not valid in most real life cases especially when the data and information available are incomplete. Fuzzy set theory can handle uncertainty in preferences and deal with this type of inexact data. The fuzzy extension of AHP enables evaluators to assign to each object a grade of membership ranging between zero and one which makes the fuzzy AHP (FAHP) approach more appropriate to deal with the uncertainty in real life as it is more accurate to give interval judgements than the fixed value judgements provided by the classical AHP technique (Kahraman et al, 2003; Chang et al., 2009). The application of FAHP in the area of green port performance has been recently studied by many researchers (Li and Yang, 2010; Park and Yeo, 2012).

In this research, a FAHP approach was used to determine the relative importance weights of the key selected green port performance indicators among container ports in Egypt namely; Alexandria, East Port Said and Sokhna. A focus group of six participants was assembled, comprising experts from the three major Egyptian container ports and academics from the Egyptian maritime sector, who have good knowledge and understanding of the green port performance. The focus group was conducted in a structured interview format. A fuzzy pair-wise questionnaire form was designed and the focus group was asked to assign a relative importance weight for each indicator. According to this questionnaire, the importance of two indicators related to each other can be rated using a scale with the values 1, 3, 5, 7 and 9, where 1 denotes equally important, 3 for slightly more important, 5 for strongly more important, 7 for demonstrably more important and 9 for absolutely more important.

A fuzzy prioritization method derived from Chang et al. (2009), was adopted to analyse the focus group's responses. The responses were aggregated based on fuzzy triangular numbers (L, M, U), where L denoted the minimum numerical value, U denoted the maximum numerical value and M was the geometric mean which represented the consensus of most experts. Consequently the aggregate pair-wise comparison matrix was established and the Eigenvector method was used for weights calculation. Table 3 illustrates the relative importance weights of the key selected indicators as generated from the FAHP questionnaire results.

Table 3. The Relative Importance Weights of the Selected Key Green Performance Indicators

Indicator	Weight (W) %
1. Air pollution avoidance (toxic gas regulation)	17.8
2. Oil spill contingency plan	15.3
3. Reducing road vehicles CO ₂ emission	14.9
4. Hazardous cargo management	13.2
5. Sewage processing and water resource control	6.89

6. Solid waste dumping management	4.56
7. Port maintenance & pollution avoidance	4.28
8. Spill prevention during disconnection of cargo pipeline	3.84
9. Use of electrically powered equipment (to replace diesel equipment)	3.75
10. Using recyclable resource, and reduce energy consumption	3.19
11. Using substitute energy and energy saving device	3.04
12. Liquid cargoes spilling contingency plan	2.85
13. Improving willingness to reuse recyclable resources	2.5
14. Encouraging public transport mode development	2.47
15. Ballast water pollutant prevention	1.42

To verify the consistency of the comparison matrix, the consistency ratio (CR) adapted from Saaty's AHP method (1980) were calculated. Saaty defined the consistency ratio (CR) as a ratio between the consistency of a given evaluation matrix (consistency index CI) and the consistency of a random matrix (RI), where the RI is the random index representing the average consistency index over numerous random entries of same order reciprocal matrices. According to Saaty's method, the CR of a comparison matrix should not exceed 0.1. For any comparison matrix, if the value of the Consistency Ratio is smaller or equal to 10%, the inconsistency is acceptable while if it is greater than 10%, the matrix should be considered inconsistent (Meixner, 2009).

Confirming Saaty's method, CR of focus group's responses was calculated to exclude inconsistent responses. Based on CR results, all responses were considered and analysed as all of them have been found consistent with CR below 0.1.

$$CR = CI/RI \quad (1)$$

4. Discussion and Findings

The focus group conducted with the experts and academics provided very important insights into the current environmental practices and performance of the Egyptian ports, in addition to the information needed to design the index. This section will thus discuss the top four green performance indicators and the design of the performance index.

4.1 Discussion on the top four green performance indicators

As it is shown in Table 3 above, the top 4 green performance indicators are: air pollution avoidance, oil spill contingency plan, reducing road vehicle CO₂ emissions, and hazardous cargo management. The following sections will provide more details on these 4 indicators and the plausible justification for their importance weights.

'Air pollution avoidance' had the highest importance weight based on the participants opinions. It was stated by one of the participants that the number one source of air pollution in ports is the equipment used, particularly in Alexandria port, which is the oldest compared to the East port Said and Sokhna port. Most of these equipment are quite old, they lack maintenance and refurbishment. Some container terminals started the initiative of replacing diesel operating equipment with electric equipment, primarily gantry cranes. However, the cost of this replacement is considerably high. Dust is another source of air pollution as mentioned by one of the participants. The level of dust emitted from some deteriorating roads within the ports' territories and from the loading and discharging of cargo such as wheat, coal and cement is quite significant. It was even claimed that a considerable number of ports' labor suffered from allergies and other respiratory illnesses due to dust pollution.

As for the 'oil spill contingency plan', all the participants agreed that the majority of Egyptian ports are not professionally prepared to face any oil spill incident which could aggravate the balance of the ports' ecosystem. One of the participants stated that oil spills occur every day in Egyptian ports particularly from

barges which do not have any maintenance. Therefore, the participants decided that the ‘oil spill contingency plan’ is an important performance indicator to be considered to measure the port’s green performance.

‘Reducing road vehicle CO₂ emissions’ is also one of the top selected green performance indicators. As stated by one of the participants “the problem of CO₂ emissions from road vehicles is a national problem”. It can be even claimed that CO₂ is the number one pollutant in Egypt. Some trucking companies still operate old trucks to transport containers to/from ports, and without the appropriate maintenance, the level of CO₂ emitted is quite high. However, it is worth noting that some container shipping lines which either use their trucks or outsource, require the operation of ‘environmentally’ sound trucks. One of the participants added that “container shipping lines do not have any problems in setting and implementing sustainable practices because they are working according to the international market standards and ethics”. He further added “the real problem in regulating CO₂ emissions is the lack of law enforcement by the ports’ authorities”.

‘Hazardous cargo management’ is the last of the top 4 performance indicators. All the participants agreed that the problem with hazardous cargo in Egyptian ports is in education and awareness. This indicator is important because the consequences of pollution caused by hazardous cargo is quite diversified and thus can harm the environment in numerous ways.

As a conclusion, the participants stated that the general problem of sustainability issues in Egypt is the culture. People tend to consider the environmental measures as unnecessary costs despite the fact that they are actually profitable on the long run. Therefore the presence of the proposed green port performance index would raise the awareness of stakeholders of the green issue and hopefully motivate them to take positive steps towards rectifying the current state of the Egyptian ports’ green performance.

4.2 *Proposing the green port performance index*

According to the recommendations of the focus group, the Egyptian environmental law no. 4 of the year 1994 would be the reference for designing the performance index. The green port performance index (GPPI) is formulated based on the relative importance weights assigned to the key selected green port performance indicators and with respect to the Egyptian environmental law no. 4 of 1994. First, a performance rating scale is established based on the permissible limits of pollutants’ concentration as stated in the Egyptian environmental law. Accordingly, green port performance indicators are benchmarked to this performance rating scale. A performance rate (0.2, 0.4, 0.6, 0.8 or 1) can be assigned for each green port indicator with respect to the maximum limits of pollution permitted by the law, where: 0.2 denotes very poor performance, 0.4 denotes poor performance, 0.6 denotes good performance, 0.8 denotes very good performance and 1 denotes excellent performance.

Then, the weighted rate (WR) of each indicator is calculated by multiplying the relative weight of each indicator by its performance rate.

$$WR = W * R \quad (2)$$

where W = the relative weight of the indicator and R = the assigned performance rate for the indicator

Finally, a weighted average aggregation method is used to aggregate the performance of all green port performance indicators in order to obtain the overall green port performance in terms of GPPI. This index reveals the overall green port performance according to an interval based performance scale: $[0.0 < R \leq 0.2]$, $[0.2 < R \leq 0.4]$, $[0.4 < R \leq 0.6]$, $[0.6 < R \leq 0.8]$, $[0.8 < R \leq 1]$; where R denotes value of the GPPI, $[0.0 < R \leq 0.2]$ denotes very poor green port performance, $[0.2 < R \leq 0.4]$ denotes poor performance, $[0.4 < R \leq 0.6]$ denotes good performance, $[0.6 < R \leq 0.8]$ denotes very good performance and $[0.8 < R \leq 1]$ denotes excellent performance.

5. Numerical Example

A numerical example is illustrated in table 4 to provide an overview of how the GPPI created can be implemented. First, following the research methodology illustrated in sections 3.1 and 3.2, the indicators affecting green port performance are identified and their relative importance weights are evaluated using the FAHP technique. Then, data are collected from the port's authority in order to determine the performance for each indicator. Each indicator has a set of standards upon which performance can be compared with respect to the details described in the Egyptian environment law. Accordingly, a performance rate (R) can be assigned to each indicator (0.2, 0.4, 0.6, 0.8 or 1) in comparison with the specifications and the range of pollution permitted by the law.

Finally, following equation no.2, the weighted rate (WR) of each indicator is calculated by multiplying the relative weight of each indicator by its performance rate; up on which the GPPI of the port is calculated. As shown in table 4, the aggregated index is 0.32 revealing that the port overall green performance is poor performance according to the interval based performance scale illustrated in section 4. To enhance the green port performance, the port authority should propose strategies to improve the indicators that need improvements, particularly the indicators that had low performance and a relatively high importance weight.

The GPPI provides a holistic view of analyzing SC performance, on the other hand, the proposed methodology enables the port to drill down to different indicators in order to trace the contribution of each indicator to the overall performance, and consequently recommend improvement strategies for those indicators that need improvement. The index can be adjusted to any port according to the records of its performance, with respect to the selected benchmark environmental law and based on the relative importance weights assigned to each green port performance indicator.

Table 4. Numerical example on GPPI

Indicator	Weight (W) %	Rate (R)	WR
1. Air pollution avoidance (toxic gas regulation)	17.8	0.2	0.036
2. Oil spill contingency plan	15.3	0.4	0.061
3. Reducing road vehicles CO ₂ emission	14.9	0.2	0.03
4. Hazardous cargo management	13.2	0.4	0.053
5. Sewage processing and water resource control	6.89	0.4	0.028
6. Solid waste dumping management	4.56	0.2	0.009
7. Port maintenance & pollution avoidance	4.28	0.4	0.017
8. Spill prevention during disconnection of cargo pipeline	3.84	0.6	0.023
9. Use of electrically powered equipment (to replace diesel equipment)	3.75	0.2	0.008
10. Using recyclable resource, and reduce energy consumption	3.19	0.2	0.006
11. Using substitute energy and energy saving device	3.04	0.2	0.006
12. Liquid cargoes spilling contingency plan	2.85	0.4	0.011
13. Improving willingness to reuse recyclable resources	2.5	0.4	0.01
14. Encouraging public transport mode development	2.47	0.6	0.015
15. Ballast water pollutant prevention	1.42	0.6	0.009
Green Port Performance Index (GPPI)			0.321

6. Conclusions and Recommendations for Further Studies

This research aimed at proposing a green port performance index to evaluate and improve the Egyptian ports' green performance as sustainability is growing to be a key factor in global competitiveness. With the majority of green port performance research originating in Asia, this research attempted to fill the gap in literature in addressing the green performance of Middle Eastern ports, namely Egyptian ports. The study revealed 15 key performance indicators upon which Egyptian ports can be evaluated. The different data collection tools used and the insights from experts and academics in the field of maritime transport enriched the study.

The proposed index can be generalized to evaluate the overall greenness of the port in any country with respect to country's environmental law and based on the relative importance weights assigned to the key

selected green port performance indicators. The index can be used as an assessment tool to reveal the overall greenness of the port and as a monitor tool to ensure maintaining the concentration of pollutants below maximum permissible limits. Moreover, this index can be used as a benchmark tool by which a port can compare its performance with other competitive ports.

References

- Abbas, Khaled and Mokhtar, Mahmoud (2003), Logistics chain analysis of Alexandria Container Handling Company in Egypt: A basis for assessing and improving services. Proceedings of the European Transport Conference (ETC) 2003 Held 8-10 October 2003, Strasbourg, France.
- Abdul Moneim, A.F. (2008), Fuzzy Genetic Prioritization in Multi-Criteria Decision Problems. *Jordan Journal of Mechanical and Industrial Engineering* 2 (4): 175-182.
- Armstrong, Victor (2013), Vessel optimisation for low carbon shipping, *Ocean Engineering*, 73: 195-207.
- Bailey, D. and Solomon, G. (2004) Pollution prevention at ports: clearing the air, *Environmental Impact Assessment Review* 24: 749-774.
- Broesterhuizen, E., Vellinga, T., Taneja, P. and Van Leeuwen, L. D. (2014), Sustainable Procurement for Port Infrastructure Projects, In *Infranomics* (11-26), Springer International Publishing.
- Cariou, P. (2011), Is slow steaming a sustainable means of reducing CO2 emissions from container shipping? *Transportation Research Part D*, 16 (3): 260–264.
- Carter, C. R., and Rogers, D. S. (2008), A framework of sustainable supply chain management: moving toward new theory, *International Journal of Physical Distribution & Logistics Management* 38 (5): 360-387.
- Chan, F.T.S. (2003), Performance Measurement in a Supply Chain. *International Journal of Advanced Manufacturing Technology* 21 (7): 534-548.
- Chang, C.W., Wu, C.R. and Lin, H.L (2009), Applying fuzzy hierarchy multiple attributes to construct an expert decision making process, *Expert Systems With Applications* 36 (4): 7363-7368.
- Chin, A.T.H. and Low, J.M.W (2010), Port performance in Asia: does production efficiency imply environmental efficiency, *Transportation Research Part D: Transport and Environment*, 15 (8): 483-488.
- Corbett, J.J., Winebrake, J.J., Green, E.H., Kasibhatla, P., Eyring and V., Lauer, A. (2007), Mortality from ship emissions: a global assessment, *Environmental Science & Technology* 41, 8512–8518.
- Denktas-Sakar, G. and Karatas-Cetin, C. (2012), Port sustainability and stakeholder management in supply chains: A framework on resource dependence theory, *The Asian Journal of Shipping and Logistics* 28 (3): 301-319.
- Esmer, Soner, Cetin, Ismail and Tuna, Okan (2010), A Simulation for Optimum Terminal Truck Number in a Turkish Port Based on Lean and Green Concept, *The Asian Journal of Shipping and Logistics* 26 (2): 277-296.
- Gupta, A.K., Gupta, S.K. and Patil, R.S. (2005), Environmental management plan for port and harbour projects, *Clean Technologies and Environmental Policy* 7 (2): 133-141.
- Kahraman, C., Cebeci, U. and Ulukan, Z. (2003), Multi-criteria supplier selection using Fuzzy AHP. *Logistics Information Management* 16 (6): 382-394.
- Kontovas, C.A., Psaraftis, H.N. (2011), Reduction of emissions along the maritime intermodal container chain. *Maritime Policy & Management* 38 (4): 455–473.
- Lam, J. S. L. and Van de Voorde, E. (2012), Green port strategy for sustainable growth and development, <http://www.stl.polyu.edu.hk/ifspa2012/Papers/M25.pdf>.
- Li, T. and Yang, B. (2010), Study on Green Logistics Operation System of Port Based on AHP-fuzzy Comprehensive Evaluation, Proceedings of 2nd International Conference on Industrial and Information Systems Held 10-11 July 2010, Dalian, China.
- Lindstad, H., Asbjørnslett, B.E. and Strømman, A.H. (2011), Reductions in greenhouse gas emissions and cost by shipping at lower speeds, *Energy Policy* 39 (6): 3456–3464.
- Lirn, T. C., Wu, Y. C. J., and Chen, Y. J. (2013), Green performance criteria for sustainable ports in Asia, *International Journal of Physical Distribution & Logistics Management* 43(5): 5-5.
- Meixner, O. (2009), Fuzzy AHP Group Decision Analysis and its Application for the Evaluation of Energy Sources, Proceedings of the The 10th International Symposium on the Analytic Hierarchy/Network Process, Multi-criteria Decision Making, University of Pittsburgh, Pittsburgh, Pennsylvania, USA.

- Mikhailov, L. (2004), A fuzzy approach to deriving priorities from interval pair-wise comparison judgments, *European Journal of Operational Research* 159 (3): 687-704.
- Mudgal, R.K., Shankar, R., Talib, P. and Raj, T. (2010), Modeling the barriers of green supply chain practices: an Indian perspective, *International Journal of Logistics Systems and Management* 7 (1): 81-107.
- Park, J.Y. and Yeo, G.T. (2012), An evaluation of greenness of major Korean ports: a fuzzy set approach, *The Asian Journal of Shipping and Logistics* 28 (1): 67-82.
- Peris-Mora, E., Orejas, J.M.D., Subirats, A., Ibañez, S. and Alvarez, P. (2005), Development of a system of indicators for sustainable port management, *Marine Pollution Bulletin*, 50 (12): 1649-1660.
- Saaty, T.L. (1980), *The Analytic Hierarchy Process*. McGraw-Hill, New York.
- Saengsupavanich, C., Coowanitwong, N., Gallardo, W.G. and Lertsuchatavanich, C. (2009), Environmental performance evaluation of an industrial port and estate: ISO14001, port state control-derived indicators, *Journal of Cleaner Production* 17 (2): 154-161.
- Shang, K. C. et al. (2010), A taxonomy of green supply chain management capability among electronics-related manufacturing firms in Taiwan. *Journal of Environmental Management*, 91 (5): 1218-1226.
- Tai, Hui-Huang and Lin, Dung-Ying (2013), Comparing the unit emissions of daily frequency and slow steaming strategies on trunk route deployment in international container shipping, *Transportation Research Part D*, 21: 26–31.
- Woo, Jong-Kyun and Moon, Daniel Seong-Hyeok (2013), The effects of slow steaming on the environmental performance in liner shipping, *Maritime Policy & Management* 41(2): 176-191.
- Wooi, G.C. and Zailani, S., (2010), Green Supply Chain Initiatives: investigation on the barriers in the context of SMEs in Malaysia. *International Business Management* 4 (1): 20-27.
- Zhu, Q. and Sarkis, J. (2004), Relationships between operational practices and performance among early adopters of green supply chain management practices in Chinese manufacturing enterprises, *Journal of Operations Management* 22 (3): 265-289.

A State-run Company: Bane or Boon?

A Case of the Korea Shipping Corporation, 1950 – 1968

Sung-june Kim

Department of Liberal Arts and Science, Mokpo National Maritime University, Korea.
Email: s-junekim@daum.net

Abstract

The free competition in the market seemed to be an irreversible trend with Liberalism becoming influential in 1990s. Considering that shipping industry is one of the most competitive and international businesses, it is quite an astonishing fact that there are so many state-run companies operating in shipping markets. That there are still many public shipping companies suggests that something remains for the national shipping companies to contribute to the development of the national economies whether developed or developing countries. After the Liberation in 1945, Korea has grown from the scratch to the position of the world top five ship-owning countries as of January 2013. There are a few promoters to this growth such as the government policy, Korea Shipping Corporation (KSC) and merchant marine officers that made the Korean shipping industry to develop so fast.

This paper tries to reveal the real background of the establishment and the privatization of KSC in 1950 and in 1968 respectively. The foundation of KSC could be a good case study to show whether the state-run shipping company can lead the national shipping industry and/ or contribute to the development of the national economy or not. The author is trying to answer the above two questions by analyzing proceedings and minutes at the National Assembly. In conclusion, KSC, as a national shipping company, sailed along a very unusual course. Firstly, it was established in 1950 not for fostering and developing the shipping industry but for reducing the financial burden to the newborn Korea government. Furthermore, the main cause of privatizing KSC in 1968 resulted from the political decision rather than the economic consideration which was the period of rapid growth of shipping industry in the world and Korea. In short, *KSC must be bane in the short run but boon in the long run for the government and the shipping industry of Korea*. From this analysis, we can say that a state-run company might not be either bane or boon. Hence, it implies that the public companies themselves are not always the sole driver for one country's economy growth.

Keywords: national company, State-run company, Korea Shipping Corporation (KSC), laissez faire, shipping policy, national economy.

1. Introduction

It is quite a remarkable historical fact for the Korean shipping industry to take off and spurt greatly from the nearly bottom to the world's top 5th position for last half century. According to the UNCTAD (2013), the number of vessels owned and operated by the Koreans stood at 1,576 vessels with 7,510,000 DWT GT (over 1,000 GT) as of 2013 January, placing Korea as the 5th shipping power in the world. People outside of shipping business may well suppose that it is a national or state-owned shipping company such as China of present day to boost the development of the Korean shipping industry. It was, however, in 1968 when the only one national shipping company in Korea was privatized. Since that year, private companies have played a decisive role for the progress of shipping industry. Surely, the private shipping companies has benefited from the various shipping policies such as cargo preference, cargo reserve, taxation, and shipbuilding subsidy from the government until 1996 when Korea became a member of OECD.

There was a national shipping company of KSC from 1950 to 1968. Most of the Koreans with concern to shipping industry have acknowledged the decisive role of KSC to the development of the shipping industry at the initial stage of the Korean economy. Up to the present, there are only a few researches done on the history of KSC and these were produced by Sohn, Yoon, Korea Maritime Research Institute and Hanjin Shipping. We

can get the full story of KSC with these books from its foundation in 1950 to the final privatization in 1968. Nonetheless, two questions might be unanswered: 1) why did the newborn Korea found the KSC as a national shipping company in 1950, only 1 year after the establishment of their own government? 2) Why was the KSC privatized in 1968, which was the period of the accelerated shipping growth in Korea?

In this paper, the author is trying to answer the above two puzzles by analyzing the proceedings and minutes of the National Assembly concerning KSC. The proceedings and minutes of the National Assembly can present the comments, remarks and statements conducted in the standing committee, an extraordinary session of the National Assembly and the National Assembly inspection of the administration at that time. We can catch the vivid atmosphere and mood of the period from these records. For this, sections 2 and 3 review the literatures and the theories on the role of the nation and the national shipping company to the development of the economy and shipping industry. Section 4 concentrates on the rise and fall of KSC by analyzing the proceedings and minutes in order to disclose the real background of the foundation and the privatization of KSC. Finally, the author presents the contribution of the KSC to the shipping industry in Korea. The author does not, of course, ignore the negative effects of KSC as a national shipping company to the Korean national economy.

2. Literature Review

There remain the original documents such as management reports, in-house bulletin 'Haegong' from 1952 to 1978, KSC Statistics ('Haegong Tonggye') and there are quite a few books on the history of KSC. It is *The 10 year History of the Korean Shipping, 1945-55* published by The Bureau of Shipping (1955) that firstly described the detailed information on KSC such as business performances, cargo shipments and tonnages from 1950 to 1954. In 1973, Yoon Ki-sun, ex-general director of The Bureau of Shipping, described the progress from the foundation to the privatization of KSC in *The 25 year History of the Korean Shipping*. He summarized the drawbacks and the contribution of KSC as a national company in the development of the Korean shipping industry.

It is Prof. Sohn Tae-hyun (1997) who analyzed the story of KSC academically for the first time. He regarded the years from 1950 to 1965 as the period of capital accumulation in the Korean shipping industry and analyzed the role of KSC in these periods. He presented the detailed information on the increase of tonnages, the expansion of sailing routes, profit and loss, the growth of capital stock, and the contribution and the shortcomings of KSC as a state-run corporation. Sohn appraised affirmatively that KSC made profits except 3 quarters, improved the composition of the fleets, expanded the trade routes from the coastal to the ocean-going, and increased the capital stocks. Nevertheless, he did not disregard that these affirmative successes included the biases as; 1) profit by the state-favors such as non-dividend for state-own stock of 80% and income tax exemption, 2) the expansion of route following the development of the Korean economy and 3) the improvement of the fleets after 1964 just before its privatization.

According to Alexander Gerschenkron (1904-78), industrialization is characterized by sudden accelerations or great spurts of economic growth. He contended that underdeveloped countries may succeed in the process of industrialization by borrowing the sources of technical assistance, skilled labor, and capital goods from advanced countries. Dr Lee Tae-woo (1996) applied Gerschenkron model to the Korean shipping industry from 1962 to 1981 which was the period of rapid growth. He confirmed that the Korean shipping industry experienced two great spurts in 1967 and 1975 respectively, and had the advantage of relative backwardness and substituted some missing prerequisites. Lee concluded that in the Korean shipping industry, various tax exemptions and direct & indirect subsidies, the government financed shipbuilding program ('Keihek Zoseon') and BBCPO (bare-boat charter with purchase option) functioned as the source of capital goods, anti-Japanese nationalism, Confucianism and anti-Communism as the ideologies, and a maritime educational institution as the source of skilled labors for fostering the Korean ocean-going fleets respectively.

Although Lee (1996) mentioned that government-owned corporation "KSC provided a field where ex-seagoing officers were able to accumulate know-how in the shipping business and management in the 1950s and 1960s (p.26)," he did not consider the role of KSC to the development of the Korean shipping industry. The starting year of his study is 1962 which was the first year of Five Year Economic Development Plans in

Korea. With implementation of these plans, the Korean economy experienced rapid growth. That's why he chose 1962 as the starting year of his analysis and did not include KSC as one of main factors for the growth of the Korean shipping industry.

Two books were published in 2001 and 2010 on the history of KSC respectively. *A History of KSC*, published by Korea Maritime Research Institute in 2001, described the pre-history before 1950, the stories of state-owned KSC from 1950 to 1968 and privatized KSC from 1968 to 1987 respectively. This book offers us 1) the full story of KSC from its pre-history from 1912 to 1949, 2) the real history of a national shipping company from 1950 to 1968 and 3) the development of privatized company from 1968 to 1988. *Hanjin Shipping History of 60 Years*, published by Hanjin Shipping in 2010, wrote the history of KSC from 1950 to 1968 as an early period of 60 year of Hanjin Shipping which merged the privatized KSC (renamed as K.S. Line) in November 1987. This book contains the detailed story of KSC as the previous company of Hanjin Shipping and the statistics on the fleets, the cargo transport performance, and profit and loss. With these 2 books, we can get sufficient information on the history and the statistics of KSC. Nevertheless, we cannot catch the real background of the foundation of KSC just after the establishment of the government and of the privatization during the years of rapid growth of the Korean shipping industry. In Section 3, the author is trying to summarize the theories on the role of the state-owned companies to the national economic growth.

3. Theories on the Role of the State-owned Companies

3.1. New Liberalism and Freedom of Marketplace

The period of 1980s was characterized as Thatcherism and Reaganomics and the culmination of the Neo-liberalism, which means that the Keynesian way on the role of the state obviously seems to end. The Neo-liberalism took its social status in 1974 and 1976 when Friedrich Hayek (1889-1992) and Milton Friedman (1912-2006) were offered the Nobel Prize in Economic Sciences respectively. Thatcher and Reagan had come to powers in UK and USA from 1979 to 1990 and from 1981 to 1989 respectively. They reformed the national policy based on the Neo-liberalism. They strongly implemented the cut of the social welfare budget, tax reduction, the privatization of national and public companies, deregulation, and the restriction of labor unions. During the reign of Thatcher nearly 50 British national companies including BT (British Telecom), BG (British Gas), BA (British Airways), British Airports Authority, BP (British Petroleum), British Steel, British Railways, Central Electricity Generating Board were privatized.

Harvey (2008) explained the characteristics of Neo-Liberalism as follows. The important characteristic of Neo-liberalism is the freedom of marketplace and trade. The Neo-liberal state's slogan is flexibility, which exaggerates the merits of the competition, but in fact it opens the marketplace to the centralized capital and monopolistic authority (pp.41 & 43). The formation of WTO in 1995 was the culmination of reforming the international organizations for the Neo-liberalism. Their main aim is to open most of the world for the capitals to flow without any hindrance (p.53). China and Russia, the two representative Socialistic states, became members of WTO in 2001 and 2012 respectively, which suggest free competition seems to be an irreversible trend.

Two latest outstanding trends in relation to policy-making are privatization and globalization. There is no more argument at all that national companies have many defects such as inefficiency of management, inelasticity to innovation, rigidity of personnel structure than private companies. Nevertheless, lots of underdeveloped and developing countries, sometimes developed countries, still maintain the national and the public companies in the various areas, especially fields of infrastructure such as railways, undergrounds, highways, airports and ports.

3.2. State-owned companies in the Most Competitive Business

Shipping industry is one of the most competitive and international businesses. Michael Roe (2002) mentioned that 'the shipping sectors have seen a considerable move towards private ownership' (p.504). With the adaptation of the open registry system in the second half of the 20th century, the role of flag fleets has declined dramatically. Sletmo (2002) wrote that "shipping policy in its traditional form based on perceived national

needs and aims at maximizing the size of national fleets through promotional and protectionist means, should be dead (p.477).” He added that “Today, most but by no means all state owned companies, apart from small liners serving domestic market, have disappeared or exist on paper only (p.479).” Nonetheless, there are still many state-owned shipping companies operating in the shipping market, especially in liner and energy transportation areas. Some nations still own and operate the national shipping companies such as COSCO of China, MISC of Malaysia, NOL of Singapore and etc even in the age of globalization and privatization. Even today the concept of “trade follows the flag” is often taken to be self-evident.

That there are still many national shipping liners suggests that something remains for the national shipping companies to contribute the development of the national economies regardless of developed and developing countries. Goss and Marlow (1993 & Sletmo, 2002) have listed the theories of defending maritime policies as 1) the infant industry argument, 2) developing new industries in developing countries, 3) shipping capacity needed to carry trade, 4) contribution to balance of payments, 5) defense purpose and 6) need to be present international organization in order to attend in international policy decisions. In short, they demonstrated the fallacy of each of these 6 propositions as follows; “They have been so many errors in so many governments’ policies towards shipping and they have generally combined such high expense with such limited effectiveness.” In contrast, Iheduru (1996) supports the role of national shipping companies to the national economy. He wrote that “The maritime sector has... become a major source of conflict between the North and the South. Shipping is, therefore, one clear example of the efforts of the weak to change the international system in their favor.”(p.21).

Shipping policy may include promotional as well as regulatory and protectionist activities. Prof. Min (1973) wrote that “the state-owned fleet is a kind of in-direct subsidy because operating loss should be covered by the national budget.”(p.573). The author, however, regards that the state-owned shipping company is a kind of direct and extreme promotional shipping policy. As mentioned above, though free competition and privatization are irreversible trend, there are still many state-owned fleets in the shipping market and its supporters inside and outside of shipping industry. KSC is one of the most suitable examples to prove whether the state-owned fleets can contribute to the development of the nation at its early stage or not.

4. Rise and Fall of Korea Shipping Corporation, 1950-1968

In this section, two main questions will be answered by analyzing the proceedings and minutes of the National Assembly of Korea. The author found one discussion on the foundation of KSC as a national shipping company in 1949 just before establishing KSC and eight inspections and audits by the National Assembly from 1950 to 1968. By analyzing these historical records, two questions can be solved. First, let’s try to reveal the real background of founding KSC as a national company.

4.1. Real Background of Establishing KSC, 1950

According to the Special Act for establishing KSC as a national company enforced on October 8, 1949, KSC was established ‘*in order to promote and develop shipping industry through carrying out the national policy concerning shipping business as a limited corporation*’ (clause 1). This clause shows that KSC was founded as a state-run shipping corporation, but the special act itself did not contain any clause on the main purpose of establishing KSC. The real intention of establishing KSC was found in the minutes of the 5th provisional meeting of the National Assembly dated on September 20, 1949. Mr. Yoo Jin-hong, a member of parliament, premised that “Shipping industry in the early stage of Korea government is very important and extremely pressing business” and made a comment on the special act for founding KSC as following; “KSC is to be established and become independent to lighten the burden of the Ministry of Transportation which has taken all the deficit of Chosun Wooseon (ex-KSC). Therefore, the purpose of KSC serving for the national development sacrificially should be coded in the special act.”

On this comment, Mr. Huh Jeong, a Minister of the Transportation, replied as follows; “Meanwhile, the Ministry of Transportation has managed shipping activity by itself. As the Ministry of Transportation conducts the administration and the management of shipping at the same time, it has revealed various inconveniences and flaws. In one year 1949 only, Chosun Wooseon made a deficit of 500 millions old Korean

Won in the national budget. If KSC of semi-government and semi-private were established to manage the shipping business separating from administration, it might be enough to make a deficit of around 100 – 200 millions old Korean Won per year.”

Prof. Sohn (1997) summarized the background of founding KSC in the similar context as below; 1) Maritime related people realized that the shipping is an important industry from a national perspective. 2) The Ministry of Transportation reflected the bad result under direct state management and evaluated the good performance of Chosun Wooseon positively under private participation. 3) Government assessed and realized the specialized knowledge and experience on shipping. He concluded that “the Ethos of shipping related people after the Liberation continued to establish KSC as a national company at the early stage of a newborn Korea government.”(p.348). According to Prof. Sohn, only a small numbers of the Korean merchant marine officers had the Ethos that shipping must not be the object for private interests, and shared the sense of duty for dedicating to the development of shipping industry just after the Liberation. This materialized taking over Chosun Wooseon after the Japanese retreated to their islands in August 1945, and managing it with very successfully (p.329).

On the other hand, Mr. Kim Yong-ju (1984), general-manager (1945-1949) of Chosun Wooseon appointed by the US military government and Korea government and the first chief executive (1950-1952) of KSC, recalled the story with some difference in his *Memoirs* as follows; “The ministry of transportation operated about 20 US-transferred military ships directly for 1 year and made a great deficit of 3 billion old Korean Won which was a very hot issue in the National Assembly. So Mr. Huh Jeong suggested me to take over and deploy these ships as the tonnages of Chosun Wooseon. But considering the great capital demand and the indispensable national support to manage shipping company, I counter-proposed him to establish a semi-government shipping company.” (pp. 103-4).

His statement was consistent with Mr. Huh Jeong’s statement afterward on the establishment of KSC. Mr. Huh (1980 & 2002) mentioned that “as state-run shipping activity resulted in a considerable loss as expected owing to the lack of flexibility and adaptability, the Ministry of Transportation could not choose but reform the direct control of shipping and establish the KSC as a semi-government company.” In reality, Chosun Wooseon which was managed by shipping specialists had a gain except the period from October 1945 to March 1947 as seen Table 1.

Table 1. Management Performance of Chosun Wooseon, 1945-1949

Term	Period	Profit and Loss (old Won)
1	Oct. 1, 1945 – Mar. 31, 1947	- 1,622,000
2	Apr. 1, 1947 – Sept. 30, 1947	+ 8,868,000
3	Oct. 1, 1947 – Mar. 31, 1948	+ 1,049,000
4	Apr. 1, 1948 – Sept. 30, 1948	+ 1,200,000
5	Oct. 1, 1948 – Mar. 31, 1949	+ 2,093,000
6	Apr. 1, 1949 – Sept. 30, 1949	+ 10,000,000*
*estimated figure		

Source: *Brief History of KSC and Summary (Haegong Yeonhyuck-gwa Gaeyo)*, p.23; cited from Sohn Tae-hyun (1997), p.336.

Mr. Seok Doo-ok, executive director of Chosun Wooseon (1946-47 & 1950-1952) and the sixth chief executive (1960-1961) of KSC, referred in more detail on the foundation of KSC in his old days. According to his *Memoire* (1990), Mr. Kim Yong-ju, his senior at that time, had in mind to purchase Chosun Wooseon and to take over the state-owned fleets from the government and manage those as the fleets under one company, and to return those to the government if it did not work out well. On this idea, he gave his opinion that it must be inevitable for those to make a loss with the composition of old non-economical fleets. Mr. Seok suggested him to manage one big shipping company as a state-policy corporation with the fleets of Chosun Wooseon and the government-owned ships in 1948. He, called one month later by Mr. Huh Jeong (a Minister of Transportation), explained the above idea on the disposal of Chosun Wooseon and state-owned tonnages. Mr.

Huh said this was a very good idea and asked him to keep this secret. Special Act for founding KSC was enacted in September 1949.

From the above, it reveals that *the real purpose of founding KSC as a state-owned shipping corporation was to reduce the financial burden for the newborn Korea government rather than to foster and promote the shipping industry*. From the very early stage of its establishment, people concerned including a Minister of Transportation and chief executive of KSC knew this fact, but most of people in the Korean shipping society afterwards consider that KSC was to develop the shipping industry through the national protective and promotional policy. This reversal phenomenon resulted mainly from the wide spread of its Prospectus published in two books, *The 10 year History of the Korean Shipping, 1945-55 (Haewoon 10 Nyeon Yaksa)* in 1955 and *The 25 year History of the Korean Shipping* in 1973. The Prospectus in November 1949 stated the purpose of establishing KSC as a national shipping company as below; “In consideration of geographical and economic conditions, it is our keen task to rehabilitate the devastated national economy and to promote the people’s spirit of overseas expansion through aiming to be the shipping nation and developing the shipping as a national policy. Unfortunately it is extremely deplorable to see the current situation of our shipping... It is to establish KSC as a special corporation of semi-government which will combine the protective and promotional policy of shipping by the government and the private entrepreneurial spirit according to the special act.”

4.2. Privatization of KSC, 1968

As revealed in the above section, the Korean government did not have any intention to keep KSC as a state-owned corporation for a long time. The Special Act prescribed that “*KSC exists for 50 months since its foundation*” (clause 5), which means KSC had to be privatized at the time of March 1955. But the Korean government changed the corporate entity of KSC from the state-run corporation under the Special Act to the national shipping corporation under the Commercial Act in October 1957. KSC kept its entity of a national shipping corporation until 1968.

During the period of a national shipping corporation, KSC had confronted with the matters of purchasing vessels and compensating the deficits. Table 2 shows us KSC started its business with quite old and small tonnages. With the take-over of the state-owned vessels, tonnages of KSC increased 34 vessels, 91,099 GT (132,682 DWT) just before repealing the Special Act in September 1957. These included 6 government-transferred ships, 35,073 GT (49,756 DWT) and 8 vessels, 30,599 GT (47,626 DWT) purchased with ICA (International Cooperation Administration, ex-AID) Credit (Sonh, pp.352-3 & Hanjin Shipping, Data, pp.154-5). In the course of increasing the tonnages, it brought about the scandal such as S/S Cheonji in 1954. The Korean government purchased 6 second-hand vessels with Korean Foreign Exchange in 1954, but tanker S/S Cheonji caused a national scandal. S/S Cheonji of 5,242 GT (5,695 DWT), contracted by Mr. Ju Young-han who was a Korean Consul in San Francisco, showed to be in very bad condition. She could navigated only 5 knots and stopped engine twice during the voyage from Italy to Korea, and finally entered into Japan for repair.

Table 2. Tonnages of KSC as of January 1950

	Chosun Wooseon’s vessels	State-owned vessels*	Total
Number	6	21	27
GT(average GT)	10,646 (1,774.3)	26,850 (1,278.6)	37,496
DWT(average DWT)	17,785 (2,964.2)	30,305 (1,443.1)	48,090
Average Ships’ Age	10.5**	8.2***	
* It included 12 US-transferred ships.			
** ‘Pyeongang’ was built in 1917 and the others between 1941 and 1945.			
*** ‘Seoul’ was built in 1910 and the others between 1941 and 1945.			

Source: *Haewoon 10 Nyeon Yaksa*, pp.344-345; *1949-2009 Hanjin Shipping · History of 60 Years*, Data, pp. 152-155.

For inspecting this scandal, the National Assembly carried out the Parliamentary Audit on KSC first time in October 1954. According to the final Report of the National Assembly Inspection (P&M, 1954), S/S Cheonji consumed 1,069,000 US dollars for hull, 27, 466 US dollars (1,648,000 Old Korean Won) for the cost for taking over the vessel from Italy and 220,000 US dollars for repair in Hitachi Shipyard. Mr. Jeong Eun-soo (P&M, 1954), chief executive of KSC, stated that KSC could purchase the similar second-hand vessel with half price without paying the cost for taking over and repairing her. This scandal was only one incident that KSC was frequently affected to purchase the tonnages, deploy the fleets, employ staffs including seamen and shore-staffs by government side.

As the results of this situation, KSC made a deficit since its foundation. In reality, KSC could not break even or make a profit without the national financial support. It caused a parliamentary dispute when the Korean government submitted the Act for transforming the legal entity of KSC from the state-run national corporation under the Special Act to the national shipping corporation under the Commercial Act in September 1957. People who were members of ruling party and government officials emphasized the inevitability of KSC to change to the commercial company to avoid the financial burden to the government. For instance, Mr. Cheon Byung-gyu (P&M, Sept. 12, 1957), a vice-Minister of Finance, explained the point of repealing the Special Act that “it was true that KSC made a loss meanwhile” and expected that “KSC would get better after transforming it to the commercial shipping company,” and Mr. Lee Young-eon (P&M, Sept. 12, 1957), chairperson of the Committee of Commerce and Industry of the National Assembly, stated that “it caused a great burden for the government’s budget in consideration of the scale of our national finance and banking.” Mr. Jeong Joon (P&M, Sept. 13, 1957), a MP of ruling party, supported a proposal remarking that “KSC as a national company did not get a positive effect and spent a great deal of the state property, and caused considerable damage to our people.” These remarks proved that KSC made a loss rather than a profit. Mr. Kim Jae-gon (P&M, Sept. 13, 1957), a MP of opposition party and ex-master mariner, placed emphasis on “that KSC could continue to exist till now was thanks to not the good management by the board of directors but bleeding protection by the government.” After a sharp debate on the pros and cons, the KSC was transformed to a limited company under the commercial act on October 5, 1957. But the government still held 80% of the total stocks.

KSC Limited had to keep on acquiring the tonnages after transforming its corporate entity as a national commercial shipping company in 1957. As a result, KSC retained 23 vessels, 114,168 GT (168,282 DWT) as of March 1968 just before its privatization. But the quality of the tonnages was not improved but rather deteriorated. Average ships’ age of 23 vessels was 17 years and 15 vessels were over 20 years. So KSC had to request the financial support for purchasing second-hand vessels to government nearly every year. The Korean government approved KSC’s requests for satisfying the demand of transporting raw material and products by keeping pace with the economic development plan started in 1962. KSC reported the detailed plan of purchasing 8 vessels, 55,000 GT to the government and the National Assembly through the intermediation of Arne Larsson & Co., Sweden in 1964 with US 14.30 million dollars, which was composed of US 5 million dollars of government investment and US 9.30 million dollars of foreign loan. According to the original plan, Arne Larsson as an S&P broker offered the loan of US 9.30 million dollars, but this project failed mainly due to Arne Larsson’s incompetence whose capital was only US 970 dollars. Arne Larsson’s scandal was the main issue on 1964 May and 1965 May respectively.(P&M, 1964 & 1965) KSC finally had to purchase 4 vessels, 30,529 GT (45,383 DWT) only with the government investment in 1965.

Even KSC prepared to be privatized as a result of transforming its corporate entity as a national commercial shipping company since 1957, there was no one to be able to take over the majority of the stocks due to its massive scale. Accordingly, KSC revised its article to be supervised by government on January 8, 1961 until it could be privatized. Meanwhile, KSC reported the management condition and requested the financial and political support for purchasing vessels and helping its management from the National Assembly and the administration. These led to enact ‘*the Act for promoting the shipping industry*’ on February 28, 1968 under the military government. The military government decided to privatize 9 state-run companies including KSC, Korea Shipbuilding Corporation, and Korea Express Corporation in 1967. After the social controversy, the Ministry of Finance announced the privatization plans of the state-run companies on April 15, 1968. It is quite interesting that there was no issue in the National Assembly for privatizing KSC and other state-run companies. This might the result of the oppressive atmosphere under the military government.

Only one remark was found in Proceedings and Minutes, in which Mr. Lee Ki-taek (P&M, 1968), a MP of opposition party, mentioned critically as follows; “The most serious problem for KSC to confront is to have too much debt of 4,000 million Won comparing its gross capital of 1,500 million Won only. I suppose KSC is in a critical condition with very low rate of profit...What is your plans to develop shipping industry after privatization?” On this Lee Maeng-ki (P&M, 1968), last chief executive of KSC, replied as follows; “KSC can reimburse loans mainly due to its long term low interest rate because it can make a profit by managing company...There might be merits and demerits if KSC is to be remained a national company or to be privatized. There might be enough time to be privatized hereafter and could overcome various difficulties meanwhile.”

On the contrary of KSC CEO’s expectation, Korea government sold out its share of 200,000 stocks to the public and decreased its share to 47.5% from 61.8% on July 11, 1968. A few months later, all the stocks owned by government were sold out to Kim Lyun-joon, the founder of Hanyang University, on November 11, 1968 and KSC was finally privatized. KSC’s privatization made us perplexed once again in consideration of following two facts; 1) KSC made a real profit from 1965 to 1967 (see Hanjin Shipping: History of 60 Years, Data, pp.176-179 & 184-185). 2) That was the booming period of the shipping industry in the world and Korea (see Figure 1). The main reason why the military government privatized KSC in the face of the very promising condition was mainly due to political decision.

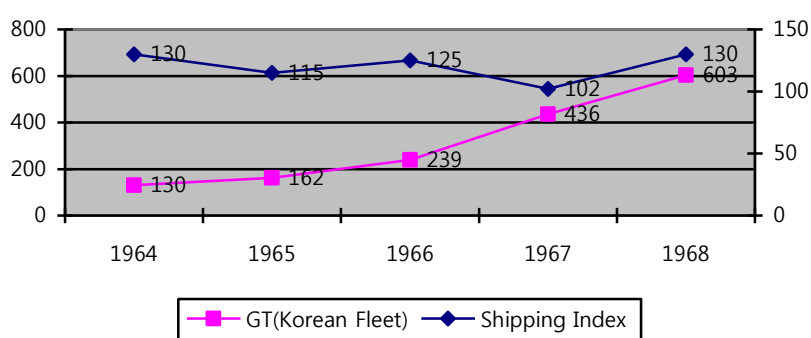


Fig 1: Shipping Index and Korean Fleet (1960 = 100, GT: 1,000)

Source: 1. Gross Tonnage of Korean Fleet: Sohn (1997), p.376.

2. Shipping Index: London Shipping Exchange; Proceedings & Minutes No.4 (April 22), 1968.

The government announced to construct the 2nd oil refinery complex in Yeosu, Jeonnam Province for which several competitors including GS, Hanhwa, Samyang and Hanyang had been lobbying to the political power group of the ruling party. GS finally was selected as the contractor in November 1966. The political power group who had been bribed could not choose but offer the preferential options for the losing strong competitors to purchase one of the state-run companies with favorable conditions. That’s why baritone singer and composer Kim Lyun-joon was able to take over the management right of KSC. Of course, this privatization caused the controversy on preferential support. According to the reminiscence of Choi Jae-soo (KMRI, 2001), general director of the division of Ocean-going Shipping of the Korea Maritime and Port Administration at that time, “the Ministry of Finance made a written-promise to offer the underwriter (Kim Lyun-joon) the long-term loan without interest.” In short, *the privatization of KSC resulted from the political background rather than the rationalization of management or the development of KSC itself or national shipping industry.*

5. Concluding Remarks

As analyzed in the previous sections, KSC, as a national shipping company of Korea, sailed along a very unusual course. It was established in 1950 not for fostering and developing the shipping industry but for reducing the financial burden to the newborn Korea government. And the main cause of privatizing KSC resulted from the political decision rather than the economic consideration in 1968 which was the rapid growth of shipping industry in the world and Korea. In short, the foundation and the privatization of KSC

were caused by the political backgrounds. It was, therefore, inevitable for KSC to make a deficit except on its last few years.

Nonetheless, KSC was not only a burden to the Korean government and its people. It is true that KSC had largely contributed the development of the nation and the shipping industry of Korea respectively. From the perspective of physical contribution, KSC shared an overwhelming majority of the ocean-going vessels in Korea (see Table 3) and managed to transport the political cargoes such as military supplies during the Korean War, fertilizers and coals, and to carry out the seaborne trade. Furthermore, KSC gained considerable US dollars as seen in Proceedings and Minutes (Feb. 4, 1964 & April 22, 1968). For instances, KSC gained 2 million US dollars of freight income comparing 18 million US dollars of the national export in 1955 and 2.5 million US dollars of freight income comparing 32.8 million US dollars of the national export in 1960 respectively (KMPA, 1980, p.390).

Table 3. KSC's Share of the Korean Ocean-going Vessels

	KSC			Non-KSC		
	Number	GT	Share	Number	GT	Share
1950	32	52,782	100 %	0	0	0
1954	20	53,618	79 %	8	14,333	21 %
1960	18	66,299	59 %	28	45,527	41 %
1965	23	101,429	53 %	55	90,122	47 %
1968	19	108,886	23 %	68	360,581*	73 %

*Mainly due to Pan Ocean Shipping being founded in 1966 with tonnages of 120,441 GT.

Source: 1. 1950 & 1954: KIM, Jae-seung (2004), pp.179, 192-194.

2. 1960 & 1965: Proceeding & Minutes No.5 (Feb. 4, 1966), p.5.

3. 1968: 30 Year History of the Korea Shipowners' Association, 1990, p.182.

It is more important that KSC functioned as a kind of shipping training center. Korea Lines Corporation was established in 1968 by late Lee Maeng-ki (ex-CEO of KSC), KSS Line in 1969 by Park Jong-gyu (ex-manager of KSC), and Dooyang Shipping in 1970 by Cho Sang-wuk (ex-manager of KSC) respectively. As well as CEOs, KSC trained the large number of seamen and offered them the floating workplaces. Above all, KSC motivated the government to enact the Act of fostering shipping industry in February 1967. The Act would be the turning-point of the government to regard the shipping industry not as a burden but as the means of creating national wealth. The Act included the flag discrimination, shipbuilding subsidy, cargo reserve, waiver system, subvention for international services, and tax exemption. Although KSC did not get any favor from this Act, the act functioned as a main promoter of the rapid development of the Korean shipping industry.

Similarly, KSC revealed lots of defects as a state-run company. First of all, 5 of the 7 CEOs appointed by the government were amateurs, which led to a costly management of KSC. Prof. Sohn (1997, pp.357-360) gave examples of the inefficiency of KSC's management; 1) the excessive number of shore staffs (37% as of 1963 comparing average 20% of 4 Japanese companies), 2) the excessive expense of general administrative cost (about 2 times higher than those of Japan through 1960-62), 3) enforcement of low-wage policy for seamen (average 6,770 Won per month for 221 seamen comparing of 7,070 Won per month for 861 shore staffs) and 4) prevalence of smuggling by seamen.

As cited in section 3, Goss and Marlow listed the theories of defending maritime policies as 6 categories. Which of these theories can apply in the case of KSC? I suppose none of those can apply for the case of KSC if the above analysis is right. That's why the main reason for founding and privatizing KSC cannot be included as one of 1) the infant industry argument, 2) developing new industries in developing countries, 3) shipping capacity needed to carry trade, 4) contribution to balance of payments, 5) defense purpose and 6) need to be present international organization in order to attend in international policy decisions. Of course, KSC made use of the above 6 theories to get more governmental support after its establishment. Michael Roe (2002) categorized the five factors that drive shipping policy as; 1) historical perspective, 2) nodes, network and system, 3) modal choice, inter-modalism and flexibility, 4) deregulation and privatization and 5) holism.

And he also presented the spatial levels of shipping policy as international, supra-national, national, regional and local origins and the contexts of shipping policy as political, economic, legal, managerial, technical, organizational, social, spatial, legal contexts. Considering the case of KSC, we can apply *historical perspective, national level and political, social and economic contexts* to the development of KSC and the shipping industry of Korea.

According to Michael Roe (2002), “shipping policy never emerges in any sector without interest groups.”(p.496). If we apply this statement to the case of KSC, KSC could be established with the governmental interest not taking the financial burden, and could be privatized with the political interest for evading the responsibility and/or the criticism from the political bribe donors. As Lee Tae-woo (1996) mentioned appropriately, “even politically motivated decisions such as the foundation of national shipping company must not violate economic principle. That is, investment operations will always be at the expense of the State budget.”(p.4). In other words, KSC could have existed at the expense of the national budget. But we cannot deny the fact that there might not be the Korean shipping industry without KSC.

In conclusion, *KSC must be bane in the short run but boon in the long run for the government and the shipping industry of Korea*. From this analysis, we can say that a state-run company might not be either bane or boon. Hence, it implies that the public companies themselves are not always the sole driver for one country's economy growth. Park & Yee (1991, p.522) wrote that “shipping policy is not to foster the shipping companies and to develop the national shipping industry but to contribute to promote the welfare of the people and the national economy.” But the case of KSC proves the above statement might be wrong or sometimes contrary to the real world. In short, *a state-run company might be both bane and boon, or either bane or boon*.

References

- Goss, R.O. and Marlow, Peter (1993), Internationalism, Protectionism and Interventionism in Shipping in K.M. Gwilliam, ed. by Current Issues in Maritime Economics, Kluwer Academic Publishers, 44-56.
- Keynes, J. M. (1926), The End of Laissez-faire, <http://www.panarchy.org/keynes/laissezfaire.1926.html>. 2013. 4.20.
- Kim, Jae-seung (2004), Circumstances of Ocean-going Vessels in Korea during 1945-1952, The Journal of Shipping and Logistics, 40: 155–196.
- Kim, Yong-ju (1984), Memoirs (Poongwoon Sidae 80 Nyun), Sinkiwonsa.
- KMI (2012), Shipping Statistics Handbook (www.kmi.re.kr).
- Korea Maritime and Port Administration (KMPA) (1980), Hankuk Haewoon Hangman Sa (The History of Korean Shipping and Ports).
- Korea Maritime Research Institute (KMRI) (2001), A History of Korea Shipping Corporation, 1950-1988(Yireobeorin Hangeok).
- Korea Shipowners' Association (1990), 30 Year History of the Korea Shipowners' Association.
- Hanjin Shipping, History of 60 Years, 2010.
- Hayek, Friedrich (1999), The Road to the Serfdom (1943), Korean translation by Yung Chung Kim (1999), Jayu Kiup Center.
- Harvey, David Harvey (2008), Spaces of Neo-liberalization (Franz Steiner Verlag, 2002), Korean translation by Dong-kun Yim et al (2008), Munhwa Gwahak Sa.
- Huh Jeong's Reminiscence (1980 & 2002), Hankook Haewoon Hangman Sa (The Korean History of Shipping and Ports), Monthly Maritime Korea, January 2002.
- Iheduru, O.C. (1996), The political economy of international shipping in developing countries, University of Delaware Press.
- Lee, Tae-woo (1996), Shipping Developments in Far East Asia: The Korean Experience, Avebury.
- Mmin, Seong-kyu (1973), Haewoon Kyengjehak (Shipping Economics), KMU Press.
- Sletmo, Gunnar K.(2002), The Rise and Fall of National Shipping Policies, Costa Th. Grammenos, ed. by, The Handbook of Maritime Economics and Business, LLP, 471-494.
- Smith, Adam (1976), An Inquiry into the Nature and Cause of the Wealth of Nations, Book IV, Clarendon Press.
- Sohn, Tae-hyun, (1997), Hankuk Haewoon Sa (The History of the Korean Shipping revised ed.), Hyosung Publishing Co.

Park, Hyun-gyu and Yee, Won-cheol (1991), *Haewooron (On Shipping)*, Korea Maritime Research Institute.

Proceedings and Minutes (P&M) of the 5th Extra Session of the National Assembly dated on September 20, 1949.

Proceedings and Minutes (P&M) No. 56 (Oct. 15), The 19th Extra Session of the National Assembly, 1954.

Proceedings and Minutes (P&M) No. 6 (September 12), The 26th Ordinary Session of the National Assembly, 1957.

Proceedings and Minutes (P&M) No.7 (September 13), The 26th Ordinary Session of the National Assembly, 1957.

Proceedings and Minutes (P&M) No.11 (May 28), The 42th Session of the Committee of the Transportation and Communications, The National Assembly, 1964.

Proceedings and Minutes (P&M) No. 2 (May 25) & No.3 (May 28), The 50th Session of the Committee of the Transportation and Communications, The National Assembly, 1965.

Proceedings and Minutes (P&M) No.4 (April 22), The 65th Session of the Committee of the Transportation and Communications, The National Assembly, 1968.

Roe, Michael (2002), *Shipping Policy in the Globalization Era: The Inter-Relationship between International, Supra-National and National Shipping Policy*, The Handbook of Maritime Economics and Business, ed. by Costas Th. Grammenos, LLP, 495-511.

Seok, Du-ok's Memoire (June 1990), *Monthly Maritime Korea*.

The Bureau of Shipping (1955), *Haewoon 10 Nyeon Yaksa (The 10 year History of the Korean Shipping Industry 1945-1955)*, reprinted in 2001 by Korea Shipping Association.

UNCTAD (2013), *Review of Maritime Transport 2013*.

Yoon, Ki-sun (1973), *Hankuk Haewoon 25 Nyeon Sa (The 25 year History of the Korean Shipping)*, Taeyoungsa.

Tworty Box to Reduce Empty Container Positionings

Ulrich Malchow

Centre of Maritime Studies, Hochschule Bremen – University of Applied Sciences, Bremen / Germany.
Email: ulrich.malchow@hs-bremen.de

Abstract

A significant share of all empty container positionings is resulting from imbalances with regard to container sizes (20ft/40ft). In order to reduce the shipments of 'containerised air' a new type of container has been developed by the author: *Tworty Boxes* can either be used as a standard 20ft or in coupled condition as a 40ft container. The outside appearance resembles any standard 20ft container. However the *Tworty Box* is unique in that it has an additional door at the front side that opens to the inside. This door can be fixed to the container ceiling and with the use of bonding elements another *Tworty Box* can be joined up, thereby creating the full 40ft inside space. Operated as a single 20ft box the additional door remains locked, access is only through the existing standard door. The *Tworty Box* does not require any additional components and fulfils all ISO and CSC requirements.

Keywords: Empty positioning, deadheading, container imbalance, equipment logistics, container sizes, 20ft/40ft.



Fig 1. A pair of *Tworty Boxes* is loaded in coupled condition on board the "OOCL Montreal"

1. Task

The commodity most often shipped in containers across the seven seas is pure air as approximately 20% of all worldwide shipped containers are empty! According to estimates direct handling costs alone are more than US\$ 15 Billion p.a.! Furthermore carrier's box fleets have to be much bigger than actually needed to satisfy shipper's demand. This results in containers standing empty or idle in average approx. 60% of the time which consequently causes additional costs in ports and at depots. Moreover empty boxes void valuable slots on board the vessels. Hence cost effective container management has become the key issue for the profitability of container lines! Already in 2001 each empty positioning has been valued at least at approx. 400 US\$/box mostly in terms of port handling costs.

The high portion of unproductive and costly empty positionings is caused by:

1. structural imbalances of the general cargo flow (general trade imbalance),
2. seasonal impacts of the dominating commodities in specific trades,
- 3. imbalances of the 20ft:40ft ratio in both trade directions!**

A significant share of the empty positioning is resulting from carrier's internal imbalances in container logistics with regard to box sizes (20ft/40ft). Carriers note strong ups and downs in supply and demand of

different container sizes in certain areas/ports especially if several services of different trades are calling the same area. Local dispatchers often report: "Too many 20s, not enough 40s", or reverse. Not always the situation can be balanced in time. Not seldom the grotesque situation occurs that a carrier has to leave laden (low paying) boxes behind in order to reduce the empty stock of a certain size and position them empty to another port of the world where they are urgently needed for high paying cargo.

2. The *Tworty* Solution

In order to significantly reduce the shipments of 'containerised air' the *Tworty Box* has been developed. Its outside appearance resembles any standard 20ft container. However the *Tworty Box* is unique in that it has doors at each end, the second door opens to the inside and can only be locked from the inside. This door can be fixed to the container ceiling and with the use of special bonding and sealing elements another *Tworty Box* can be joined up, thereby creating a watertight 40ft unit of full value (with standard doors at both ends).

Thus *Tworty Boxes* can either be used as a standard ISO 20ft or coupled as a 40ft container:

$$\text{Twenty} + \text{Forty} = \text{'Tworty'}$$

If two *Tworty Boxes* are coupled to form a 40ft box the additional doors will be opened supported by cables and fixed to the container ceiling to receive the full 40ft inside space. Operated as a 20ft box this door is locked, access is only through the existing standard door. Two coupled *Tworty Boxes* make a 40ft container with doors at both ends. The system does not require any additional components and the coupled boxes remain watertight. The *Tworty Box* complies with all ISO requirements for containers and has successfully passed the full CSC testing procedure with Germanischer Lloyd (now DNV-GL).



Fig 2. Front side with additional door (to be opened to the inside) and bonding elements adjacent to the corner castings



Fig 3. Inside view of closed additional front side door (cables to open the door are visible)

The coupling is carried out by bonding elements which guarantees that two *Tworty Boxes* can be handled like a single 40ft container. The connection of two *Tworty Boxes* can only be released from the inside. Four coupling elements are located adjacent to the corner castings (Figure 2). Each *Tworty Box* has two male and two female bonding elements. They also keep the distance of 76 mm between the boxes in order to comply with the ISO regulation for the length of a 40ft container.

The *Tworty Box* concept is protected by international patents. Following main design targets have been followed:

- minimum changes compared to standard 20ft containers
- robustness
- easy handling
- (almost) no loose parts

Compared to single standard 20ft/40ft boxes the losses of the *Tworty Box* with regard to payload and capacity (if any) are marginal (Table 1). The only loose parts are the flat surrounding sealing ledges which are screwed after the coupling process from the inside into the gap between both boxes providing the necessary watertightness. As each *Tworty Box* carries a set of seals under the ceiling but only one is needed for the coupling of two *Tworty Boxes* there is enough redundancy if one sealing element was missing or damaged leaving enough time for a replacement. The seal fully complies with international customs regulations.

Table 1. Comparison of payload and capacity

	20 ft (8'6" high)		40 ft (8'6" high)	
	Payload [t]	Capacity [m ³]	Payload [t]	Capacity [m ³]
standard container	21.8 ... 28.2	32.8 ... 33.2	25.8 ... 26.7	65.3 ... 67.7
<i>Tworty Box</i>	27.8	33.1	25.2	63.5

Source: Various container specifications

By operating *Tworty Boxes* empty positionings caused by the need to balance different supply and demand of 20ft and 40ft container sizes can be significantly reduced. Even if empty *Tworty Boxes* have to be empty positioned (e.g. due to inevitable imbalances of the general cargo flow) they can be coupled and immediately 50% of the lift on/lift off charges are saved.



Fig 4. Bolting mechanism with handle for hinged door (from the inside)



Fig 5. Box for bottom male coupling element

On account of forwarding company DHL a pair of prototype boxes which had been stuffed with commercial cargo has already made a trial trip in 2013 on board of OOCL and Hapag-Lloyd vessels from Hamburg to Montreal and v.v. to the full satisfaction of the forwarder.

3. Economics

Approx. 205 Mill TEU (Twenty Foot Equivalent Unit) have been shipped across the seven seas in 2011. Thereof 21% were empty (42 Mill TEU).

In 2011 the world container fleet consisted out of 30 Mill TEU (of which 27 Mill TEU were standard 20ft/40ft dry cargo boxes), i.e. in average each TEU has been shipped only 6.8 times throughout the year – thereof 1.4 times empty (empty share of 21%). In average each shipment has caused 2.9 port handlings (the average value of more than '2' is caused by transshipments).

Already in 2001 each empty positioning has been valued at least at approx. 400 US\$/box mostly in terms of port handling costs. It is assumed that this amount has increased now at least to 450 US\$/box. Hence in 2011

with a global 20ft/40ft split of 1,53 TEU/box within the standard dry cargo box fleet each TEU has caused at least approx. 410 US\$ just for being empty positioned ($1.4 \times 450 \text{ US\$/box} : 1,53 \text{ TEU/box} \approx 410 \text{ US\$/TEU}$).

As the average life time of a container is 8 to 9 years it is obvious that each container causes empty positioning costs during its entire life time which are exceeding its current purchase price (approx. 2,000 US\$ for a standard 20ft container) by far. Hence the focus on reducing empty positioning is much more important than on the lowest possible purchase price of standard container equipment!

3.1. Focus on single Boxes

Maximum savings can be achieved when 2 x *Tworties* are substituting 2 x 20ft and 1 x 40ft standard boxes which are normally due to be empty positioned in opposite trade directions. Table 2 illustrates the economics of operating *Tworty Boxes* compared to standard 20ft/40ft containers.

For the comparison three relevant cost items have been considered whereby the costs of crane moves and the costs for coupling/de-coupling have been varied within a realistic bandwidth. Considering the slightly higher investment for the *Tworty Box*, its daily capital costs have been set more than two times (!) the value of a standard 20ft box, which is by all means much more than the additional door will realistically cause. This leaves some reserve for an eventually slightly higher daily M+R allowance.







- daily capital costs:
 - standard 20ft container: 0.85 US\$/box/day
 - standard 40ft container:ⁱ 1.36 US\$/box/day
 - ***Tworty Box* (worst case assumption): 2.00 US\$/box/day (incl. much safety margin)**
- avg. costs per crane move: 100 ... 200 US\$/move
- avg. cost for coupling/de-coupling: 20 ... 100 US\$/(de-)couplingⁱⁱ

In addition the duration of the container voyage and the number of transshipments have also been varied in order to analyse all relevant impacts on the profitability of *Tworty Box* operation:

- duration of container round voyage: 50 ... 100 days
- number of transshipments (during one voyage): 0 ... 2

Table 2. 2 x *Tworty Boxes* replacing 2 x 20ft and 1 x 40ft

		Duration	Unitcosts [US\$]		Trans-shipment
		RV [days]	Move	Coupling	
		100	100,-	100,-	0

	eastbound	westbound
2 x 20' (full)		→
2 x 20' (empty)	←	
1 x 40' (empty)		→
1 x 40' (full)	←	
<hr/>		
2 x <i>Tworty</i> (full)		→
2 x <i>Tworty</i> (full)	←	

Capital Costs [US\$]	Moves [US\$]	Coupling [US\$]	Voyage Total [US\$]
85	400	0	485
85	400	0	485
68	200	0	268
68	200	0	268
Total			1.506
200	400	100	700
200	200	100	500
Total			1.200

Difference	306
Percentage of conv. costs	20%

3.2. Result of single box view

Table 2 illustrates the most unfavourable case for the operation of *Tworty Boxes* within the given range of parameters (arrow in the diagrams below), i.e.:

- minimum lift on/lift off rate
- maximum coupling/de-coupling rate
- longest duration of container voyage
- no transshipment

Nevertheless savings of 306 US\$ have been revealed for a round trip of the boxes, i.e. two shipments, compared to conventional box operations. This amount represents savings of 20% compared with the operation of standard containers. This magnitude exceeds by far the industries average profit margin per container shipment (especially at present times). Saved costs for slots on board which do not need to be used for empty positioning have not even been considered.

Savings would logically increase if costs for coupling/de-coupling were decreased. However considering the wide range of this parameter the impact on the *Tworty Box* profitability is not dramatic. It can also be revealed from Figure 6 that the impact of the duration of the single container voyage is rather negligible. It is much more the applicable average lift on/lift off rate which is of significant influence on the savings. For general guidance the following rough amounts can be applied (according to the specific trade a respective average from both ends has to be considered):

- Europe: approx. 100 US\$/move
- N.America: approx. 200 US\$/move
- Asia: approx. 300 US\$/move

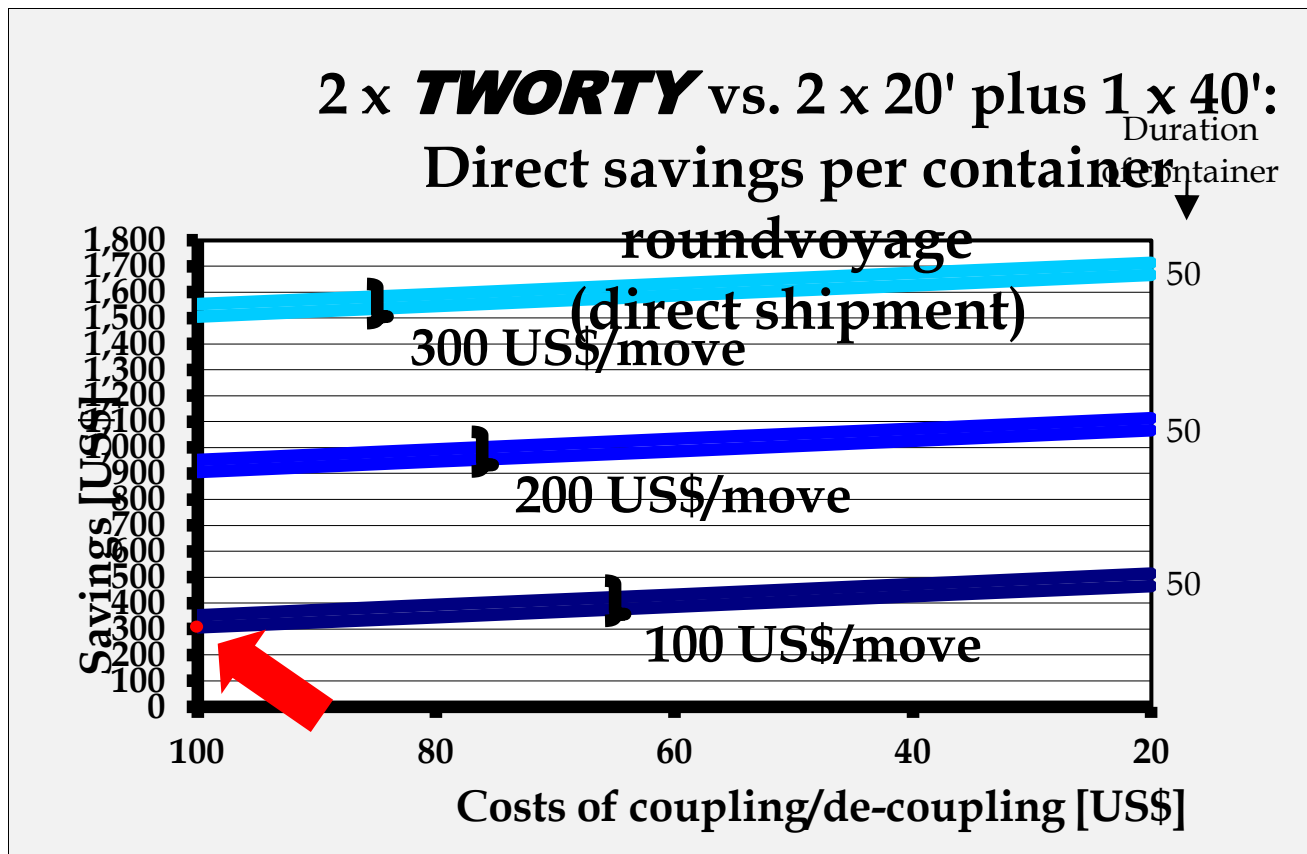


Fig 6.

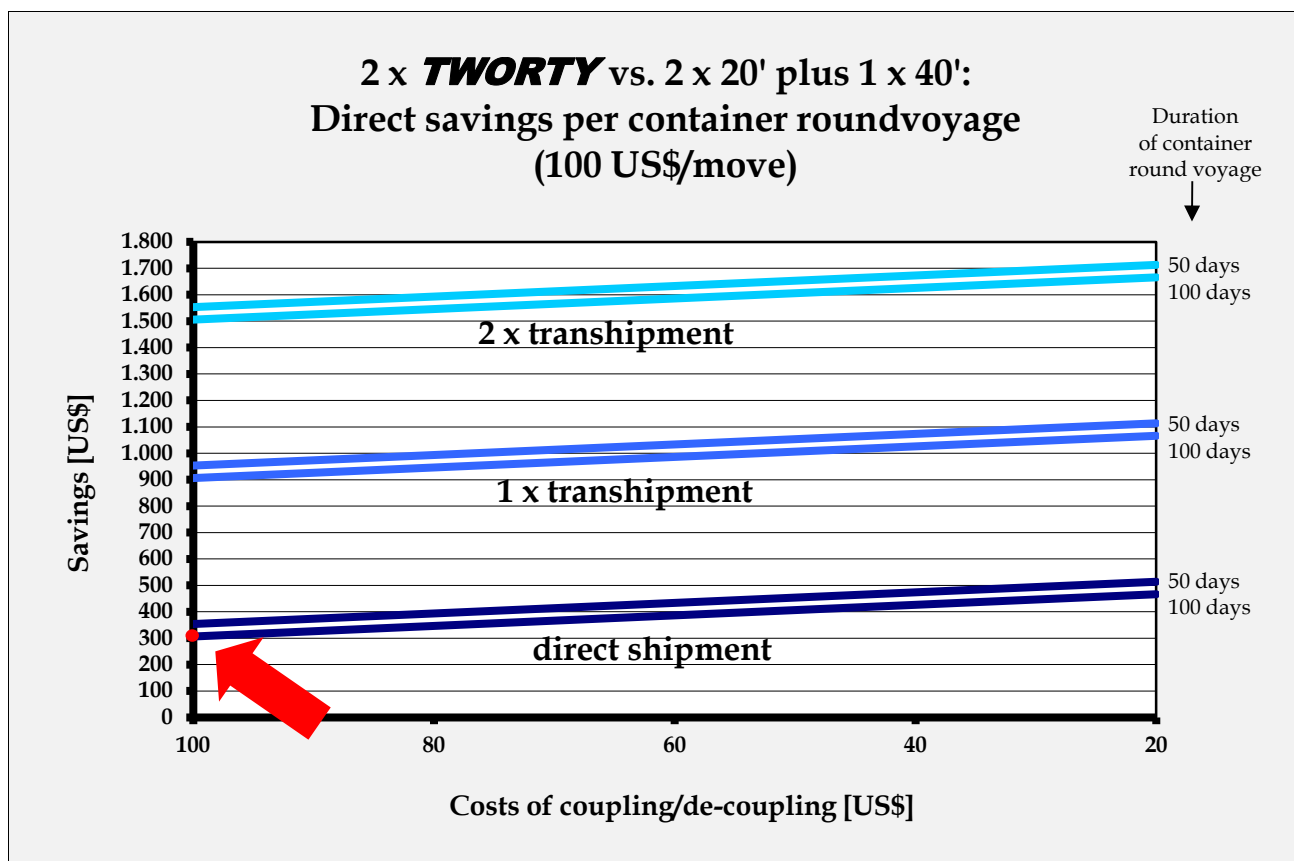


Fig 7.

As more and more container lines are following the "hub-and-spoke" strategy the influence of transshipment has to be considered as well. In the meantime the share of transhipped boxes in port's global container throughput has risen from 10% in 1980 to more than 30% in 2011! It can be clearly revealed from Figure 7 that the savings the *Tworty Box* can provide become higher the more often the containers are transhipped! Furthermore savings are even much higher if average lift on/lift off charges in excess of 100 US\$/move meets with the necessity to tranship empty containers at least once.

It can be concluded that the introduction of *Tworty Boxes* can provide dramatic savings if they are operated and kept in certain imbalanced trades where their advantages can be fully utilised. Thus contrary to standard containers they have to be individually tracked and treated as special equipment like e.g. flats, reefers etc.

3.3. Focus on carrier's entire fleet

Almost all container trades are characterised by imbalances with regard to the volume of cargo flow and the related 20ft:40ft ratio. Imbalances are not static but are changing continuously over time and location. The ideal case of a balanced trade with an identical cargo flow in both directions resulting into the same 20ft:40ft ratio in all ports and in both directions does not exist! Furthermore local and temporary imbalances mostly exceed the summarised average extend.

A simple low scale example as per Figure 8 demonstrates that even trades with an almost balanced cargo flow and an identical general 20ft:40ft ratio both ways shall very much benefit from the *Tworty Box*. It is assumed that in a hypothetical trade 100 TEU have to be shipped eastbound whereas 120 TEU are due to be carried westbound. Contrary to reality and not beneficial for *Tworty Box* operation both volumes shall exactly have an identical 20ft:40ft ratio (= 0.86) on their ocean leg. In reality this ratio is however varying more or less around an average figure among the various loading and discharging ports involved.

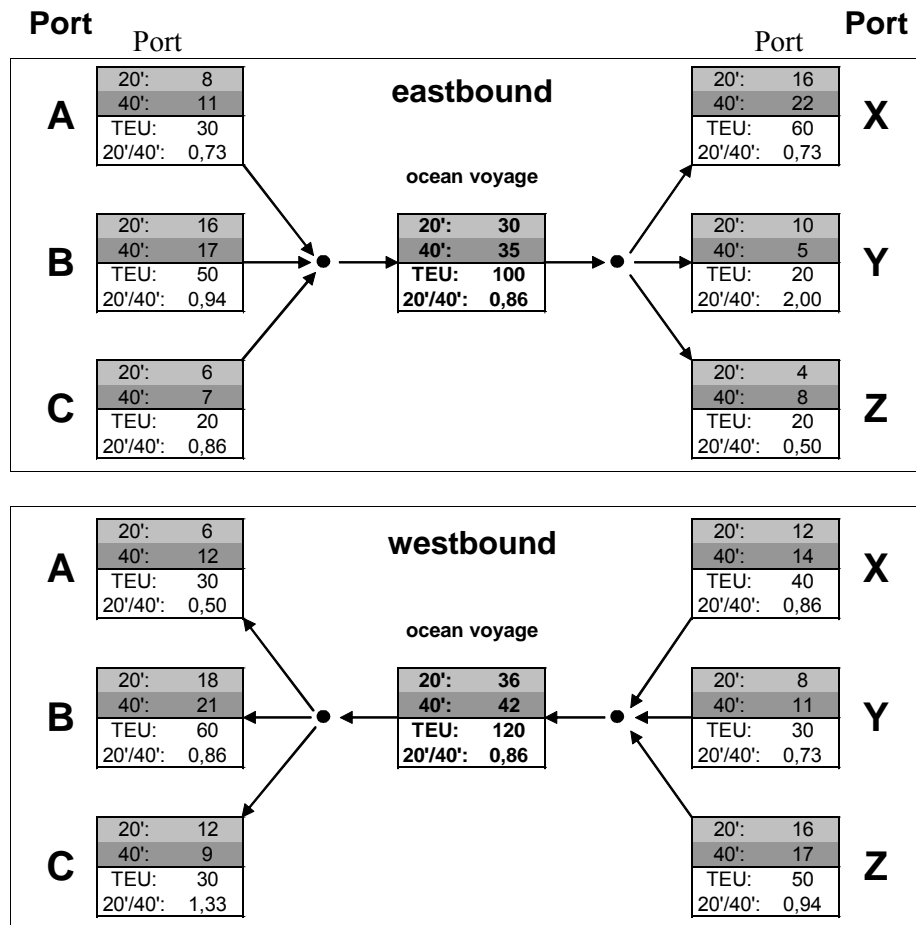


Fig 8. General trade imbalance (low scale example)

Hence deadheading is not only required to compensate the general imbalance in required equipment flow between both regions but also to balance the various requirements for different container sizes among the ports within a region. The required box fleet is determined by the dominant trade direction. In this case for both sizes the westbound leg is stronger. Hence at least 240 TEU of equipment would be required to ship both volumes simultaneously.

Just due to the apparent general trade imbalance only additional 20 TEU ($6 \times 20\text{ft} + 7 \times 40\text{ft} = 13$ boxes) seems to be necessary to be empty positioned eastbound (Figure 9). However considering also the various local imbalances at each port 44 TEU ($14 \times 20\text{ft} + 15 \times 40\text{ft} = 29$ boxes) have actually to be shipped empty (also within the regions) in order to compensate the imbalanced supply and demand of container sizes. This is 120% more (in terms of TEU) than one would expect from the pure general trade imbalance, resulting in 123% more empty box movements! Also the box fleet has to be slightly larger than originally anticipated as boxes which are due for an additional intra-regional deadheading cannot be immediately stuffed after having been stripped.

3.4. Result of carrier's entire fleet view

At all ports which suffer from a sudden or permanent lack of one size and a surplus of the other size (e.g. port "A" and "Y") the operation of *Tworties* would be very advantageous (Figure 10). If in the example only 4 x *Tworties* were introduced (replacing 2 x 40ft standard boxes) and these boxes were kept plying only between port "A" and "Y" just only 40 TEU (including the *Tworties*) would have to be empty positioned (instead of 44 TEU). Hence a *Tworty* share of only 2% (in terms of TEU) within the box fleet could theoretically lead to a reduction of deadheading costs by 10%! Furthermore the entire fleet could be reduced by 4 TEU (-2%)!

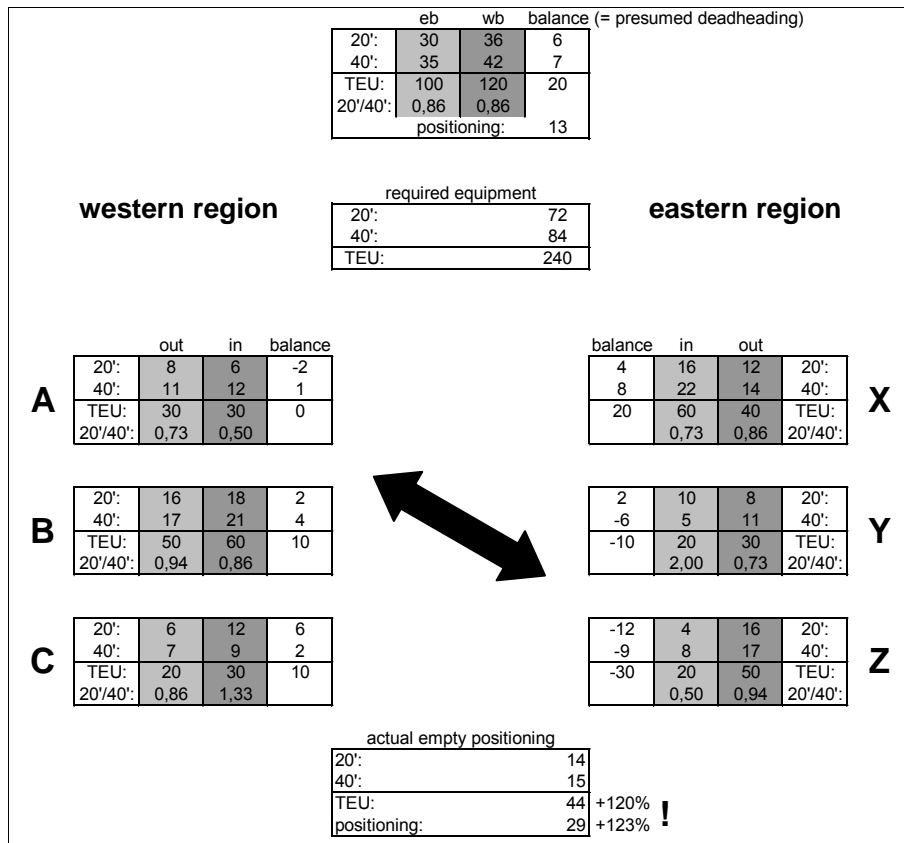


Fig 9. Empty positioning caused by general trade and local imbalance (example)

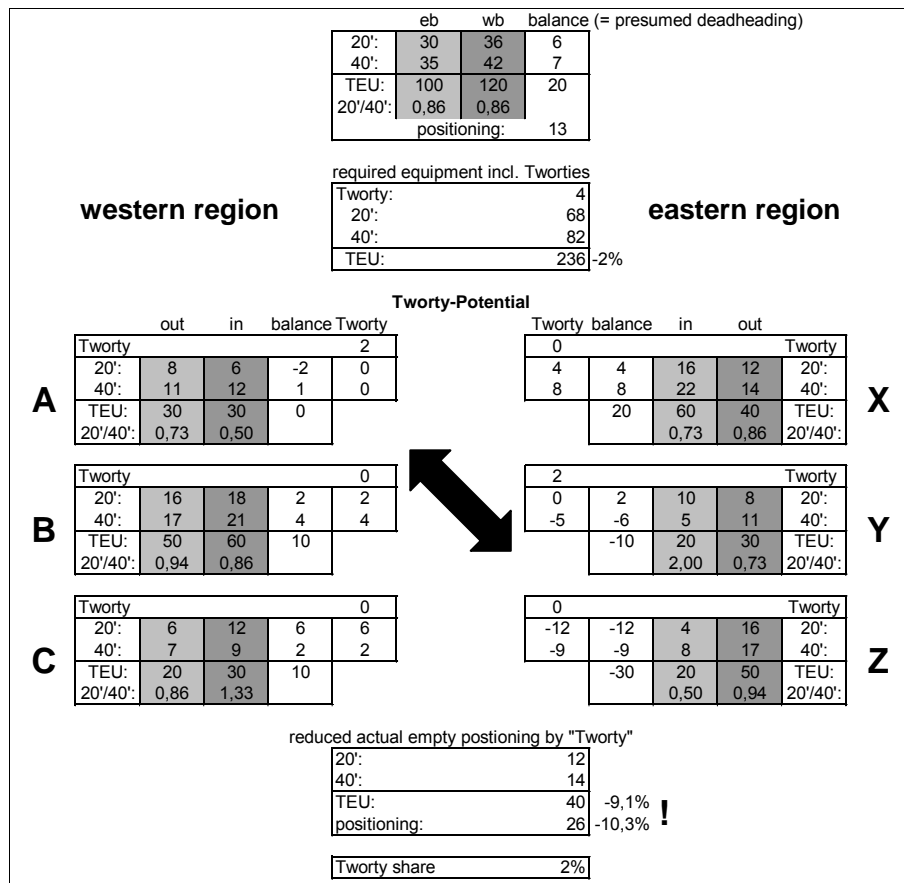


Fig 10. Empty positioning caused by general trade and local imbalance (example) reduced by *Tworty Boxes*

Thus a homogeneous container fleet existing completely out of *Tworties* is not necessary. The huge majority of the fleet can still consist out of standard 20ft and 40ft boxes. As it can be derived from the example even a small number of *Tworty Boxes* which are kept plying between ports where a chronic surplus of one size meets with the lack of the other size can significantly contribute to improved economics of a carrier's container fleet.

Table 3. Expected effect of *Tworty Box* operation

		just by general trade imbalance (theory)	in reality due to locally imbalanced container sizes	including 2 % <i>Tworty</i> share	savings
Necessary	boxes	13	29	26	-10 %
Deadheading	TEU	20	44	40	-9 %
required fleet	TEU	240	240 plus	236 plus	-2 %

Although the *Tworty Box* cannot supersede all repositioning necessities, there are many trades where the 40ft:20ft ratio of equipment is varying among the ports and where the system can help substantially.

Because 2 x *Tworty Boxes* are destined to replace approx. 2 x 20ft standard boxes and 1 x 40ft standard box the capital costs of the entire box fleet do not increase as the additional expenses for one *Tworty Box* would not exceed half the costs of a 40ft standard box.

4. Conclusions

The *Tworty Box* is most advantageous for container trades which suffers from a clear imbalance with regard to the container sizes, i.e. where the 20ft/40ft split of both trade directions differs significantly.

However the calculations have revealed that significant savings can even be realised in case of imbalances with regard to the pure trade volume, i.e. when coupled *Tworty Boxes* could replace 2 x 20ft standard boxes which otherwise would have to be empty positioned individually. By using *Tworty Boxes* the empty movement can be realised as one unit, i.e. the respective handling costs can be cut by 50% which exceeds the additional expenses for coupling/de-coupling by far.

Hence the *Tworty Box* can avoid empty positioning caused by having not the right container sizes available and even if empty positioning is unavoidable it can cut the costs for empty movements of 20ft containers almost by half.

Who is benefiting? It is the container lines which would directly take advantage from operating *Tworty Boxes*. Presently 53% of the world container fleet is operated by container lines, thereof 90% are of standard 20ft/40ft dry cargo type. However it is not necessary that a container line replaces its entire container fleet by *Tworty Boxes* to gain maximum savings. Only the portion equivalent to the lines' individual (average) imbalance needs to be replaced. It is not expected that leasing companies which presently control approx. 44% of the world's container fleet would be immediately interested to operate *Tworty Boxes*. They are only reacting to the demand of the container lines and therefore would only be interested at a later stage. However big forwarders with shipper's owned containers might be interested as well as it has been already proven by global forwarder DHL which have tested two prototype boxes on occasion of a trial trip.

According to Boedeker, Global Head Ocean Freight, DHL Global Forwarding, (2013) the *Tworty Box* is a very attractive solution which ensures flexible container management and cost efficiency by eliminating empty positioning due to structural imbalances in the general cargo flow or seasonal fluctuations in the dominant commodities in specific sectors. It was quoted to be a smart alternative for customers that note strong ups and downs in supply and demand of different container sizes in certain areas, especially if several services of different trades are calling the same country or region.

Taking the fact that 21% of all containers shipped are empty for reasons of imbalance of whatever kind it is assumed that the potential market volume for the *Tworty Box* might be 20% of the existing global standard

20ft/40ft dry cargo container fleet which is presently operated by container lines, i.e. presently 27 Mill TEU x 0.53 x 0.2 = 2.9 Mill TEU! Hence with an average life time of 8.5 years 34.000 TEU of *Tworty Boxes* could be needed to be introduced annually.

References

- DHL, Press Release, June 25, 2013
Drewry Maritime Research, Container Market Review and Forecast, Annual Report 2012/13.
Drewry Maritime Research, Container Forecaster, 2013.
Drewry Shipping Consultants, Container Census – 2012, 2012.
Hapag-Lloyd Ag, Container Specification, 2010.
Konings, R. and Thijs, R. (2001), Foldable Containers: A New Perspective on Reducing Container Repositioning Costs, TU Delft.
Malchow, U., Aus zwei mach eins, Deutsche Verkehrs-Zeitung, Dec. 10, 2013.
Port of Hamburg Magazine (2013), 3: 34-39.
Tworty Box GmbH and Co. Kg, Hamburg, website: www.tworty.com (Accessed in Feb. 2014).

ⁱ According to the industry standard the capital costs of a standard 40ft container are defined to be generally 1.6 times higher compared to a standard 20ft container.

ⁱⁱ These costs may also cover the efforts to track the *Tworty Box* fleet to ensure that two boxes are always available to be coupled if needed.

Competitiveness of Global Ports: The Kaohsiung and Dubai Experience

Shiva Madani and Booi. H Kam

School of Business IT and Logistics, RMIT University, Melbourne

Abstract

The competitive environment affecting port operations is in a constant state of flux, to the extent that distribution and evolution of container traffic has been described as following a random walk instead of logic of scale. Maritime researchers attribute this to the interplay of a range of factors including the redefinition of port hinterland and foreland, the rise of port-centric logistics, and the growth of China as the manufacturing hub of the world, among others. Drawing on the tenets of resource-based view of the firm and dynamic capability theory, this study examines how two global ports - Kaohsiung and Dubai - built their operational capabilities to sustain their competitive positions among the top container ports in the world during the last two decades. Aiming to offer a fresh perspective on understanding how ports compete, this research opens a new avenue for formulating a framework for strategic port development.

Keywords: Ports, Competitiveness, Dynamic Capability Theory, Resource Based View

1. Introduction

Research on port competitiveness has been a dominant theme among maritime and port studies for more than two decades. In 1990's, Rugman and Verbeke (1993) suggested that there were six factors that led to a port's competitive position: 1) factor conditions (e.g., production, labour and infrastructure), 2) demand conditions, 3) related and supporting industries, 4) firm structure and rivalry, 5) chance, and 6) government intervention. In early 2000s, when sea ports were recognized as an integral part of value added chains, prime factors supporting port competitiveness were identified as hinterland accessibility, productivity, quality, cargo generating effect, reliability and reputation (Meersman et al., 2002). A more recent study on port competitiveness by Carbone and Gouvernail (2007), however, suggested that factors influencing port competition have further evolved. These new factors include relationships with other actors in the supply chain, availability of port-infrastructure, proximity to major sourcing and final markets, road and rail network configuration, transit time, number of direct connections to overseas destinations, extent of feeder service available, good labour climate, and inland waterways connections.

The changing factors affecting port competitiveness imply that ports that managed to retain their competitive strengths over the last two decades are likely to be those that have moved with the tune of the time and are not dependent on their natural endowment, like a deep sea harbor, as have been the case in the past (Veltz, 2001). Rather obviously, the massive built-up in port capacity and port-related resources (Haralambides, 2002), as well as major improvement in inland transport systems that led to the expansion of port hinterlands (Ducruet, 2009) during the last two decades are deliberate, and strategic, actions taken by far-visioned port authorities.

In line with the above argument, this paper contends that understanding the dynamic complexity determining port competitiveness is not limited to identifying factors contributing to port success. Such an understanding requires an in-depth evaluation of the growth and developmental path that a port has traversed, either by default or by design, or both. This paper presents our analysis of how two global ports, Dubai and Kaohsiung, built their competitive capabilities in different ways to sustain a competitive position as one of the top container ports in the world. Specifically, this study will review how the two ports developed their port-related infrastructure at each phase of growth. It will analyze how the formulation of strategic policies at each port evolved from the interplay of resource exploitation, both tangible and intangible. This research aims to offer a fresh perspective on understanding how ports develop their competitive strengths, opening a new avenue for

building a theory of competitive global ports based on resource investment and exploitation. The findings are expected to be of use for formulating a framework for strategic port development.

2. Dynamic Capability Theory and The Resource Based View

In mainstream organizational behavior literature, resource based view (RBV) of the firm (Barney, 1991) and dynamic capability (Eisenhardt and Martin, 2000) are two of the popular theories that explain how firms exploit resources to develop capabilities, competencies and, ultimately, competitive advantage (Javidan (1998). RBV comprises two main streams: resource picking theory and resource building theory (Barney, 2001, Makadok, 2001). Resource picking theory posits that if resources readily available to firms are valuable, rare, hard-to-imitate and difficult to be substituted, they are sources of competitive advantage (Barney, 1991). Transforming these resources to capabilities and competencies to create competitive advantage would require the adoption of firm-specific strategies to capture and deploy them (Wernerfelt, 1984, Wright et al., 2001), including embedding factors prompting innovation and product-related strategic linkages (Helfat and Raubitschek, 2000).

The transformation of resources into distinctive capabilities, such as firm-specific unique routines, or core competencies takes time (Helfat and Peteraf, 2003, Day, 1994). In dynamic markets, these unique routines do need to undergo constant change, regardless of how inimitable, rare, valuable and difficult-to-substitute the resources used to generate them are. Fiol (2001) argues that in a highly competitive environment, firms' resources and the way firms employ resources must constantly be changed to produce continuously evolving temporary advantages. This argument implies that competitive advantage cannot be sustained, since the circumstances that shape them are constantly changing. Firms, therefore, derive superior rents from their ability to destroy and rebuild unique routines overtime. The need to develop dynamic capabilities to renew competitive advantage constitutes the core of the resource building theory.

Eisenhardt and Martin (2000) argued that dynamic capabilities are necessary but not sufficient conditions for competitive advantage. This is because the functionality of dynamic capabilities can be duplicated across firms, and competitive advantage is created from resource configurations, not from capabilities (Eisenhardt and Martin, 2000). In a moderately changing market, routines, as dynamic capabilities, need to be modified through small but frequent reconfiguration of resource utilization and deployment. In short, dynamic capabilities should be changed, or even destroyed, to serve the purpose of sustaining competitive advantage. Both RBV and dynamic capability theories offer valuable insights on how global ports build their capabilities and competencies by investing in and utilizing port-related infrastructure, a capital-intensive tangible resource. Drawing on the tenets of the mentioned theories, this paper examines how Kaohsiung and Dubai Ports built and exploited their port-related infrastructure to gain, and maintain, a competitive position globally.

3. Methodology

The Port of Kaohsiung was selected due to its sustained status on the world's top 25 container traffic port list since early 1980s, and also its stature as one of the main shipping hubs in Central Asia. Dubai was picked because of its recent rise as a global port in the Middle-Eastern region and its rapid rise to become one of the world's top 10 container ports since 2000's. A second reason for selecting Kaohsiung and Dubai was because the two ports present a contrasting pair in their relative shift in ranking in the world container league table between 1998 and 2012 (see Figure 1). Prior to 2006, the port of Kaohsiung was way ahead of Dubai Port in terms of container traffic handled. Since 2007, Dubai had overtaken Kaohsiung.

Based exclusively on secondary data and published information on, or related to, the growth and development of Kaohsiung and Dubai since 1990s, the case analysis will focus on the development of port-related infrastructure and the operational strategies the two ports employed. Guided by the tenets of RBV and dynamic capability theory, we began, in the next section, by examining the physical infrastructure development and investments the two ports undertook in the last two decades. The aim is to identify the strategic actions the two ports took respectively to build a robust tangible resource base. This will then be followed by a discussion of the service (or soft) infrastructure initiatives put in place to optimize the use of the physical assets available, as a means to understand how these two ports built their dynamic maritime

capabilities in respond to changes in the surrounding economic environment. We then relate the two sets of information to the growth in container traffic recorded at the two ports (as an indicator of performance) over the last two decades as a means to assess the causal linkages between resource building as well as capability development and performance.

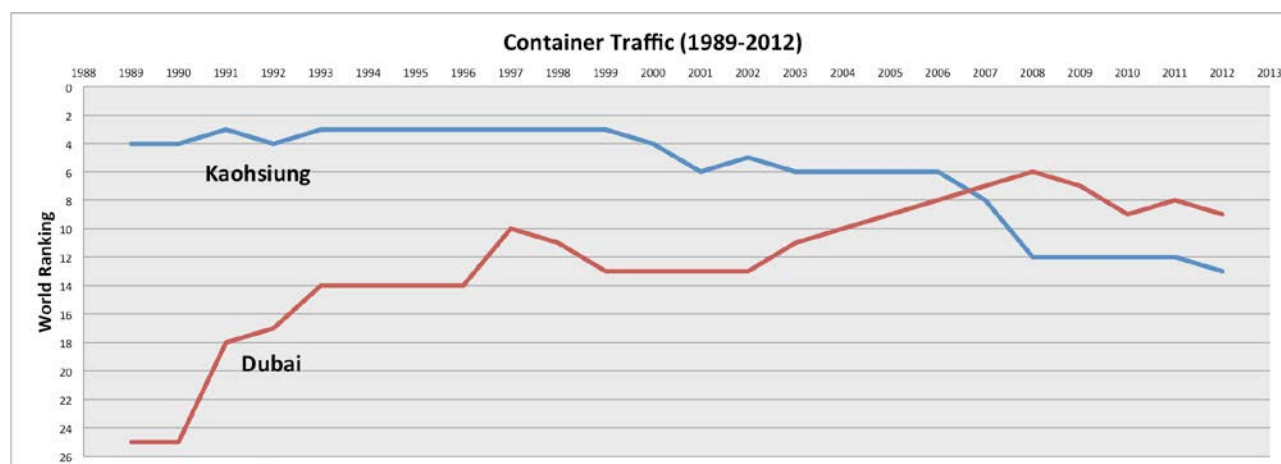


Fig 1. Ranking of Port of Kaohsiung and Dubai

4. Analysis

4.1. Physical Infrastructural Development

Kaohsiung

The development of Kaohsiung Port can be briefly summarized into two main phases. The first phase started from 1945 after the 2nd World War when Taiwan - a Japanese-ruled country - was returned to China. The Kaohsiung Harbor Bureau (KHB) was established in December 1945 to take charge of harbor restoration, which was by and large completed in 1955. In 1958, the KHB began a 12-year project to reclaim 544 hectares of shoreline to support increasing trade volumes (Kaohsiung, 2013b). The second phase of development started from 1970 up till 1999, with the progressive construction of five container terminals, an extensive plan in adaptation to the new trends of Port-Urban interface, defined by Hayuth (2005) as containerization, inter-modality and globalization. These five terminals, with a total of 26 berths and a combined capacity of 10 million TEUs, were fully operational by 2000. Between 2000 and 2006, there appeared to be a hiatus in port infrastructure expansion in Kaohsiung. In 2007, the construction of Terminal 6 commenced. Expected to be completed in 2014, Terminal 6 would add an additional three million TEUs to the overall handling capacity of Kaohsiung (Kaohsiung, 2013b).



Fig 2. Map of the Kaohsiung Port
Source: Port of Kaohsiung (2012)

Dubai

Located at the Persian Gulf, Dubai is one of the seven United Arab Emirates (UAE) that were founded as a federation in 1971 (Jacobs and Hall, 2007). With regards to port developments, the major milestone was in 1976, when the historical seaport of Port Rashid was expanded to a new port in the Jebel Ali area. Jebel Ali port was a unique development project at the time, as it was the largest man-made harbor in the world (Economist, 2004). With 67 berths and a size of 134.68 square kilometer, Jebel Ali has played a key role in transformation of Dubai into a modern port city and commercial hub (DP, 2011).

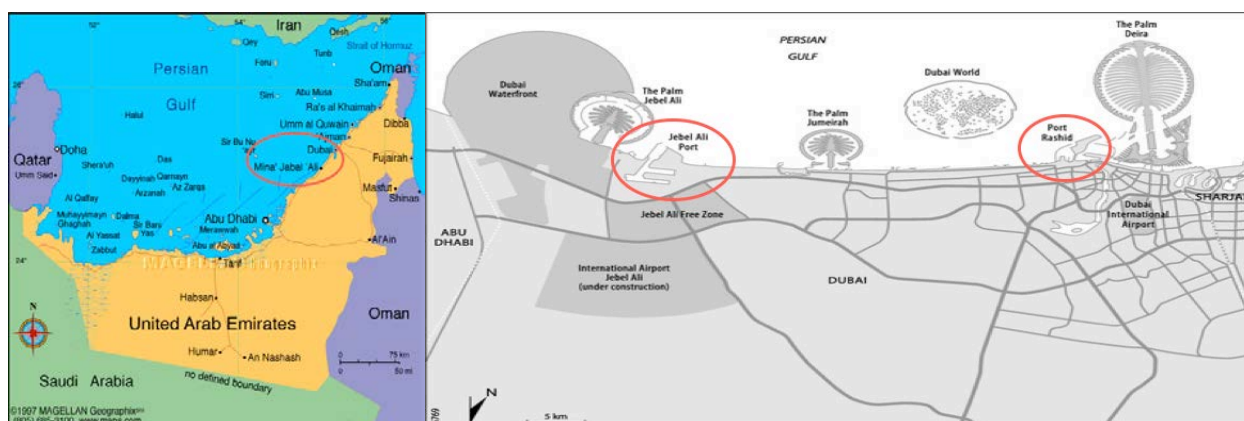


Fig 3. Overall Map of Dubai Ports
Source: Adapted from 2DAYDUBAI (2010)

Currently Dubai holds the position of the major transshipment and logistics hub in the Middle East region, a stature reflective of the high level performance of the twin ports of Jebel Ali and Port Rashid (Figure 3). Since the establishment of Jebel Ali port, development of Dubai Port was no longer limited to physical expansion, but introduction of a range of ancillary activities, such as shipbuilding, repair and maintenance. Figure 4 displays the multiple aerial images of Jebel Ali port from 1977 to 2008, which demonstrate the extent of development in the Jebel Ali Port area over a period of 30 years.



Fig 4. Jebel Ali Port in 1977, 1979, 1984, 1988, and 2008 – United Arab Emirates
Source: Adapted from DP World (2014c)

The major infrastructural developments related to Port Dubai and Port Kaohsiung are summarized in Table 1, which reveals the way resource investments took place in each port over the last 30 years. These investments are split into two main streams - tangible and intangible resources - to indicate the focus of the respective authority on particular means of achieving competitiveness.

Infrastructural developments in Dubai, as outlined in Table 1, concentrated heavily on building tangible assets, revealing strategies aligned with anticipation in growth of trade and consumption in the Middle Eastern region. From the early phases of growth, seaport development in Dubai has been in parallel with the development of a host of mutually supportive logistics infrastructure services, including a Free Trade Zone and multimodal interchange facilities, aiming at increasing the logistics capacity and providing a seamless intermodal transport connectivity within the region.

In comparative terms, resource investments at the Port of Kaohsiung had been more modest (see Table 2), with emphasis on formulating policy measures centered on developing capabilities to capitalize on the economic and other opportunities that impacted on its maritime environment. The introduction of Export Processing Zone (EPZ) in the port area, the offering of dedicated container terminals to shipping lines as a means to secure long term relationship, the establishing an Offshore Shipping Center and the introduction of a Free Trade Zone strategy in anticipation of upgrading the port from a transshipment center to a logistics and distribution center are examples of such measures, which will be discussed in the next section.

Table 1. Tangible and Intangible Resource Building in Dubai and Kaohsiung (1980 – 2014)

	DUBAI	KAHHSIUNG
Tangible Resource Building	<ul style="list-style-type: none"> • Jebel Ali Free Zone (JAFZA) constructed around the Jebel Ali port area (1985) • Dubai Ports International (DPI) acquired the CSX Terminals (2004) • DP World acquisition of P & O, expanding their portfolio of terminals (2006) • Expansion of Jebel Ali Port Terminal 2: Phase I (2001-2006), Phase II (2008- 2013) Terminal 3 (2011- 2014) • Construction of a n International Airport in Jebel Ali area (Al Maktoum Airport) with handling capacity for both Cargo and Passenger (opened 2010), projected annual capacity of 12 million tons of Freight • Construction of a multimodal logistics platform in Jebel Ali area - Dubai World Central (DWC – under development since 2012) • Intermodal Rail Terminal in Jebel Ali Port (Projected) 	<ul style="list-style-type: none"> • Construction of Container Terminal Terminal 3 (1980-1981) Terminal 4 (1985-1991) Terminal 5 (1995-2000) • Construction of the Cross Harbor Tunnel (1981-1984), linking Container Terminal 4 and Chichin district to the rest of the port, increasing annual capacity of the port by more than 2 million TEU • Construction of Container Terminal 6 (Intercontinental Container Terminal) Phase I (2007-2014) Phase II (2010-2019)
Intangible Resource Building	<ul style="list-style-type: none"> • Dubai Ports International (DPI) founded as the first Container Terminal Operator in UAE (1999) • Dubai Ports International (DPI) merged with DPA (Dubai Port Authority) and formed DP World (2005). DP World is developed to one of the largest terminal operators in the world, with a portfolio of more than 65 marine terminals across 6 continents, handled more than 55 million TEU in 2013. Intangible resources of DP world can be listed as: <ul style="list-style-type: none"> - Human capital: Experienced and professional team of 28,000 people across the globe - Structural capital: Technical and professional knowledge, culture and databases - Relational capital: established relationship with customers overtime • Customer oriented services introduced such as e-token, e-payment (2008) 	<ul style="list-style-type: none"> • Introduction of Export Processing Zone in the port area (1980s) • Establishing long term relationship with shipping lines by offering dedicated container terminals (1980s) • Establishing an Offshore Shipping Center (1997) • Lifting the limitation of dedicated container terminals and upgrading the shipping lines to “Terminal Operators”, offering opportunities for higher volume of transshipment cargoes (late 1990s) • Introduction of Free Trade Zone in the Port area, Terminals 2,3,4 and 5 approved as Free Trade Zones (2004)

Source: Port of Kaohsiung (Kaohsiung, 2013b) and DP World (2012, 2013, 2014c)

Table 2. Specifications of Container Terminals in Jebel Ali Port (Dubai) and the Port of Kaohsiung

PORT	DUBAI (Jebel Ali)			KAOHSIUNG						
Container Terminal	T 1	T 2	T 3 Completion 2014	T 1	T 2	T 3	T 4	T 5	T 6 Under Development Phase I 2007- 14 Phase II 2010-19	
Number of Berth	15	7	6	4	4	3	8	7	4	5
Quay Length (Meter)	4875m	2600m	1862m	848m	1204m	1072m	2533m	2444m	1500m	6515m
Water Depth (Meter)	11- 17m	17m	17m	10.5m	12m	14m	14m	14-15m	16.5m	16-18m
Total Area (Hectare)	165ha	165ha	72ha	10.5ha	45ha	48ha	100ha	90ha	74.5ha	422.5ha
Capacity (TEU) Million	15 M		4 M	10 M					2.8 M	4 M

Source: (DP, 2014a, Chien-Chang et al., 2003) of the original source (Kaohsiung, 2014)

4.2. Service Infrastructure Programs

Kaohsiung

A large natural port located in the centre of the Asia-Pacific region, Port of Kaohsiung offers the shortest links to the major international harbours nearby (Singapore, Shanghai, Hong Kong, Pusan and Tokyo), by an average sailing time of 53 hours (Chen, 2002). In addition to its geographical and natural advantages, as well as modern facilities on offer, a combination of strategies were taken by the Taiwanese authorities during the last three decades to boost and strengthen the competitiveness of Kaohsiung Port. However, the rapid growth of other ports in the region, particularly in Mainland China, which benefitted from the fast-growing Chinese economy, posed considerable threats to the competitive strengths of Kaohsiung Port, shaving off its share of the regional container traffic. Despite experiencing continuous growth in container traffic in the early 2000s, the Port of Kaohsiung exited from the list of the top 10 container ports in the world in 2008, primarily due to a drop of over 677 thousands TEUs in transshipment cargo from 2007 to 2008, which continued to decline in 2009 (by about 420 thousands TEUs).

Kaohsiung has been the primary gateway of Taiwan's trade. Partly, this was attributed to the burgeoning activities of two EPZs in Kaohsiung. The Kaohsiung EPZ, a 68-hectare harbour side enclave established in December 1966, was the first EPZ in the Asia-Pacific region (Crook 2010). Its success led to the establishment of other EPZs on the island, including another in the Nanzte suburb of Kaohsiung (now spelled as Nanzi EPZ) in 1971 (Crook 2010). Amirahmadi and Wu (1995) referred the establishment of EPZs in Taiwan as a strategy of a custom free manufacturing with the assistance of foreign investment.

Development of EPZs in Kaohsiung can be divided into five main phases (Imin, 2012). The trend reflects the major shift in Taiwan's economy with emphasis on manufacturing high-value, low volume products.

- 1) 1966 - 1976: Rapid growth of manufacturing industries mainly consumer electronics products, garments and apparel.
- 2) 1977 - 1986: Still focused on manufacturing but upgraded to high level consumer electronics and components. The volume of garment and apparel products had decreased.
- 3) 1987 - 1996: Products manufactured in the EPZs, which were not permitted to be sold domestically since the introduction of EPZs, were allowed for domestic sales. More than 75% of the total production consisted of electronics components.
- 4) 1997 - 2004: More than 80% of products were mid-high end key electronics components (LCD, IC and optical).
- 5) 2005 onwards: Focused on high added-value industries (LCD, IC, optical and digital contents).

The change in production emphasis in the EPZs had, to a certain extent, affected the volume of container traffic handled by the Port of Kaohsiung. Also, up till 1986, all goods manufactured within the EPZs were required to be exported. The relaxation of this rule and its eventual removal in 1997 also had an impact on the volume of container traffic going through Kaohsiung Port, with the volume of non-transshipment cargo dropping by 0.3% between 1997 and 1998.

To attract container traffic from international shipping lines, the Port of Kaohsiung used to offer a long-term lease (e.g., 10 years) of container berths to a number of strategically selected shipping lines. The drawback with this approach was that both facilities and services on offer for vessels in the dedicated terminals were limited to the exclusive use of shipping lines leasing the terminal, making it difficult for Kaohsiung Port to extend services to other shipping lines. This policy was reviewed and service restriction on dedicated container terminals was lifted in late 1990s, while shipping lines leasing the berths were upgraded to “terminal operators” (Chen, 2007). The change enabled Kaohsiung Port to secure new strategic business with other international shipping lines. Currently, nine of the world’s top shipping companies hold the status of terminal operators in Kaohsiung, maintaining dedicated wharves in the port. Three Taiwanese shipping lines - Evergreen Marine Corporation, Yang Ming Marine Transport and Wan Hai Lines - are among them (Cheng, 2012).

In 1997, the Taiwanese government set up an “Offshore Shipping Centre” in Kaohsiung in response to the rising demand for cross-strait sea transport between two sides of the Taiwan Strait, which was suspended since 1949. The purpose of Offshore Shipping Centre was to handle transshipment cargos shipped between Fuzhou or Xiamen on mainland China and Kaohsiung, i.e., cargos that neither get customs clearance nor enter Taiwan. Otherwise, ships carrying regular cross-strait trade cargo had to anchor at a third place, such as Ishigaki in Japan or Hong Kong, to get customs clearance without unloading for transshipment before arriving at Taiwanese ports to avoid the direct shipping prohibition. The establishment of the Offshore Shipping Centre removed the operating inefficiency, and, hence, the additional cost, time, and risk (Yang 2013). Both the removal of service restriction on dedicated container terminal and the establishment of the Offshore Shipping Centre resulted in a sharp rise in transshipment cargos at Kaohsiung Port, from 2.08 million TEUs in 2006 to over 4.82 million TEUs in 2002.

By the start of the new millennium, 51% of the total throughput of Kaohsiung Port were transshipment cargos, an increase of about 10% from the average of 40% during the early 1990s. Transshipment cargos reached a high of 57% in 2003, when port services were privatized. Kaohsiung Port introduced the Free Trade Zone in anticipation of upgrading the port from an Asian transshipment centre to a “Logistics and Distribution” centre in 2004 (Kaohsiung, 2013c). The free trade zone offers opportunities for its tenants to perform various type of trade services, such as transshipment, distribution, reassembly, consolidation of containers, as well as simple and in-depth processing (Yang, 2009). Incentives considered for the tenants included exemption from custom duty, tax and service fees for goods, machinery and equipment transported from overseas for their operations, and zero tax rate on goods sold to an occupant enterprise for its business operation by a business entity in a tax zone or bounded area (Yang, 2009).

With emergence of new ports in China (e.g., Shanghai, Shenzhen) and the political disputes between Taiwan and China, (Chen, 2007) argued that Kaohsiung had lost its most valuable hinterland. This apparently had not been the case, as evidenced from China based cargo processed at Kaohsiung’s offshore shipping centre. Between 1997 and 2004, China based cargo processed at Kaohsiung’s offshore shipping centre accounted for up to 8% of the total cargo traffic (Chen, 2007). A more recent study, however, revealed that the figure has improved to 16% in 2009 (Chen, 2010). This is a reflection of Kaohsiung Port’s ability to recapture what appears to be lost opportunities on the surface and could be attributed to a number of measures taken by both the local and national authorities. In the national level, an agreement with China was reached in 2008, lifting the cross-strait ban which suspended trade between two sides of the Taiwan Strait since 1949 (Yang and Chung, 2013). This was one of the most instrumental approaches for achieving economies of scale through direct shipping to/from China. At the local level, in addition to the physical expansion for accommodating larger vessels and increasing port capacity, Port of Kaohsiung authorities lowered the port tariffs, as well as reorganizing its bureaucratic procedures for cargo processing (Kaohsiung, 2013a, KaoPort, 2013).

Dubai

It has been suggested that Dubai's overall success has been one of luck rather than a thought-out development strategy (Matly and Dillon, 2007). However, with regards to trade, transportation and logistics, the aforementioned suggestion does not appear to be a reasonable judgment. Emerging from a small city-state, based on fishing and trade, to a major transshipment and logistics hub in the region within a time frame of four decades cannot be expounded by sheer luck. Undeniably, the initial stage of mass development in Dubai was reliant on oil production; nonetheless the position of the largest port in the Middle East certainly would not have been accomplished without enduring and premeditated growth strategies.

The earliest commencement of these strategies was a vision of Dubai's ruler prior to the discovery of oil in 1959, that got actualized by borrowing funds to dredge the creek and making it deep and wide for movement of ships, along with building wharves, and warehouses (Molavi, 2007). From 1966 onwards and following the discovery of oil, the government of Dubai started making heavy investments on infrastructure, building roads and ports aiming at underpinning the long-term economic sustainability (Baluch, 2005).

Currently considered as the main transportation hub in the Middle East, Dubai is ranked after Hong Kong and Singapore as the third most important re-export center in the world with 60 % of the region's imports transiting its borders (Thorpe and Mitra, 2011). Attaining such a position, as described by Thorpe and Mitra (2011), is associated with the following factors:

- Accessibility by air, sea and land due to prime geographical location and good connectivity. Jebel Ali is connected through the main UAE / GCC road network accessing anywhere in the GCC by land transit within 2-3 days. In terms of sea connectivity, Jebel Ali offers more than 98 weekly services to over 115 direct ports of call (DP, 2014b).
- Strong local and regional economies that demand excess logistics and distribution capacity. As Figure 6 shows, container throughput in the Middle East region increases by 250% from 2001 to 2012 (Griffith, 2013).

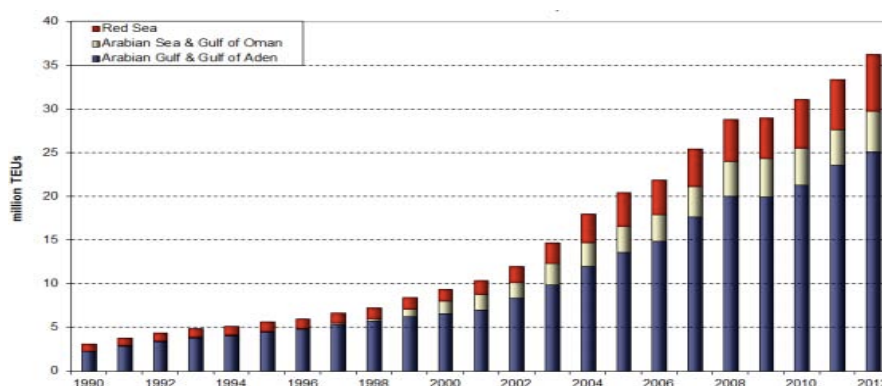


Fig 6. Middle East Container Throughput (1990-2012)

Source: Adapted from (Griffith, 2013)

- Lack of significant regional competition
As determined by the World Bank's Logistics Performance Index (LPI), the UAE is ranked 17 in 2012. LPI is a benchmarking tool comparing performance of logistics operations among 160 countries across the globe, based on indicators of 1) customs, 2) infrastructure, 3) international shipments, 4) logistics competence, 5) track and trace, and 6) timeliness (WB, 2012). LPI for UAE can be looked upon as a representative index for Dubai as it accounts for a major part of the logistics infrastructure in UAE (Fernandes and Rodrigues, 2011). Across the gulf region among competitor countries, Qatar ranked 33, Saudi Arabia 37, Oman 62, Kuwait 70, and Iran 112 (WB, 2012).

The structure of Dubai ports has been explained by three main attributes (Jacobs and Hall, 2007): physical, institutional and political. First, Dubai has the advantage of a strategic location as a bridge between east and west. However, the key to Dubai ports success is its superior facilities that are widely recognized as state-of-

the-art infrastructure and superstructure (Drewry, 2000). Second, the institutional arrangements are designed in a way to confer competitive supply chain advantages, e.g., no corporate or personal taxes, full foreign ownership in free zones, and attractive tariffs and discounts to shipping lines. Third, the Emirate of Dubai is under a governance structure fully supportive of a growth agenda, with encouraging and relatively easy implementation procedures. In terms of location, although Dubai is positioned favorably midway between Europe and Far East, it still does not own a superior locational advantage when compared with a number of other ports in the region. Therefore, the key attributes of its success and its main competitive advantage can be conclusively attributed to its superior facilities, and the availability of different transport modes that offer easy access to the entire region. These help position Dubai as a globally integrated logistics hub.

4.3. Container Traffic

Since the main concerns of the deep-sea container carriers in selecting ports are factors, such as depth of containership berth, port charges, rent and tax rates, port operation efficiency, and the hinterland economy (Chou, 2010), the process of resource picking and resource building for ports might appear a unified practice across the globe. However, the contrasting experience of Kaohsiung and Dubai has indicated that this is not the case. In addition to having far-sighted vision of building physical infrastructure that is hard to acquired in a short span of time, the stories of Kaohsiung and Dubai have demonstrated the need to constantly developing capabilities that utilized these capital-intensive resources to maritime advantages in respond to changing economic circumstances in the larger region.

Figure 7 shows the growth in container traffic of both Kaohsiung and Dubai, inserted with highlights of the major phases of infrastructural developments in both ports. Prior to 2000s, Dubai was experiencing a relatively slow rate of growth. Its growth took off in around 2002 and accelerated after 2004, when Dubai Ports International (DPI) acquired the CSX Terminals. Other than the slight dip during the global financial crisis, container traffic at Dubai Port has been on the increase. It should be pointed out that the share between transshipment cargo and cargo destined for UAE had remained relatively constant (between 45% and 50%) throughout this period, as indicated by the senior vice-president and managing director of DP world UAE region: "the volume in Jebel Ali port is quite balanced 50-50 percent in terms of transshipment and cargo which belongs to the UAE" (Wharton, 2013).

In contrast, the Port of Kaohsiung led a moderate growth prior to 2000s, marked by a continuous steady stream of physical infrastructural investment. The gradual increase in the transshipment rate reached the peak of 57% in early 2000s, following the removal of restriction governing the use of dedicated container terminal and the establishment of Offshore Shipping Centre in 1997. The container traffic of Kaohsiung Port recorded a relative modest growth from 2004 onwards, with a noticeable drop in 2008 and 2009, the years of the global financial crisis.

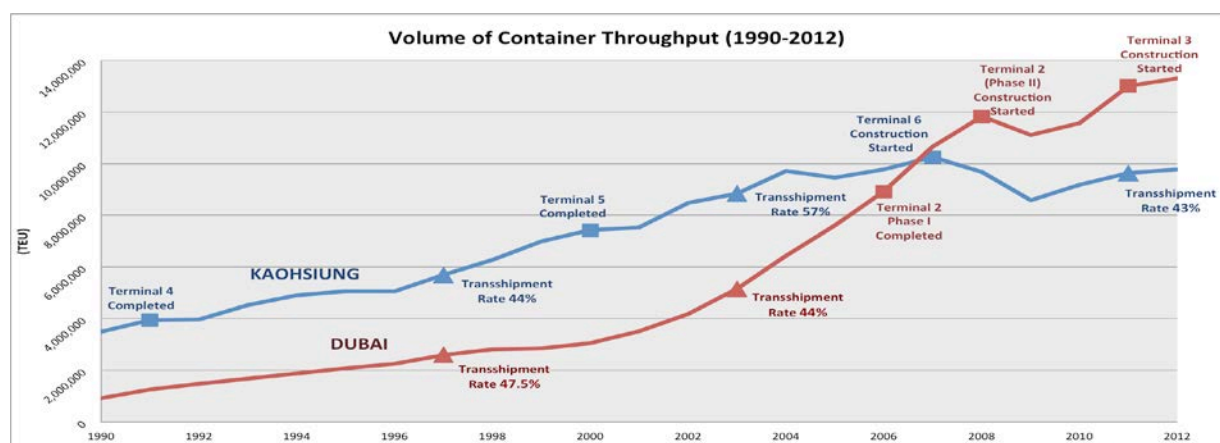


Fig 7. Volume of Container Throughput in Port of Kaohsiung and Dubai

5. Discussion of Results

Capability building programs that Dubai embarked upon is founded on major investments in infrastructure and superstructure, and in parallel with creation of the Free Trade Zone, which hosts regional production and distribution centers of global and multinational corporations utilizing the Dubai Port as its hub for distribution to regional locations. The port and free zone evidently share an interdependent relationship: the port's proximity attracts various value-added activities (e.g., assembling, labeling, repacking) into the free zone, and the free zone safeguards the transshipment cap of the port. In addition to the bundle of Port and Free Zone, the strategy of air-linking the local economy to the world through formation of an air hub (establishment of Emirates Airline) allowed Dubai to insert itself in the global production chain. In Dubai the entire mega project, comprising port planning, physical expansion and further advancement, were implemented in alignment. The infrastructural investments were not limited to ports, maritime, free zones and road transport facilities. The aviation industry and information technology systems were equally fundamental, as stated by Saidi et al. (2010): "Dubai is entering and creating a new geography where infrastructure and logistics with institutional trade facilities will multiply opportunities for trade and provide international connectedness for a region that has been, so far, on the periphery of global supply chains". Dubai Port's investment to expand its port-related physical infrastructure underscores a far-sighted vision of building tangible resources to spur, and accommodate, anticipated growth. Equally, its development path also suggests the importance of developing parallel capability building programs to ensure the optimal utilization of the expanding physical resources.

In the case of Kaohsiung Port, the development of its container terminals was based very much on a build-operate-transfer (BOT) scheme, i.e., operational facilities are built and paid for by the operators. Since container terminal investment is a major strategic decision based on cost-benefit analysis, not many deep-sea container carriers would be financially capable and interested in participating (Wiegmans et al., 2008). Despite its comparatively modest level of physical infrastructure development compared with Dubai, Kaohsiung Port did manage to gain a competitive status in global ranking during 1990s and early 2000s. This is due to a number of strategic initiatives, e.g., introducing EPZs and dedicated container terminals, which provided a complementary impetus to container traffic growth at the port. In addition, the experience of the Kaohsiung port also highlighted the importance of another attribute - a dynamically agile capability - to respond creatively to the exigency of the economic and political environments by the re-configuration of available resources, as demonstrated by the establishment of the offshore shipping center to overcome the restrictions imposed on cross-strait traffic between Taiwan and mainland China. As explained earlier, these initiatives did have an effect in boosting the transshipment traffic at Kaohsiung, which is vital for a port that does not have a sizeable physical hinterland.

6. Conclusions

From the RBV and dynamic capability perspective, the experiences of Kaohsiung and Dubai Ports indicate that there are three basic sets of valuable parameters critical to maintaining ports' competitiveness. Because modern port operations require the support of capital-intensive transport and logistics infrastructure that has a long delivery lead time, a far-sighted vision to invest in state-of-the-art port-related resources is a fundamental ingredient to develop a range of associated capabilities, which would be difficult for competitors to imitate in the short run. The second essential ingredient is the parallel development of a set of complementary resource utilization programs that fit well into the regional economic (and political) environment and the global trading patterns to ensure the optimal utilization of the expensive physical resources. The meteoric rise of Dubai Port can be largely attributable to the combination of these two rare, valuable, hard-to-imitate and hard-to-substitute resources.

The story of Kaohsiung Port does corroborate with the above argument, though the scale of physical infrastructure development had not been of the same scale and level as that of Dubai Port. The apparent lack of physical infrastructure investment during the early 2000s and the eventual dip in container port traffic at Kaohsiung Port in the late 2000s provides further evidence on the importance of having superior physical port-related resources. In addition, Kaohsiung Port's path to achieving competitiveness also exemplifies a third competitive ingredient: a dynamically agile capability to respond to and overcome external threats,

turning them into strategically beneficial opportunity. The staging of the Offshore Shipping Centre is the case in point.

The maritime environment is in a constant state of flux. While it is hard to anticipate the next wave of major changes, it is suffice to infer that, from the developmental experiences of Dubai and Kaohsiung Ports in the last 20 plus years, having a far-sighted vision to invest in state-of-the-art port-related infrastructure, supplemented by a program of complementary resource utilization programs and the building of a dynamically agile capability are three indispensable factors for ports to lay the foundation of their long term competitiveness.

As a n e xploratory study based e ntirely on publ ished i nformation, this pa per ha s a num ber of obv ious limitations. One of the most severe limitations is that the data reviewed may not be comprehensive and may contain many inaccuracies. Further an alyses a re w arranted w hen m ore i n-depth d ata b ecome av ailable. Moreover, the conclusion reached is limited to the analysis of Dubai and Kaohsiung ports. Extending the study to include other global ports, such as Hong Kong, Rotterdam, Shanghai and Singapore, would help augment the present findings, adding to our understanding of how global ports build their competitive strength.

References

- 2DAYDUBAI (2010), Dubai City Map Dubai Geography 2DAYDUBAI.
- Amirahmadi, H. and Wu, W. (1995), Export processing zones in Asia, *Asian Survey*, 35: 828-828.
- Baluch, I. (2005), *Transport logistics: past, present, and predictions*, Winning Books.
- Barney, J. (1991), Firm resources and sustained competitive advantage, *Journal of management*, 17: 99-120.
- Barney, J. B. (2001), Resource-based theories of competitive advantage: A ten-year retrospective on the resource-based view, *Journal of management* 27: 643-650.
- Carbone, V. and Gouvenal, E. (2007), Supply chain and supply chain management: appropriate concepts for maritime studies.
- Chen, C.-H. (2010), Study on Transshipment Flow at Kaohsiung Port.
- Chen, H.-H. N. (2002), Harbor City Under Globalization: Kaohsiung and Shanghai in Comparison. *Forum on Urbanizing World and UN Human Habitat II*: 101.
- Chen, T. (2007), Kaohsiung: Pending Direction. In: Cullinane, K. and Song, D.-W. (eds.) *Asian container ports: Development, Competition and Cooperation*, Palgrave Macmillan.
- Cheng, D. C.-Y. (2012), The New Era of Kaohsiung Port Port of Kaohsiung, Taiwan International Ports Co.
- Chien-Chang, C., Ching-Wu, C. and Gin-Shuh, L. (2003), Competitiveness analysis of major ports in Eastern Asia, *Journal of the Eastern Asia Society for transportation studies* 5: 1-16.
- Chou, C.-C. (2010), AHP model for the container port choice in the multiple-ports region, *Journal of Marine Science and Technology* 18: 221-232.
- Day, G. S. (1994), The capabilities of market-driven organizations. *Journal of marketing*, 58.
- DP (2011), Jebel Ali Port – Dubai's gateway to the world. *Port Planning, Design And Construction*, Port Technology International.
- DP. (2014a), Facilities and Services , <http://www.dpworld.ae/en/content.aspx?P=fxP7qHof%2fgsE0giJLkwR2A%3d%3d&mid=CW8SJWcj%2bhX1sqCpgEZqDA%3d%3d> (Accessed 10 March, 2014).
- DP. (2014b), Jebel Ali Port Performance, DP World, <http://www.dpworld.ae/en/content.aspx?P=DfQ08pya%2btZYFyPx5PV4ew%3d%3d&mid=BNTrRRiGfT6CY7uojhPjJA%3d%3d> (Accessed 15 March 2014).
- DP (2014c), Nurturing Trade, Geared for Growth In: World, D. (ed.) *Media Center Downloads DP World*
- Drewry (2000), *Middle East Container Ports and Shipping*, London: Drewry Shipping Consultants.
- Ducruet, C. (2009), Port regions and globalization. *Ports in Proximity: Competition and Coordination among Adjacent Seaports* 41-53.
- Economist, T. (2004), Dubai: Arabia's field of dreams.
- Eisenhardt, K. M. and Martin, J. A. (2000), Dynamic capabilities: what are they? *Strategic management journal* 21: 1105-1121.
- Fernandes, C. and Rodrigues, G. (2011), Dubai's Potential As An Integrated Logistics Hub. *Journal of Applied Business Research (JABR)*, 25.
- Fiol, C. M. (2001), Revisiting an identity-based view of sustainable competitive advantage, *Journal of Management* 27: 691-699.

- Griffith, I. (2013), Middle East Containerport Markets to 2025, Ocean Shipping Consultants.
- Haralambides, H. E. (2002), Competition, excess capacity, and the pricing of port infrastructure, *International Journal of Maritime Economics* 4: 323-347.
- Hayuth, Y. (2005), Globalisation and the port-urban interface: conflicts and opportunities, *International Workshop on Ports, Cities and Global Supply Chains*, Hong Kong, China.
- Helfat, C. E. and Peteraf, M. A. (2003), The dynamic resource-based view: Capability lifecycles, *Strategic Management Journal* 24: 997-1010.
- Helfat, C. E. and Raubitschek, R. S. (2000), Product sequencing: co-evolution of knowledge, capabilities and products, *Strategic Management Journal* 21: 961-979.
- Imin, C. (2012), Export Processing Zone Period of the Republic of China, Export Expansion Period, *Encyclopedia of Taiwan*.
- Jacobs, W. and Hall, P. V. (2007), What conditions supply chain strategies of ports? The case of Dubai, *GeoJournal* 68: 327-342.
- Javidan, M. (1998), Core competence: what does it mean in practice? *Long range planning* 31: 60-71.
- Kaohsiung (2013a), Port of Kaohsiung to Hold an Explanation Meeting Introducing Full Subsidy Scheme for Dockage and Towage Fees for Berth-shifting, Port of Kaohsiung, Taiwan International Ports Corporation, Ltd., http://www.khb.gov.tw/english/index_m_e.aspx?Link=News_List_E.aspx (Accessed 10 March 2014).
- Kaohsiung (2014), Facilities, Port of Kaohsiung, Taiwan International Ports Corporation, Ltd., http://www.khb.gov.tw/english/index_m_e.aspx?Link=Facility_List_E.aspx?id=246 (Accessed 10 Nov 2013).
- Kaohsiung (2012), Overall Map, Port of Kaohsiung, Taiwan International Ports Corporation, Ltd., http://www.khb.gov.tw/english/index_m_e.aspx?Link=Facility_List_M_E.aspx?id=420 (Accessed Oct 2013).
- Kaohsiung, P. O. (2013b) History, Port of Kaohsiung, Taiwan International Ports Corporation, Ltd., http://www.khb.gov.tw/english/index_m_e.aspx?Link=Facility_List_M_E.aspx?id=431 (Accessed 24 May 2013).
- Kaohsiung, P. O. (2013c), Port of Kaohsiung 2040 Master Plan Executive Summary, Comprehensive Planning and Development, Taiwan International Ports Corporation, Ltd.
- KAOPORT (2013), Transshipment Cargo Incentive, KaoPort Newsletter 54, Port of Kaohsiung.
- Makadok, R. (2001), Toward a synthesis of the resource-based and dynamic-capability views of rent creation, *Strategic management journal* 22: 387-401.
- Matly, M. & Dillon, L. 2007. Dubai strategy: past, present, future. Harvard Business School, 1-20.
- Meersman, H., Van De Voorde, E., Van Hooydonk E., Verbeke, A., Winkelmanns, W. and Huybrecht, M. (2002), Port competitiveness: an economic and legal analysis of the factors determining the competitiveness of seaports, *Antwerp, De Boeck Ltd* 39-41.
- Molavi, A. (2007), Dubai, The world's hottest property, *Sudden City*, National Geographic 94-113.
- Rugman, A. M. and Verbeke, A. (1993), How to operationalize Porter's diamond of international competitiveness, *The International Executive* 35: 283-299.
- Saidi, N., Scacciavillani, F., Ali, F. and Prasad, A. (2010), Dubai World Central and the Evolution of Dubai Logistic Cluster, *DIFC*.
- Thorpe, M. and Mitra, S. (2011), The evolution of the transport and logistics sector in Dubai.
- Veltz, P. (2001), City and university in the knowledge age, *European journal of engineering education*, 26: 53-62.
- World Bank (2012), Global Rankings 2012, International Lpi Global Ranking, The World Bank Group.
- Wernerfelt, B. (1984), A resource-based view of the firm. *Strategic Management Journal* 5: 171-180.
- Wharton (2013), Gulf Countries Navigate Billions into Mega Port Projects, *Knowledge@Wharton* (ed.). University of Pennsylvania, The Wharton School.
- Wiegman, B. W., Hoest, A. V. D. and Notteboom, T. E. (2008), Port and terminal selection by deep-sea container operators, *Maritime Policy & Management* 35: 517-534.
- Wright, P. M., Dunford, B. B. and Snell, S. A. (2001), Human resources and the resource based view of the firm, *Journal of Management* 27: 701-721.
- Yang, S.-H. and Chung, C.-C. (2013), Direct shipping across the Taiwan Strait: flag selections and policy issues, *Maritime Policy & Management* 40: 534-558.
- Yang, Y.-C. (2009), A Comparative Analysis of Free Trade Zone Policies in Taiwan and Korea based on a Port Hinterland Perspective, *The Asian Journal of Shipping and Logistics* 25: 273-303.

Research on Prosperity Index Constructing for Maritime Transport Market

Yifei Zhao¹ and Tatsuo Yanagita²

¹Antai College of Economics and Management, Sino-US Global Logistics Institute, Shanghai Jiao Tong University, P. R. of China.

²Department of International Studies, Graduate School of Frontier Science, The University of Tokyo, Japan.

Abstract

There are a lot of well-known indices in the global shipping market like as BDI, WS, Clarksea Index. Most of them focus on the freight of special markets. Although evidence shows that maritime freight indices have many functions and are widely used, they still have a lot of shortages in the business practice. For instance, some important factors like transport volume are neglected/excluded in these freight indices. Moreover, operating cost of shipping companies consists of fuel price, salary of crew, port charge and ship depreciation. The freight indices just give the price cycle of maritime transport and cannot describe the benefit situation.

For example, on Dec.5, 2008, WTI price of crude oil was 40.83USD/B, Brent price of crude oil was 37.18 USD/B, and BDI was 663 point. On Dec.28, 2012, WTI price of crude oil was 101.17USD/B, Brent price of crude oil was 110.32 USD/B, and BDI was 699 point. The evidence shows that carrier was more difficult on Dec.28, 2012. However, the evidence also shows BDI was higher on Dec.28, 2012. Therefore simply using any freight index framework cannot explain this phenomenon.

This paper proposes a new index named the prosperity index of global maritime transport (PIGMT) for better measuring and evaluating the conditions of the global maritime transport market and its trend. Not only freight rate is considered as a factor, but also the volume of transport, operation cost, and scale of fleet. Prosperity indices are usually used for describing the macro economy for countries or general situations of industries like as real estate, auto and petroleum. It is seldom to be found in some research papers or practice cases for shipping prosperity indices.

PIGMT is established by using the time series correlation analysis, cluster analysis, etc., classify these indicators into three categories of the preceding, the simultaneous and the lagging indicators; collect the statistics of the global maritime economy in recent eight years as a sample, illustrate global maritime transport prosperity indices and the results, and comprehensively assess the dynamic process of the global maritime transport industry prosperity.

PIGMT can be issued monthly or seasonally. The start point is set in Jan.2005 with 100. The biggest point would be 200 and the smallest point would be 0. The market is warm when the PIGMT is bigger than 100, or is cold when the PIGMT is less than 100. By doing so, PIGMT can be used as a more accurate barometer of global maritime transport.

1. Introduction

The relationship between maritime transport and world economy could be described as follows: 1) The development of world economy gives huge demand to global maritime transport industry, 2) The development of maritime technology supports the growth of world economy strongly, 3) The progress of maritime business model promotes the diversity of international trade and 4) The recession of world economy is crowning calamity to the maritime transport industry.

International trade drives the demand of maritime transport market. The scale of fleets in the world provides the capacity of maritime transport. In most cases of this market, the demand is in the leading position and is not affected by the internal factors of the market, the supply is in the passive position and its main task is to

meet the needs of international trade.

Cycles are not unique to maritime transport market, they occur in many industries. All of oil market, ore market, grain market and finance market appear cycle's wave. Because of the close relationship between commodity market and maritime transport market, cycles pervade the maritime transport industry. The cycles of maritime transport market is combined by three parts: long cycle, short business cycle and seasonal cycle. In the understanding of Martine Stopford, the main reason of long cycles is the global macroeconomic development cycle. The unbalance of vessel supply and transport demand causes the short business cycle. Seasonal cycle is caused by the life cycle of product. For example, wheat and cotton is in summer, rice and corn is in autumn, in winter more coal and oil are needed for keeping warm.

As the most famous maritime freight index, BDI is issued daily by Baltic Exchange based in City of London. Clarkson also issues series of sea freight indices named ClarkSea Index daily. Chen Feier and Zhao Yifei (2010) summarized the indices for maritime transport market. We found most indices in maritime transport market are about freight rate of voyage charter and time chartering rate. Only CCFI and SCFI issued by Shanghai Shipping Exchange focus on liner market. It is necessary to develop more indices for whole market, liner market and other sub-market.

2. The Reason of the Paper

2.1 The function of maritime freight indices

The function of maritime freight indices could be list as follows:

1) To help shipper and carrier to reach agreement on the freight rate

Freight rate is the important clause in bill of lading and charter party. Shipper and carrier could make their forecasts for the new freight rate by history freight index data. Then they can reach agreement of the freight rate easily. This is the basic function of maritime freight indices.

2) To help international trader to forecast the cost of maritime transport

When the international trade both sides negotiate contract content, maritime freight rate is an important part of commodity prices. Especially in the CIF and CFR conditions, sellers needs forecast the freight rate before chartering a vessel. In this situation, freight index could give them big support.

3) To help investor estimate the revenue of maritime transport companies

Maritime transport is the high risk and some time high revenue industry. According the research of Martin Stopford, sea freight rate used to be very low, sometimes suddenly rose to a very high level, and then dropped rapidly in a very short period. Therefore, in his book, the first sentence is "Shipping is a fascinating business".[1] No investor, no development of maritime transport. The confidence to the market and the future expected income are important means to attract investors. The sea freight indices are the good tools.

4) To provide a freight risk tool by Forward Freight Agreement

Before 1985, sea freight index was known only in shipping market. Appearance of BFI led sea freight indices to global finance market. FFA based on BDI is well known not only in maritime market, but also in global trade and finance market. BDI is called even the barometer of global economy. Carrier, trader, charterer, broker, banker and investor could reduce their freight rate risk by buying or selling FFA.

2.2 The shortage of sea freight indices

Although it is evidence that sea freight indices have so many functions and are widely used, they still have a lot of shortages in the business practice. There are some examples as follows:

1) The data source of sea freight indices is not comprehensive enough

At present, most of sea freight indices are mainly based on the prices provide by brokers. The main bodies of the market like as shippers and carriers seldom do this. Although the member of Baltic Exchange is over 550,

they still are a part of global shipping market. Indexers put more attention to the tanker and bulk markets but a few on others (like as ro-ro carrier market, chemical vessel market, new building market and demolition market). They have not set up efficient channels and systems to collect enough data to create new indices for other markets.

Shanghai Shipping Exchange created a series of indices for container liners like as CCFI and SCFI. Its data source also is very limited. The main channel is the freight filling system set by MOT of China. So SSE only has the data of Chinese export container freight by support from government and just could issues export freight index only for container liner.

2) Existing products of the sea freight indices just cover less than half of maritime market

Modern maritime transport market could be divided four parts: tanker market for liquid bulk, bulk carrier market for dry bulk, container liner market for products and other markets for large equipment, offshore supplier and automobile etc. Although the transport volume of tanker market and dry bulk market some time is over half of total sea transport volume, but the value must be lower. Each index like as BDI, BPI, BCI and BDTI just gives its price lever for one or several types of vessels. There is no index for total global maritime transport market now.

3) Freight rate is not the only feature of maritime transport market

On the other hand, for maritime transport industry, freight rate is just one feature for the revenue of shipping company. Volume of transport also is the factor that could influence the revenue. Moreover, operating cost of shipping company also should be concerned like as fuel price, salary of crew, port charge and ship depreciation.

For example, on Dec.5, 2008, WTI price of crude oil was 40.83USD/B, Brent price of crude oil was 37.18 USD/B, and BDI was 663 point. On Dec.28, 2012, WTI price of crude oil was 101.17USD/B, Brent price of crude oil was 110.32 USD/B, and BDI was 699 point. It is evidence that carrier was more difficult on Dec.28, 2012. BDI was higher on same day then on Dec.5, 2008.

There is no index that could give a reasonable explanation for the phenomenon like the case above.

4) Most of sea freight indices are for business not for the real world

All of the indices existing in maritime transport market are for business. The reasons are: a) the indexers are businessmen or companies like as Baltic Exchange and Clarkson, even SSE; b) the sponsors and users are businessmen or companies like as RBS, NYK, BHP and NSC etc; and c) business mechanism provides the power to be continuously improved for the indices system.

Although the market “was led by an invisible hand”, market failure still occurred occasionally. Maritime transport market is no exception. For example, BDI usually could give the freight rate lever of bulk market. But Baltic Exchange could not give the time and drop range for the rapid decline in 2008. After the incidents, the risks and opportunities could be found easily. Most of people wish to know what will happen tomorrow. BDI could not give the answer.

2.3 The purpose of research

Based on index theory, in defects of maritime freight indices, the purpose of research is to find a kind of index which could solve at least one shortage of above. This index should exhibit the future tendency, reflect the panorama of the global shipping market, and give an early warning for investors.

3. The Indices of Economy

3.1 General opinion for the indices of economy

According to the principle of economics, the market price reflects interaction between supply and demand. Each price corresponds to each kind of commodity or service in particular market. So that the sea freight rate

for specific goods is the result of interaction of international trade volume of this goods and capacity of global corresponding fleets in the market.

To show the commodity price lever compared with other region or other time, economists created a series of price indices by a normalized average (typically a weighted average) of price relatives for a given class of goods or services in a given region, during a given interval of time. Some notable price indices include: Consumer Price Index (CPI), Producer Price Index (PPI) and GDP deflator. This index method was used in particular products or services: WTI for oil, Platts for energy and metal, FPI for food, NASDAQ and NSA for stock, etc.

Most economists traditionally use a simple economic measure known as GDP to define prosperity. Whether measured in total for a country or on a per-capita basis, GDP is the most familiar and widely used measure of national progress. It captures the value of all goods in the economy—whether consumed by households, governments, or businesses—and as such, it is an extremely useful single measurement of a country's well-being.

In 2008 when the financial crisis happened, French president Nicolas Sarkozy created the Commission on the Measurement of Economic and Social Progress. Sarkozy believes that GDP is not a sufficient measurement of national well-being. While GDP encompasses myriad economic variables—broadly representing a nation's income and, hence, economic progress over time—it fails to capture important ingredients of prosperity, such as health, personal freedom, and security. Meanwhile some different opinions exist. Diane Coyle argues that GDP increasingly underestimates wellbeing, and therefore reports of economy's stagnation may be greatly exaggerated. There is no Great Stagnation. There is only a widening gap between the rate of economic improvement and the ability to measure that improvement.

As the most famous prosperity index, The Legatum Prosperity Index™ provides the world's only global assessment of prosperity based on both income and wellbeing annually since 2009. Its purpose is to encourage policymakers, scholars, the media and the interested public to take a holistic view of prosperity and understand how it is created. Holistic prosperity extends beyond just material wealth, and includes factors such as social capital, health, opportunity, security, effective governance, human rights and liberties, and overall quality of life.

3.2 *The research on prosperity index*

To exactly and iconically describe the business cycle, the National Bureau of Economic Research (NBER) developed a system of leading, coincident, and lagging economic indicators in the 1930s. Now this system has been widely used in not only the United States but also European countries, China, Japan, Canada, etc. to appraise the state of the business cycle. Because of differences in content or methodology, however, these independent efforts do not provide comparable materials. In 1973 the NBER began to develop an international economic indicator system (IEI) that would provide comparable data, organized and analyzed in a comparable manner, for a number of industrial countries. The Center for International Business Cycle Research at Rutgers University in New Jersey has continued this work since 1979. The research has demonstrated that such a system can be helpful in tracking an international recovery or recession, in revealing factors that are holding back recovery or leading to recession, in anticipating changes in foreign trade flows, and in providing early warning of new inflationary trends. The Organization for Economic Cooperation and Development (OECD) and statistical agencies in Canada, the United Kingdom, West Germany, France, Italy, Japan, and the United States have cooperated with the NBER and with the Rutgers Center in compiling and analyzing the current data for this system of indicators. The practical results of this research program are now available for use.

Legatum Institute makes a good progress on the application of prosperity index. This also induces the research on the prosperity index in the global maritime transport market.

4. **Construction of PIGMT**

4.1 *Framework of PIGMT*

According to the methodology of IEI, there are three indicator groups: leading, coincident, and lagging indicators. Link them to global maritime transport market, framework of PIGMT could be list in Fig.1.

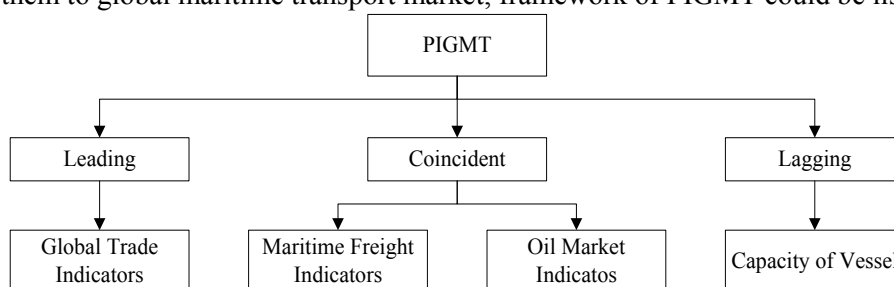


Fig 1. Framework of PIGMT

After analyzing the indicators of macro economy, international trade, maritime freight rate and maritime transport capacity, according to the demand of calculation for prosperity index, 11 trade indicators, 8 freight indicators, 5 maritime transport volume indicators, 6 maritime transport capacity indicators, total 30 indicators were selected as the members of prosperity index of global maritime transport. 8 of them are dimensionless. Others have 7 kinds of various dimensions. Of particular note is, in these 30 indicators, 21 positive and 9 negative correlations with PIGMT. These 9 negative indicators are marked with * in the 1.

Table 1. The Indicators System for PIGMT

	Character	Indicator	Dimension
Leading indicators	Trade Value	Grain	Million US Dollars
		Iron ore	
		Coal	
		Crude oil	
		Products	
	Future Freight Agreement	Dry FFA	/
		Tanker FFA	/
		Liner FFA	/
Coincident indicators	Future Price of Crude Oil	Brent*	US Dollars/barrel
		ALCOP*	US Dollars/barrel
	Transport Volume	Grain	Million Tons
		Iron ore	
		Coal	
		Crude oil	
		Container	Million TEU
	Freight Rate	BDI	/
		BCI	/
		BPI	/
		BDTI	/
		CTRI	/
	Price of Fuel	380 Singapore*	US Dollars/ton
		380 Rotterdam*	US Dollars/ton
		MDO Singapore*	US Dollars/ton
		MDO Rotterdam*	US Dollars/ton
Lagging indicators	Orderbook capacity	Bulk	Million tons
		Tanker	Million tons
		Container	Million TEUs
	Present capacity	Bulk*	Million tons
		Tanker*	Million tons
		Container*	Million TEUs

1) Leading indicators

Leading indicators are indicators that usually change before the economy as a whole changes. They are therefore useful as short-term predictors of the economy. For global maritime transport market, various global trade indicators are in the leading group. As there are a lot of indicators in global trade market, the identification of specific indicators will be based on the requirement to select algorithm and the data characters.

2) Coincident indicators

Coincident indicators change at approximately the same time as the whole economy, thereby providing information about the current state of the economy. A coincident index may be used to identify, after the fact, the dates of peaks and troughs in the business cycle. Coincident indicators of PIGMT are mainly from global transport market. As fuel price is the important factor for cost of maritime transport industry, some indicators of global oil market should be considered. The identification of specific indicators will be based on the requirement to select algorithm and the data characters.

3) Lagging indicators

Lagging indicators are indicators that usually change after the economy as a whole does. Typically the lag is a few quarters of a year. From the side of supply chain, new building and demolition of vessels is guide by maritime transport industry. Therefore some indicators of ship market will be considered in lagging group. The identification of specific indicators will be based on the requirement to select algorithm and the data characters.

4.2 Hypothesis

There are seven hypotheses as follows for PIGMT:

1) PIGMT issued monthly

The reasons of PIGMT issued monthly are three points: a) From characteristic of prosperity index, they only characterize the situation of macro economy or industry economy, not for pricing. So most of prosperity index is issued monthly, seasonally and annually; b) From the side of investment on vessels or shipping companies, it is not necessary for investors to know the prosperity index daily or weekly. A continuous monthly prosperity index is enough and c) Some original data like as value of global international trade is issued only monthly.

2) If related to money, the indicator is denominated in US dollar

There are 11 indicators which dimension is related to money (read table1). They already are denominated in US dollar fortunately. This hypothesis is for index adjustment when non US dollar denominated indicator chosen.

3) Regardless of the fluctuation of exchange rate

This hypothesis is related to 2). If a non US dollar indicator be changed to be denominated in US dollar, the nominal exchange rate can be used.

4) Regardless of changes in the value of US dollar

This hypothesis is related to 2) and 3). If any US dollar indicator be chosen, only the current value of US dollar is used because PIGMT is also the current.

5) If the chosen indicator issued monthly, the data will be used regardless its method

There are 10 indicators issued monthly in table 1. They are in trade group and transport volume group. In addition to a number of indicators both daily and weekly data, they also have monthly data, for example BDI, BCI, BPI, etc. If the publisher of indicator provides monthly data, this data will be used, regardless of its conversion method.

6) If the chosen indicator issued weekly or daily, the data will be changed monthly from the arithmetic mean value of period real issued data.

Some indicators are issued daily and weekly. Their publishers do not provider monthly data for them like as

the indicators in FFA and price of fuel groups. In this situation, the daily data or weekly data will be converted to monthly data by the arithmetic average method.

7) PIGMT is dimensionless

Finally, PIGMT must be dimensionless as the chosen indicators have different dimensions. Actually, most of prosperity indices are dimensionless as they are also composite indices. For this reason, it is necessary for every indicator to be removed dimension.

4.3 Algorithm

For calculation of PIGMT, three points are important: weights of indicators, dimensionless and calculation formula of PIGMT.

1) Calculation for weight

Fig.1 gives the indicator framework of PIGMT. But this framework makes the weight calculation difficult as comparing intricate. If changing the indicator framework to Fig. 2, it is easier to compare the indicators using weighting method of AHP.

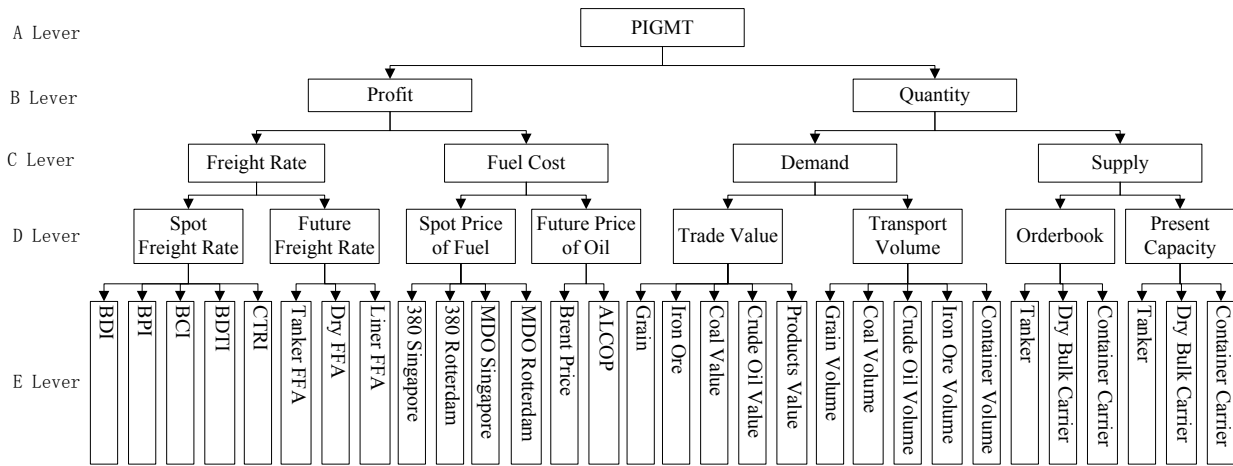


Fig 2. Weight Framework of PIGMT

There are five levers in the framework. The weights of lower lever indicators to higher lever indicator can be given by industry counselors.

$$w_i = \prod_{l=1}^e w_{il} \quad (1)$$

In formula 1,

w_i — weight of no. i indicator

l — lever number of indicator

e — less 1 than amount of levers in the indicator framework

w_{il} — weight of the indicator in l lever to upper lever, given by industry counselors

For y indicator, if there are x indicators in next down lever, then to y indicator, the sum of weights of indicators in the lever must be 1.

$$\text{That is: } \sum_{x=1}^k w_x = 1$$

According to the regulation above, the w_i for every indicator can be calculated.

2) Dimensionless

For 7th hypothesis above, it is necessary to remove the dimension for all of indicators. As there are 21 positive indicators and 9 negative indicators, the dimensionless methods are different.

a) For positive indicator

Formula 2 can be used to remove the dimension for positive indicator.

$$I_{pt} = \frac{I_t}{I_0} \quad (2)$$

In formula 2,

I_{pt} — dimensionless value of positive indicator at t time

I_t — value of indicator at t time

I_0 — original value of indicator

b) For negative indicator

Formula 3 can be used to remove the dimension for negative indicator.

$$I_{nt} = \frac{I_0}{I_t} \quad (3)$$

I_{nt} — dimensionless value of negative indicator at t time

3) Calculation formula of PIGMT

Based on research above, the calculation formula of PIGMT can be provided as formula 4.

$$PIGMT_t = \sum_{i=1}^p 100 \times w_i \times \frac{I_{it}}{I_{i0}} + \sum_{j=1}^n 100 \times w_j \times \frac{I_{j0}}{I_{jt}} \quad (4)$$

In formula 4,

$PIGMT_t$ — value of prosperity index of global maritime transport at t time

i — serial number of positive indicator

p — amount of positive indicators

w_i — weight of no. i positive indicator

I_{i0} — original value of no. i positive indicator

I_{it} — value of no. i positive indicator at t time

j — serial number of negative indicator

n — amount of positive indicators

w_j — weight of no. j negative indicator

I_{j0} — original value of no. j negative indicator

I_{jt} — value of no. j negative indicator at t time

4.4 Results of PIGMT

Based on formula 4, the value of PIGMT at t time can be calculated. Middle value of PIGMT is 100. Different value of PIGMT gives different situation of global maritime transport market like as table 2.

Table 2. Color for Prosperity of Global Maritime Transport Market

Value of PIGMT	Situation of global maritime transport market	Color for Prosperity
$180 < \text{PIGMT} \leq 200$	Heat death	Red
$160 < \text{PIGMT} \leq 180$	Overheated	Light Red
$140 < \text{PIGMT} \leq 160$	Hot	Pink
$120 < \text{PIGMT} \leq 140$	Warmer	Yellow
$100 < \text{PIGMT} \leq 120$	Warm	Light Yellow
$80 < \text{PIGMT} \leq 100$	Cool	Light Green
$60 < \text{PIGMT} \leq 80$	Cold	Green
$40 < \text{PIGMT} \leq 60$	Freeze	Light Blue
$20 < \text{PIGMT} \leq 40$	Iced	Blue
$0 \leq \text{PIGMT} \leq 20$	Winterkill	Dark Blue

5. Testing and assessment for PIGMT

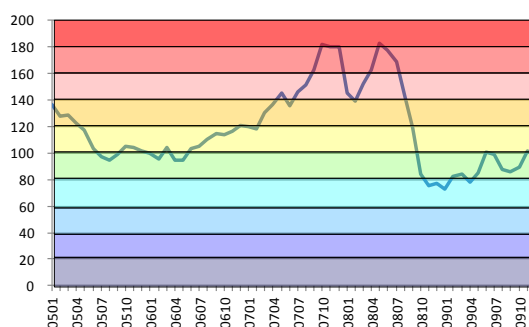
5.1 Testing for PIGMT

Many thanks for the data supply to Clarkson Research Service Ltd., World Trade Organization Statistics Database, UNCTAD Stat., Baltic Exchange, Intercontinental Exchange, Inc. and US Energy Information Administration. Many thanks for the development of internet technology. Without them, it is impossible to develop the PIGMT. From their electronic databases, the data of most indicators since 1999 in table 1 could be searched. But the data of FFA of BDI started after 2004, and the data of FFA for liner market started after 2010. So the three indicators of FFA cannot be considered in indicator system.

After calculation, a set of reasonable result can be list as table 3. The initial 100 point was set in January 2006.

Table 3. The Test Calculate Result for PIGMT

Month	2005	2006	2007	2008	2009
Jan	136.37	100.00	120.09	145.22	72.34
Feb	128.06	95.50	118.60	138.86	82.24
Mar	128.59	104.55	130.52	152.59	84.08
Apr	122.13	94.43	136.28	162.29	78.23
May	116.90	94.69	145.42	183.15	84.79
Jun	103.77	102.98	135.31	177.52	100.40
Jul	97.07	104.73	146.39	168.83	98.70
Aug	94.37	110.71	150.97	143.14	87.80
Sep	98.85	114.64	162.51	118.86	86.29
Oct	105.05	113.85	182.14	84.37	89.58
Nov	104.10	116.22	179.89	75.66	101.72
Dec	101.83	120.93	179.82	76.77	96.97

**Fig 3. Test Result Curve for PIGMT (Jan 2005 — Dec 2009)**

The curve of PIGMT (2005-2009) was showed as Fig. 3. This curve told us the global maritime transport market was warm and warmer in most time from January 2005 to February 2007, but overheated in fall and winter 2007 and in spring and summer 2008. As the impact of the financial crisis 2008, the global maritime transport market went to cold in six months. At that period, the price of oil also fell rapidly, the lowest point just be 72.34 in January 2009. It was not too cold.

5.2 Assessment for PIGMT

1) Compared with real data of shipping company

To inspect the accuracy of PIGMT, the profit data (Jan 2005 – Dec 2009) of a famous Chinese state owned large shipping group company was processed as fig.4. Compared with fig. 3, the shape of curve in fig. 4 was quite similar if 2 singular points (a, b) be cancelled. These 2 points happened at the end months in these two years.

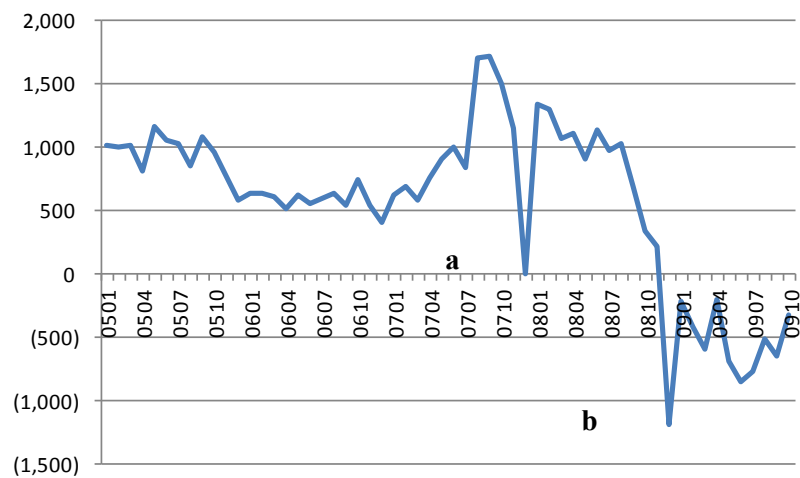


Fig 4. Profit Index of A Shipping Group (Jan 2005 – Oct 2009)

2) Further calculation

Further calculation is to collect more 27 months data and to calculate the PIGMT in the periods. Table 4 gives the calculate result for PIGMT. Fig. 5 gives the four curves for the 3 years and 3 months. It shows that the most terrible situation did not happen in end of 2008 and beginning of 2009. After 6 months, the global maritime transport market became little warm as the governments launched aggressive monetary policy to slow the economy recession. Effect of these policy lasted for about two years. With the sustained downturn of the global economy and the durative high price of crude oil, since the January 2012, the global maritime transport market became more and more cold.

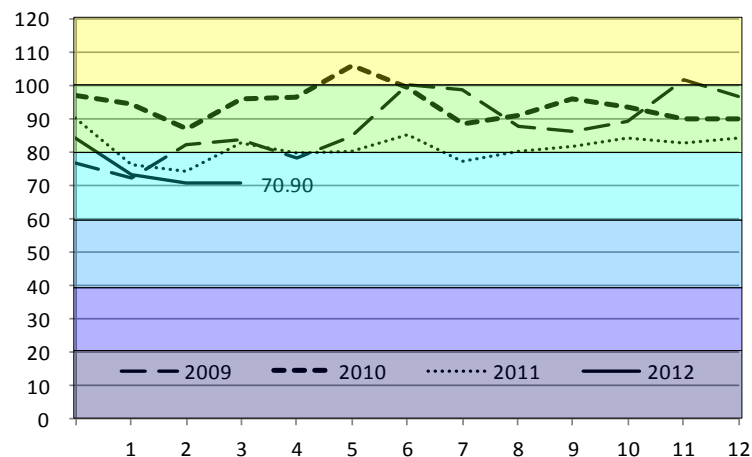


Fig 5. PIGMT Curve (Jan 2009 — Mar 2012)

Table 4. Calculate result for PIGMT (Jan 2009 — Mar 2012)

	2009	2010	2011	2012
1	72.34	94.66	76.61	73.40
2	82.24	87.14	74.53	70.95
3	84.08	96.32	83.00	70.90
4	78.23	96.58	79.64	
5	84.79	106.03	80.58	
6	100.40	99.77	85.55	
7	98.70	88.68	77.25	
8	87.80	91.23	80.61	
9	86.29	96.05	81.91	
10	89.58	93.44	84.13	
11	101.72	90.06	82.68	
12	96.97	90.24	84.22	

6. Summary

There are many large scale global maritime transport companies whose stock values are over billion US dollars. These companies have not only dry bulk carriers but also tankers, box carriers and other type vessels. BDI just gives the freight lever in global dry bulk market, BDTI just gives the charter rate lever in global tanker market, CCFI just gives the freight lever in Chinese liner market. There is no global maritime transport index supplier now. This research gives the possibility to develop a kind of index for global maritime transport market. People can measure the trends of the market by using existed data without a large numbers of investigation even interviews. Research shows that the calculation method is easy and results are reliable.

There are 3 problems to be solved: a) to add more indicators which can be representative for the relative markets like as FFA, liner and other submarkets, b) to make the weight more reliable and c) to find more accurate algorithm. Again, this paper is only an exploratory. Comments welcome and wish more faculties and experts join the discussion.

Reference

- Bate, Roger (2009), What Is Prosperity and How Do We Measure It?
- Chen, Feier and Zhao, Yifei (2010), Research on Shipping Indexes' Suggestions to Shipping and Financing Centers Construction, Navigation of China 2: 100-105.
- Coyle, Diane (2014), GDP: A Brief but Affectionate History, Princeton and Oxford: Princeton University Press.
- Legatum Institute (2013), The 2013 Legatum Prosperity Index™, http://media.prosperity.com/2013/pdf/publications/PI2013Brochure_WEB.pdf.
- Moore, Geoffrey H. (1983), Business Cycles, Inflation, and Forecasting (Second edition), Cambridge, Mass: Ballinger Publishing Company 65 – 92.
- Qu, Lin Chi and Liu, Xun Liang (2013), Who Decided Shipping Indices?, Pearl River Water Transport 2.
- Smith, Charles Emrys (2009), Economic Indicators in C. Wankel (ed.), Encyclopedia of business in Today's World, California, USA.
- Stopford, Martin (2009), Maritime Economics (3rd edition), London, Routledge,
- Sullivan, Steven and M. Sheffrin (2003), Economics: Principles in Action, New Jersey, USA: Pearson Prentice 314.
- Zhao, Yifei and Hu, Jin (1999), Weight Calculation of the Intrinsic Qualification Factors in Survey of Comprehensive, Journal of Shanghai Jiao Tong University (Social Sciences Edition) 1(7): 63-69.

Shipping Market Integration – The Case of Sticky Newbuilding Prices

Roar Adland

Department of Economics, Norwegian School of Economics, 5035 Bergen, Norway

Abstract

In this paper we derive an equation defining contemporaneous equilibrium prices across the four shipping markets: the newbuilding market, the second-hand market, the demolition market and the freight market. The model requires rather general conditions, namely that (i) all second-hand ships are priced based on linear depreciation down to scrap value, (ii) expectations of the future scrap value and lifespan of the vessel are equal to current values and (iii) the term structure of (timecharter) freight rates is observable. In the empirical part of the paper we use this equilibrium relationship to illustrate the presence of a “term structure of newbuilding prices” and show that the lower volatility of newbuilding prices compared to second-hand values is a result of a time-varying delivery lag which is positively correlated with the alternative cost of operating in the freight market. These observations are important for statistical analysis of the dynamics of ship values.

Keywords: newbuilding prices, market integration, term structure

1. Introduction

One of the remaining puzzles in maritime economics is the observation that newbuilding prices appear exogenous or inelastic with respect to the demand for new vessels. Put differently, newbuilding prices are too “sticky” or insufficiently volatile given the often rapid changes in market fundamentals. This long-held belief appears to have started with Zannetos (1966) who states (p.80) that newbuilding ‘prices, however, are neither explosive nor are they perpetually establishing new lows...these shifts do not bring about a balance in supply and demand but are, instead, disequilibrating’. The explanation has traditionally been one of externalities and organizational rigidities. Zannetos (1966) argues that, in times of shipbuilding overcapacity, shipyards have a incentive to smooth out production across the cyclical low to avoid job cuts and maintaining knowledge and competency levels. Given that such social functions are left out of economic models, newbuilding prices will appear sub-optimal. Strandenes (2002) suggests that the strong presence of labour unions in the shipbuilding industry has led to lower flexibility and that the presence of subsidies distorts newbuilding prices. Dikos (2004) suggests that an alternative explanation can be found within the framework of a functioning competitive equilibrium if the actions of shipyards are interpreted as a result of exercising real options (to offer capacity) under uncertainty. In particular, within the traditional framework of investment under uncertainty (see, for instance, Dixit and Pindyck, 1994), there will exist an upper threshold level for the newbuilding price that would immediately trigger many yards to offer capacity. Yards would rationally anticipate this, imposing an upper reflecting barrier to the price process that can account for the lack of volatility in newbuilding prices when compared with charter rates.

However, a newbuilding contract, a resale (the sale of a ship under construction) and a modern vessel are near perfect substitutes from the viewpoint of the shipowner. Ignoring technological differences, they will only differ in terms of price and time to delivery (i.e. the time the asset starts to generate revenue). Moreover, most shipowners are price takers competing for yards lots and existing tonnage in a competitive market. Consequently, while subsidies may affect the *level* of the newbuilding price, this will instantaneously ripple through to the second-hand market such that market agents are indifferent between ordering a newbuilding at the prevailing contracting price and buying a resale or an existing vessel. In this framework, none of the possible imperfections mentioned in the literature will actually affect the integration of the newbuilding, second-hand and freight markets and, conversely, the corresponding volatility of prices is completely described by the dynamic equilibrium between the markets. In the maritime economic literature, the assumed degree of market integration and, consequently, the approach to modeling the markets, has changed over time.

Beenstock (1985) assumes that new and second-hand ship prices are perfectly correlated, though he observes that this condition is unlikely to hold because newbuilding prices are “sticky” compared to second-hand prices. In subsequent work (Beenstock and Vergottis, 1989), this stringent assumption is relaxed by separate dynamic modeling of the newbuilding market. Strandenes (1984, 1986) defines the long-run expected earnings of a vessel based on its newbuilding price and assumes that the second-hand value is a weighted average of short and long-term freight earnings. Tsolakis et al (2003) investigate second-hand prices in an Error Correction Model with a theoretical basis and find that newbuilding prices and timecharter rates are the main drivers. Adland et al. (2006) test the instantaneous equilibrium relationship between second-hand values, contracting prices and freight rates in a Vector Error Correction model framework and accounts for the time-varying delivery lag. Their empirical tests suggest that the second-hand market for bulk carriers is closely cointegrated with the fundamental freight and newbuilding market, with no evidence of a short-term “asset bubble” even in the boom years in the early part of the century. Greenwood and Hanson (2013) argue that ship prices are way too volatile given the observed mean reversion in freight earnings and propose a behavioral model where firms over-extrapolate exogenous demand shocks and partially neglect the endogenous investment responses of their competitors. Their formal estimation of the model confirms that both types of expectational errors are needed to account for the empirical evidence. Recent research has followed up on the importance of “time to build” in terms of market volatility. Kalouptsi (2014) examine the impact of construction lags and their lengthening in times of high investment activity by constructing a dynamic model of entry and exit from the shipping markets. Kalouptsi finds that moving from time-varying to constant to “no time” to build reduces prices while increasing both the level and volatility of investment.

In this paper we propose an entirely new line of reasoning that does not contradict with market efficiency – namely that newbuilding prices are not actually comparable across time because the parameters of the newbuilding contracts (primarily the delivery lag and payment schedules) will vary. In other words, the observation that newbuilding prices are “sticky” is largely a result of systematic changes in the specification of the newbuilding contract underlying the price index. The contribution of this paper to the literature is threefold. Firstly, we derive a new and simple single-equation model that relates contemporaneous prices in all four shipping markets (newbuilding, secondhand, freight and demolition) in equilibrium. Secondly, we use this model to illustrate the presence of a term structure of newbuilding prices and why a time-varying delivery lag means newbuilding and second-hand values are not directly comparable. Thirdly, we show how a time-varying delivery lag that is positively correlated with the freight market will result in “sticky” newbuilding prices and that this is not a sign of market inefficiency. The remainder of this paper is organized as follows. Section 2 derives the equilibrium relationship between contemporaneous prices in the four markets, Section 3 illustrates empirical applications related to the term structure and volatility of newbuilding prices and Section 4 concludes.

2. Defining Market Integration

In this section we define mathematically the equilibrium condition where investors are indifferent between investing in the second-hand and newbuilding markets. Let $F_t(\tau)$ be the net present value at time t (current time) of the payments to the shipyard according to a newbuilding contract for a ship delivered at the future time τ . We note that, in general, $F_t(\tau)$ need not correspond to the quoted newbuilding price in the market as payment schedules (both timing and percentages) tend to vary with market conditions¹. Furthermore, let $S_{t,0}$ and $S_{t,\tau}$ be the second-hand value at time t of ships of age zero and τ , respectively. We define the net present value of the profit earned by a modern ship between time t and time τ as

$$I_{t,\tau} = \sum_{i=t}^{\tau} \frac{TC_{t,\tau} - OPEX}{(1 + r_{t,\tau})^{\tau-t}} \quad (1)$$

where $TC_{t,\tau}$ is the prevailing period timecharter rate at time t for the duration $(\tau - t)$ years, $r_{t,\tau}$ is the risk-free interest rate for the corresponding maturity and OPEX is the daily operating cost for a modern vessel. Finally, let Z_t be the scrap value of the vessel and T_t be its life expectancy. We follow the results in Adland and Koekebakker (2007) and assume that all second-hand ships are priced based on linear depreciation down to scrap value. The linear depreciation function at any future time $\tau \in [0, T)$ can be written as:

$$S_{\tau,\tau} = Z_{\tau} + (S_{\tau,0} - Z_{\tau}) \frac{T_{\tau} - \tau}{T_{\tau}} \quad (2)$$

In the remainder of the paper we will assume that investors have myopic expectations with regards to the vessel life expectancy and scrap value such that $E_t(Z_{\tau}) = Z_t$ and $E_t(T_{\tau}) = T_t$. Put differently, investors do not expect the scrap value or the expected useful economic life of the vessel type to change between time t and τ .

Given that future vessel values are uncertain, we can interpret the investment in a newbuilding contract or, alternatively, a brand new vessel, as having uncertain payoffs. If you invest in a newbuilding contract, the known payment stream with net present value of $F_{t,\tau}$ will result in the ownership of a brand new (age zero) vessel upon delivery at time τ . In other words, the payoff in present value terms is given by:

$$F_{t,\tau} = \frac{1}{(1 + r_{t,\tau})^{\tau-t}} S_{\tau,0} \quad (3)$$

Alternatively, an investment in an existing brand new vessel provides a known freight income from the period timecharter market plus an uncertain residual value of a vessel with age τ at the future time τ . Formally, we can write the latter as:

$$S_{t,0} = I_{t,\tau} + \frac{1}{(1 + r_{t,\tau})^{\tau-t}} S_{\tau,\tau} \quad (4)$$

In equilibrium, prices have adjusted such that shipowners are indifferent between these two investment alternatives. Therefore, substituting Equation 2 into Equation 4 we get

$$S_{t,0} = I_{t,\tau} + \frac{1}{(1 + r_{t,\tau})^{\tau-t}} \cdot \left[Z_{\tau} + (S_{\tau,0} - Z_{\tau}) \frac{T_{\tau} - \tau}{T_{\tau}} \right] \quad (5)$$

which, using Equation 3, can be rewritten as

$$S_{t,0} = I_{t,\tau} + \frac{1}{(1 + r_{t,\tau})^{\tau-t}} \cdot \left[Z_{\tau} + (F_{t,\tau} \cdot (1 + r_{t,\tau})^{\tau-t} - Z_{\tau}) \frac{T_{\tau} - \tau}{T_{\tau}} \right] \quad (6)$$

which, assuming $Z_{\tau} = Z_t$ and $T_{\tau} = T_t$ for all τ , can be further shortened to

$$S_{t,0} = I_{t,\tau} + F_{t,\tau} \frac{(T_t - \tau)}{T_t} + \frac{Z_t \cdot \tau}{T_t} \frac{1}{(1 + r_{t,\tau})^{\tau-t}} \quad (7)$$

Under the above assumptions, Equation 7 defines the equilibrium relationship between the prices in all the four shipping markets at time t . It follows that if we know, for instance, the current value of a new vessel $S_{t,0}$, the applicable timecharter rate and the scrap value Z_t , we can derive the theoretically consistent newbuilding contract value $F_{t,\tau}$. We note that in the theoretical case of immediate delivery ($\tau = 0$), Equation 7 is reduced to a simple equality between the resale price for an age-zero vessel and the newbuilding price, as expected. Importantly, Equation 7 allows for the possibility of a time-varying delivery lag ($\tau - t$). Our equilibrium equation requires rather general conditions, namely that (i) all second-hand ships are priced based on linear depreciation down to scrap value, (ii) expectations of the future scrap value and lifespan of the vessel are equal to current values and (iii) the term structure of (timecharter) freight rates is observable.

3. The Term Structure of Newbuilding Prices

When discussing shipbuilding capacity it is useful to distinguish between capacity to build (say, global compensated gross tonnes produced per year) and the ordering capacity. The former is clearly constrained in the short run by the number of drydocks and other areas of ship assembly, while the latter has no theoretical capacity since a yard will book its building slots also for future use. There exists, in fact, a term structure of newbuilding prices, describing the combinations of cost and time to delivery between which shipowners would be indifferent. If the opportunity cost of time for the operation of modern vessels is positive, this term structure will be downward sloping such that early delivery slots (and resales) command a premium over deliveries further into the future. Given that the quoted newbuilding price in the market refers to the prevailing typical time to delivery, which will necessarily vary with the size of the orderbook and developments in shipyard productivity, the assumptions underlying the observations will therefore result in a time series that is inconsistent across time. Drawing empirical conclusions on this basis, in relation to price volatility or otherwise, may therefore be severely misleading, though the literature has hitherto not acknowledged this problem.

The delivery lag is often interpreted as the time required building a ship (cf. “time-to-build” as in Kalouptsi, 2014), though in practice this is usually not the main component. Rapid development of shipyard technology and productivity over the last 20 years, with the aid of computerised steel cutting and modular ship sections, means a large tanker can be built in a matter of several months. The actual delivery time between the contracting date and handover is instead largely decided by the availability of time slots in the drydock facilities of the individual yard, which again depends on the size and composition of its orderbook and the bargaining power of the customer. However, subject to differences in quality and customisation, the competitive nature of the shipbuilding market and the dissemination of information by newbuilding shipbrokers means that contracting prices and chronological slot availability do not differ much among the main shipbuilding groups. It is worth emphasising that the different types of ships will compete for the same slots, and so the delivery lag for bulk carriers, for instance, will be influenced by the demand for other ship types such as tankers and gas carriers. The empirical results in Adland et al (2006) suggests that there is no clear relationship between the size of the ship and the delivery lag, presumably as smaller vessels will tend to be built by smaller less efficient yards. It follows from the above that estimates of the time-varying delivery lag should be based on the entire orderbook across vessel types and shipyards, but with a focus on a particular size range for the sake of consistency.

For the sake of illustrating the shape of the term structure of newbuilding prices we rewrite Equation 7 in terms of $F_{t,\tau}$:

$$F_{t,\tau} = \left[S_{t,0} - I_{t,\tau} - \frac{Z_t \cdot \tau}{T_t} \frac{1}{(1 + r_{t,\tau})^{\tau-t}} \right] \frac{T_t}{(T_t - \tau)} \quad (8)$$

Keep in mind that $F_t(\tau)$ is the net present value at time the current time t of the payments to the shipyard according to a newbuilding contract for a ship delivered at the future time τ , which is generally not equal to the quoted newbuilding price in the market as payment terms are not standardised. In the numerical examples below we have assumed 20% payment upfront and the remaining 80% upon delivery of the vessel.

Our empirical estimates concerns the Capesize bulk carrier segment (100,000 DWT+). Clarkson Research Ltd. provided data for period time charter rates, resale prices, average scrapping age by year and average delivery lags by order year, the latter two of which are illustrated in Figure 1 below. The risk-free interest rates on 6-month, 1-year, 3-year and 5-year constant-maturity U.S. Treasury securities were obtained from the H.15 statistical release of the Federal Reserve. We assume daily operating costs (OPEX) of \$8,000/day.

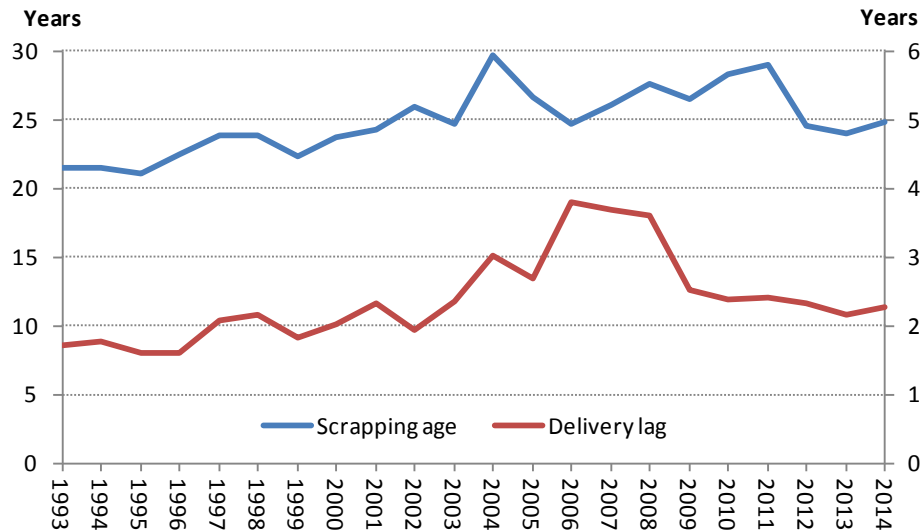


Fig 1. Capesize Scrapping Age and Delivery Lag
Source: Clarkson Research Ltd.

We note that both delivery lag and scrapping age increased sharply during the drybulk freight market boom between 2003 and 2008, with owners having to wait up to four years for delivery.

Next, using Equation 8 we can illustrate the shape of the term structure of newbuilding prices as shown in Figure 2 below. At these points in time, the actual delivery lag was around 2.4 years as indicated by the arrow. We note that the term structure is downward sloping, reflecting mainly the alternative cost of operating an existing ship at period timecharter rates that, at least for periods longer than a year, will always cover our assumed operating cost level. Figure 2 already points to why the volatility of newbuilding prices *should be* lower than that of existing vessels (resale ships with immediate delivery, in this case): Good markets, which would be associated with both long delivery lags (high τ values) and a steep term structures of freight rates, and therefore a steep term structure of newbuilding prices (ref. the impact of $I_{t,\tau}$ in Equation 8) will naturally result in a newbuilding price that is much lower compared to second-hand tonnage. A time series of newbuilding prices will therefore appear much “stickier” and have lower volatility than the price of existing modern vessels. Figure 2 can be interpreted as the combinations of delivery times and costs where an owner would be indifferent between a resale and a contract for future delivery.

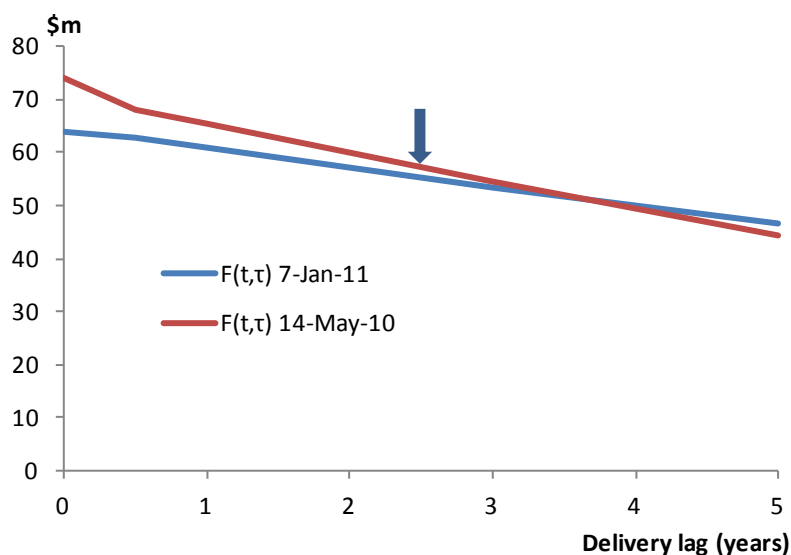


Fig 2. The Term Structure of Newbuilding Prices

The above argument becomes clear when looking at the difference between the actual price of existing ships ($S_{t,0}$), the observed newbuilding price (adjusted for payment terms, $F_{t,\tau \text{ obs}}$) and the estimated newbuilding price given observed delivery lags and Equation 8 ($F_{t,\tau \text{ est}}$) shown in Figure 3 below. We see that proper adjustment for time-varying delivery lags and an alternative cost “smooths out” the newbuilding prices, certainly in the stronger markets in the first part of the sample. Indeed, the sample standard deviation of these three time series are: $S_{t,0}$: \$10.77m, $F_{t,\tau \text{ est}}$: \$6.30m and $F_{t,\tau \text{ obs}}$: \$4.27m. In other words, applying basic maritime economic theory has seemingly reduced much of the “sticky newbuilding prices” paradox as discussed in the literature.

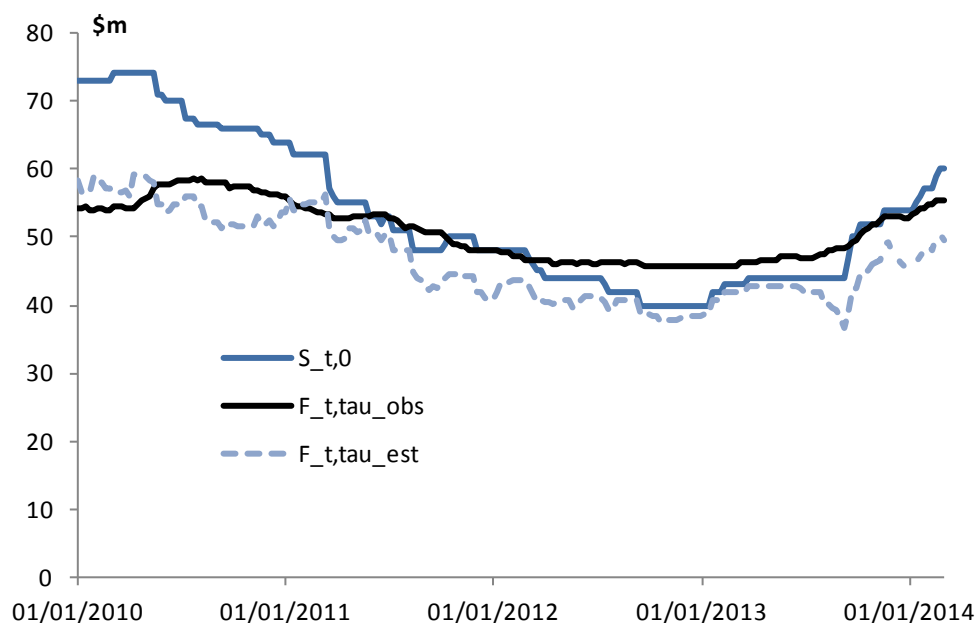


Fig 3. Observed vs Estimated “Equilibrium” Asset Values

Source: Clarkson Research and author’s calculations

4. Concluding Remarks

The literature contains several suggestions that the volatility of contracting prices is too low compared to second-hand values (“sticky” prices), and this is often interpreted as a sign of market inefficiency or a result of externalities. However, as long as a newbuilding and an existing ship are largely fungible, differing only in the time until they generate revenue, equilibrium prices will adapt such that investors are indifferent between alternatives. In this paper we have derived a single-equation mathematical relationship defining contemporaneous equilibrium prices across the four shipping markets: the newbuilding market, the second-hand market, the demolition market and the freight market. Our equilibrium equation requires rather general conditions, namely that (i) all second-hand ships are priced based on linear depreciation down to scrap value, (ii) expectations of the future scrap value and lifespan of the vessel are equal to current values and (iii) the term structure of (timecharter) freight rates is observable. We use this equilibrium relationship to illustrate the presence of a “term structure of newbuilding prices” which means that newbuilding prices are not comparable across time because the parameters of the newbuilding contracts (primarily the delivery lag and payment schedules) will vary. When properly accounting for the alternative cost of operation and the time-varying delivery lags we show that the price for the newbuilding contract – which is merely a kind of futures contract – must necessarily have lower volatility than that of existing new ships.

While this approach seemingly solves part of the “puzzle” of sticky newbuilding prices it also leaves at least one remaining open question for future research. During very poor freight markets, such as those experienced in 2012, newbuilding prices appear too elevated compared to fundamentals. One way to resolve this is to assume that asset prices rationally reflect the default risk inherent in period timecharters – that they are not risk free as implicitly assumed herein. This opens up the possibility of measuring the default risk premium in period timecharters as the residual that aligns the equilibrium prices in the freight and asset markets, but we leave this for future research.

Another possibility is measurement error arising from low liquidity in both period timecharter markets and newbuilding markets during times of freight market stress. Given the lack of transactions, brokers' estimates underlying the timeseries provided may be subject to greater noise than usual.

References

- Adland, R. and Koekebakker, S. (2007), Ship valuation using cross-sectional sales data: A multivariate non-parametric approach, *Maritime Economics and Logistics*, 9: 105 – 118.
- Adland, R., Jia, H. and Stranden, S.P. (2006), Asset bubbles in shipping? An analysis of recent history in the drybulk market, *Maritime Economics and Logistics*, 8: 223 – 233.
- Beenstock, M. (1985), A theory of ship prices, *Maritime Policy and Management*, 12: 215 – 225.
- Beenstock, M. and Vergottis, A. (1989), An econometric model of the world shipping market for dry cargo, freight and shipping, *Applied Economics*, 21: 339 – 356.
- Dikos, G. (2004), Newbuilding prices: Demand inelastic or perfectly competitive? *Maritime Economics and Logistics*, 6: 312 – 321.
- Dixit, A. and Pindyck, R. (1994), *Investment under uncertainty*, Princeton University Press, Princeton.
- Greenwood, R. and Hanson, S. (2013), Waves in ship prices and investment, NBER working paper no. 19246
- Kalouptsi, M. (2014), Time to build and fluctuations in shipping, *American Economic Review*, 104(2): 564 – 608.
- Stranden, S.P. (1984), Price determination in the time charter and second hand markets, discussion paper 05/84, Norwegian School of Economics and Business Administration: Bergen, Norway
- Stranden, S.P. (1986), *Norship: A simulation model of markets in bulk shipping*, discussion paper 11/86, Norwegian School of Economics and Business Administration: Bergen, Norway
- Stranden, S. P. (2002), Economics of the Markets for Ships. *The Handbook of Maritime Economics and Business*, 186-202.
- Tsolakis, S., Cridland, C., and Haralambides, H. (2003), Econometric modelling of second-hand ship prices, *Maritime Economics and Logistics*, 5: 347 – 377.
- Zannetos, Z. (1966), *The theory of oil tankership rates*, MIT Press: Cambridge, MA.

ⁱ The two would only be identical in the case of full upfront payment to the shipyard; a rare occurrence.

Determinants of Ship Berthing Safety at Port Dock

Wen-Kai K. Hsu and Chiu-Fang Chiu

Department of Shipping and Transportation Management, National Kaohsiung Marine University, Taiwan,
R.O.C

Abstract

The purpose of this paper is to discuss the determinants of ship berthing safety at port dock. Based on the features of ship's berthing operations and the relevant literature, the safety factors (SFs) of ship berthing at port docks are first investigated. A Safety Index (SI) with Fuzzy AHP model is then proposed to assess those SFs from port marine pilots, by which port managers and ship carriers may make policies to improve their ship berthing safety at port docks. To validate the model, the ships' berthing operations at Kaohsiung Port in Taiwan were empirically investigated. The results indicate the main safety factors affecting ship berthing at port docks are: *Work concentration*, *Specific and performance mooring lines*, *Emergency response*, *Port policy for improving business* and *Berth's length*. Based on those results, the theoretical and managerial implications for ship berthing safety at dock are finally discussed.

Keywords: ship navigation, safety, port, fuzzy AHP

1. Introduction

Recently, in line with increasing global trading activities, shipping companies continue to build large vessels for shipping markets. The ships in the world, therefore, are not only becoming faster and larger, but also rapidly increasing in quantity. With fixed shipping lines, a growing number of vessels will lead to increasing maritime accidents (Hsu, 2012). A historical analysis of ship accidents during 12-20th century indicated a significant increase in the frequency of accidents over time: 83% of the accidents occurred in the last 20 years and 59% in the past decade (Darbra and Casal, 2004).

Generally, a ship accident may result in an incredible loss. The most common damages caused by a ship accident includes ships crashed, port facility damage, cargo damage and human casualties. In practice, those damages may decrease the reputations of shipping carriers and port companies, which may lead to decreased business. Further, more seriously, a ship accident in port may cause fuel oil leakage, leading to port pollution. Since the losses from a ship accident can be so enormous, many port authorities in the world have paid attention to reducing the incidence of ship accidents in port.

Practically, the common ship accidents include collisions, running on a reef and grounding, in which collisions are the most frequent maritime accident (Hsu, 2012). In practice, collisions most commonly occur when ship berths at port dock. Thus, to reduce ship accidents, issues related to ship berthing safety should be seriously considered. Unfortunately, in the relevant literature, there is a lack of studies on such topics.

The purpose of this paper is to discuss the determinants of ship berthing safety at port dock. Based on the relevant literature and the features of ship's berthing operations, the safety factors (SFs) of ship berthing at port docks are first investigated. Since, ship berthing safety is a highly professional issue, a Safe Index (SI) based Fuzzy AHP model is then proposed to assess those SFs from marine pilots, who are the main operating staff in ship's berthing operations. The Safe Index consists of two weights, the SFs' importance weights and frequency weights. The former is defined as a SF' importance degree in causing ship accidents, while the latter is explained as the frequencies of the SF causing ship accidents. In practice, the former depends on the SF's features, and the latter depends on the performance of port management. In the relevant literature, most studies only focus on the former (e.g. Lu and Tsai, 2008; Hsu, 2012). Based on the Safe Index (SI), port authorities and carrier managers may make policies to improve their ship berthing safety at docks. Finally, as

an empirical study, the carriers berthing their ships at Kaohsiung Port in Taiwan were investigated to validate the model. The rest of this paper is organized as follows. Section 2 reviews the literature. Section 3 explains the research method in this paper. The results are then examined in Section 4. Finally, some general conclusions and limitations for further research are given.

2. Literature Reviews

Based on the relevant research and the features of ship's berthing operations, this paper reviews the literature on ship berthing safety from five dimensions: marine pilot, ship factor, tugboat operation, dock operation, port management and the operating staff's health.

2.1. Marine pilot

For ship's berthing operations, the marine pilot is the main commander. Thus, the professional skills of the marine pilots should be the most important determinant of the operations. Further, the workplace of a marine pilot on a vessel is an international environment, where the pilot deals with crews from different cultures that speak different languages. Thus, poor communication may lead to crews misunderstanding the marine pilot's steering order, and as a result, reduce the ship's berthing safety. Therefore, in addition to professional skills, a marine pilot's language ability, and communication ability may also affect ship berthing operations at ports. Previous relevant studies showed poor communication between crews and marine pilots was one of the determinants of marine disasters near ports (Hetherington et al., 2006; Darbra et al., 2007; Hsu, 2012). Further, the language and cultural diversity of seafarers may affect the shipping safety (Hetherington. et al., 2006; Knudsen and Hassler, 2011).

2.2. Ship factor

In practice, for ship berthing safety, the ship factor comprises ship staff and berthing equipment condition. The former includes the ship crews' operational skills and work attitudes in cooperating with the mariner pilot; while the latter contains the performances of steering gears and windlass. The previous relevant studies indicated the ship workers' professional skills and work attitudes may affect ship navigation safety (Lu, 2007). Feedback from crews to the ship master significantly affect the reporting performance (frequency) of shipping accidents, and so do the interpersonal relationships and communication among crews (Oltedal and McArthur, 2011). A ship crew's improper operation, machinery failure (Darbra et al., 2007) and vessel performance (Liu et al., 2005; Hsu, 2012) may also lead to marine disasters. The type, size, age and condition of the vessel at the time of the accident are important determinants ship loss (Kokotos and Smirlis, 2005).

2.3. Tugboat operation

The main operations of tugboats are to assist vessels in berthing alongside and departing from docks, including pushing and towing the vessels. The previous related studies showed tugboat failure is one of the causes of marine accidents in ports (Darbra et al., 2007). Further, the factors affecting the quality of tugboat operations include the number of tugboats, the horsepower of the tugboat, and the operating skills of the tugboat drivers (Hsu, 2012).

2.4. Dock operation

For ship berthing safety, the dock operation factor contains line handling operation and dock facility. The relevant studies indicated the operating skills and work attitudes of linemen may affect ship navigation safety in port (Hsu, 2012). Further, the number of windlass in the dock and the operating location of the line handling boat (mooring buoy operation) may be another determinant of ship berthing safety (expert interviews). As for the dock facility, in practice, the berth's length should be the most important factor to affect ship berthing safety. Practically, the berth's length should be 1.2 times longer than the berthing vessel (Liu et al., 2005), to allow the vessel enough space for ship mooring operations. However, due to the global development of large-sized ships, the space may frequently be decreased, leading to collisions between neighboring ships.

2.5. Port management policy

This factor contains two parts: Port management regulations and Port policy for business improvement.

2.5.1. Port management regulations

To ensure port safety, port authorities may develop related rules to regulate the ships' operations in port. For example, in Kaohsiung port, the relevant regulations for ship's berthing operations include: *Marine pilot laws*, *Ship navigation regulations in port*, *Tugboat operator regulations* and *Line handling operator regulations*. The relevant studies indicate safety management systems are a determinant of offshore safety (Wang, 2002). However, in practice, those rules or systems may not be completely developed, and further the operators may not comply with them perfectly.

2.5.2. Port policy to improve business

For improving business, the port authority may allow too many ships to berth simultaneously, increasing the density of ships in ports. This may result in rushed ship berthing operations, which could lead to increased ship collisions. The relevant studies indicate ship collisions increase with the density of ship at a specific water area (Cockcroft, 1983). Further, another policy for improving port's business is to speed up the logistical operations of terminals. This may result in the berthing operations of ships being performed hastily, which may also lead more ship accidents (Hsu, 2012).

2.6. The operating staff's health

The operating staff of a ship's berthing operations include marine pilots, ship crews, tugboat drivers and linemen. In practice, the staff need to work in shifts. Therefore, their physical and mental health may affect their work concentration, which may influence ship navigation safety (Hsu, 2012). Previous relevant research illustrated there were potentially disastrous outcomes from fatigue in terms of poor health and diminished performance (Josten, et al., 2003; Hetherington, 2006). Shift patterns contribute to fatigue and in turn cause poorer health and safety performance (Hsu, 2012).

3. Research Method

3.1. Research Framework

The research framework of this paper is shown in Figure 1. The safety factors (SFs) for ship's berthing operations are first investigated. A fuzzy AHP model (Hsu and Huang, 2014) is then proposed to weight both the SFs' importance and frequency degrees. Based on those two weights, a Safety Index (SI) is finally created to assess the ship berthing safety, by which port managers and ship carriers may make policies to improve their ship berthing safety at port docks.

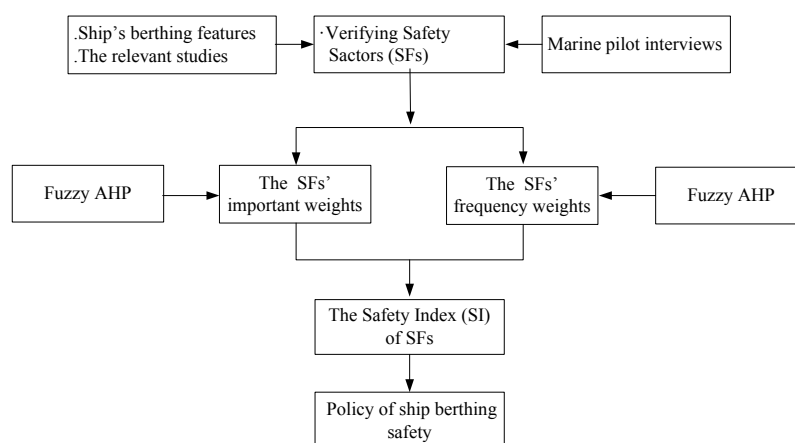


Fig 1. Research Framework

3.2. Measurement of safety factors

3.2.1. The definitions of safety factors

Based on the relevant literature and the features of ship's berthing operations, the safety factors (SFs) are first constructed from five dimensions and defined as follows:

1) Human factor

For ship berthing, the operating staff includes the marine pilot, ship crews, turbot drivers and linemen. The Human factor is defined as the capabilities of the staff, including professional skill, communication, emergency handling and work concentration, etc.

2) Machinery (ME)

Machinery is defined as the performance and number of machines and equipments for ship's berthing operations, including the main engine and steering engine of ship, turbots, deck machines (windlasses) and mooring lines.

3) Port management (PM)

Port management is defined as the completeness and performance of the rules or regulations for ship's berthing operations, and the policy for improving the business of the port, such as speeding up the logistical operations of the port, encouraging large ships to stay, etc.

4) Port facility

Port facility is defined as the port equipments for ship's berthing operations, including berth length and the performance and number of bollard and pads.

Based on the above definitions, a two-layer hierarchy structure of SFs for ship berthing safety was first constructed. For improving the practical validity of the SFs, three practical marine pilots were then invited to revise those SFs and check if any important SFs were missed. Further, they also checked the independences among those SFs. After several rounds of discussions and revisions, the final hierarchy structure of the SFs, shown in Table 1, contains four dimensions of SFs for the first layer and 14 SFs for the second layer.

Table1. Hierarchical structure of safety factors (SFs) for ship berthing operations

Layer 1: Construct		Layer 2: Safety factors (SFs)
Human factors (HF)	HF1	Professional skills.
	HF2	Communications.
	HF3	Emergency response.
	HF4	Work concentration.
Machinery (ME)	ME1	The performance of the main engine and steering engine.
	ME2	The number and performance of the tugboats.
	ME3	The number and performance of the windlasses.
	ME4	The performance of the mooring lines.
Port management (PM)	PM1	The completeness of the port's rule and regulations.
	PM2	The performance of the port's rule and regulations.
	PM3	The port policy for improving business.
Port facility (PF)	PF1	The width and depth of the main channel.
	PF2	The berth's length
	PF3	The shore equipment, such as bollard and pads.

3.2.2. Questionnaire design

In this paper, an AHP questionnaire (Saaty, 1980) with a nine point rating scale was designed to measure the marine pilot's perceived "importance" and "frequency" toward each SF respectively. Based on the

hierarchical structure of SFs in Table 1, an AHP questionnaire with five criteria and 14 sub-criteria was created. To validate the scale, the questionnaire was then pre-tested by the three previous marine pilots to check if the statements were understandable.

3.2.3. Research Sample

In practice, marine pilot is the main operating staff for ship's berthing operations. Thus, the marine pilots of Kaohsiung Port were surveyed in this paper. To enhance the validity of the survey, an assistant was dispatched to help the respondents fill out the questionnaire. Currently, there are 42 marine pilots at Kaohsiung Port, from which we surveyed 30 marine pilots randomly and interviewed them on May, 2013. For each of the sample, the consistency index (C.I.) was first computed to test the consistency of its pairwise comparison matrix. The results indicated two samples with C.I. > 0.1 were highly inconsistent (Saaty, 1980). Therefore, these two questionnaires were discarded. The profiles of the validated 28 respondents' characteristics are shown in Table 2. It can be seen all of the subjects had at least 10 years of experience with over 80% respondents having over 20 years. Note, the remarkable qualifications of the respondents endorse the reliability of the survey findings.

Table 2. Profile of the respondents

Characteristics	Range	Frequency	Percentage (%)
Marine pilot experience at Kaohsiung Port	Under 10	4	14.29
	10-15	4	14.29
	16-20	6	21.43
	Above 20	14	50.00
Age (years)	Under 50	2	7.14
	51-55	8	28.57
	56-60	10	35.71
	Above 60	8	28.57
Education level	Master	2	7.14
	University	10	35.71
	College	16	57.14

3.3. The weights of safety factors

From the sample data, 28 pairwise comparison matrices were obtained for each comparison of the SFs in each layer. In the past, most relevant studies used the arithmetic mean or geometric mean to integrate multiple subjects' opinions. However, those two means are sensitive to extreme values. Thus, a fuzzy number is considered to integrate the subjects' perceptions in this paper. First, the geometric mean was employed to represent the consensus of respondents (Buckley 1985; Saaty 1980). A triangular fuzzy number characterized by minimum, geometric mean and maximum of the measuring scores was then used to integrate the 28 pairwise comparison matrices into a fuzzy positive reciprocal matrix. Based on the fuzzy reciprocal matrices, a fuzzy AHP approach was finally conducted to determine the weights of the SFs, including both of the measurements of important and frequency.

3.3.1. The fuzzy positive reciprocal matrix

Let $\tilde{A} = [\tilde{a}_{ij}]_{n \times n}$ be a fuzzy positive reciprocal matrix with n SFs, where $\tilde{a}_{ij} = [l_{ij}, m_{ij}, u_{ij}]$ is a triangular fuzzy number with

$$[l_{ij}, m_{ij}, u_{ij}] = \begin{cases} [1, 1, 1], & \text{if } i = j; \\ [1/u_{ji}, 1/m_{ji}, 1/l_{ji}] & \text{if } i \neq j. \end{cases}$$

For ease of demonstration, let $A^{(k)} = [a_{ij}^{(k)}]_{n \times n}$, $k = 1, 2, \dots, m$, denote the pair-wise comparison matrix of m subjects. Then, those m matrices can be integrated into the following fuzzy positive reciprocal matrix:

$$\tilde{A} = [\tilde{a}_{ij}]_{n \times n} \quad (1)$$

where $\tilde{a}_{ij} = \left[\min_{1 \leq k \leq m} \{a_{ij}^{(k)}\}, \left(\prod_{k=1}^m a_{ij}^{(k)} \right)^{1/m}, \max_{1 \leq k \leq m} \{a_{ij}^{(k)}\} \right]$ is a triangular fuzzy number, $i = 1, 2, \dots, n$, $j = 1, 2, \dots, n$ and $k = 1, 2, \dots, m$.

3.3.2. The consistency tests

Before calculating the weights of the SFs in the fuzzy positive reciprocal matrix (\tilde{A}), an immediate problem is to test the consistency of \tilde{A} . The problem results from the fact that the criteria (SFs) within the \tilde{A} are fuzzy numbers, so the consistency of the \tilde{A} can not be tested directly as traditional AHP. Buckley (1985) conducted the consistency test for a fuzzy positive reciprocal matrix whose criteria are trapezoidal fuzzy numbers. He first used the geometric means to defuzzify the criteria and thus convert the fuzzy positive reciprocal matrix into a crisp matrix. Then, the consistency test can be undertaken for the crisp matrix, as traditional AHP. In this paper, we use the method of Buckley (1985) to defuzzify the \tilde{A} . Specifically, for the positive reciprocal matrix \tilde{A} , the fuzzy numbers $\tilde{a}_{ij} = [l_{ij}, m_{ij}, u_{ij}]$ can be defuzzified as:

$$a_{ij} = (l_{ij} \cdot m_{ij} \cdot m_{ij} \cdot u_{ij})^{1/4}, \quad i = 1, 2, \dots, n, \quad j = 1, 2, \dots, n \quad (2)$$

Generally, the following C.I. (Consistency Index) and C.R. (Consistency Ratio) are the two indexes used to test the consistency of a crisp positive reciprocal matrix in traditional AHP :

$$\text{C.I.} = \frac{\lambda_{\max} - n}{n - 1} \quad (3)$$

and

$$\text{C.R.} = \frac{\text{C.I.}}{\text{R.I.}} \quad (4)$$

where λ_{\max} is the maximum eigenvalue of the positive reciprocal matrix and n is the number of criteria in the matrix. The R.I. represents a randomized index, whose values are shown in Table 3 (Hsu and Huang, 2014). Saaty (1980) suggested that a value for $\text{C.R.} \leq 0.1$ is an acceptable range for consistency test of the crisp positive reciprocal matrix.

Table 3. The randomized index of the R. I.

n	3	4	5	6	7	8	9	10	11	12
R.I.	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49	1.52	1.54

In our sample data, the results of consistency tests are listed in Table 4. Since all of the C.R. indexes in Table 4 are less than 0.1, all of the positive reciprocal matrixes in the sample data are consistent.

Table 4. The results of the consistency tests

Shipmaster's perceptions	Layer	C.I.	R.I.	C.R. (C.I./R.I.)
Importance	Layer 1	0.076	1.115	0.068
	Layer2: HF	0.085	0.882	0.096
	Layer2: ME	0.071	0.882	0.080
	Layer2: PM	0.028	0.525	0.053
	Layer2: DF	0.053	0.882	0.060
Frequency	Layer 1	0.054	1.115	0.048
	Layer2: HF	0.034	0.882	0.039

	Layer2: ME	0.021	0.882	0.024
	Layer2: PM	0.035	0.882	0.040
	Layer2: DF	0.019	0.882	0.022

3.3.4. The local weights of SFs

The local weights of SFs can be determined from the eigenvectors of matrix \tilde{A} . However, due to the special structure of the positive reciprocal matrix, Saaty (1980) suggested four methods to find the eigenvectors: Average of Normalized Columns (ANC), Normalization of the Row Average (NRA), Normalization of the Reciprocal of Columns Sum (NRCS) and Normalization of the Geometric Mean of the Rows (NGMR). In this paper, the NGMR method was used to determine the local weights of SFs in the \tilde{A} .

For the fuzzy positive reciprocal matrix \tilde{A} , the geometric means of the triangular fuzzy numbers for the i th SF ($i = 1, 2, \dots, n$) can be found as:

$$\tilde{w}_i = \left(\prod_{j=1}^n \tilde{a}_{ij} \right)^{1/n} = \left[\left(\prod_{j=1}^n l_{ij} \right)^{1/n}, \left(\prod_{j=1}^n m_{ij} \right)^{1/n}, \left(\prod_{j=1}^n u_{ij} \right)^{1/n} \right], \quad i = 1, 2, \dots, n. \quad (5)$$

From Equation (5), we have:

$$\sum_{i=1}^n \tilde{w}_i = \left[\sum_{i=1}^n \left(\prod_{j=1}^n l_{ij} \right)^{1/n}, \sum_{i=1}^n \left(\prod_{j=1}^n m_{ij} \right)^{1/n}, \sum_{i=1}^n \left(\prod_{j=1}^n u_{ij} \right)^{1/n} \right]. \quad (6)$$

Also, from Equations (5)-(6), the fuzzy weight of the i th SF ($i = 1, 2, \dots, n$) can then be obtained as:

$$\tilde{W}_i = \tilde{w}_i / \sum_{i=1}^n \tilde{w}_i = \left[\frac{\left(\prod_{j=1}^n l_{ij} \right)^{1/n}}{\sum_{i=1}^n \left(\prod_{j=1}^n u_{ij} \right)^{1/n}}, \frac{\left(\prod_{j=1}^n m_{ij} \right)^{1/n}}{\sum_{i=1}^n \left(\prod_{j=1}^n m_{ij} \right)^{1/n}}, \frac{\left(\prod_{j=1}^n u_{ij} \right)^{1/n}}{\sum_{i=1}^n \left(\prod_{j=1}^n l_{ij} \right)^{1/n}} \right], \quad i = 1, 2, \dots, n \quad (7)$$

3.3.5. The defuzzification process

Since the local weight, \tilde{W}_i , of the i th SF ($i = 1, 2, \dots, n$) is fuzzy, this paper uses Yager's index (1981) to defuzzify the \tilde{W}_i into a crisp number W_i , $i = 1, 2, \dots, n$. For convenience of explanation, let $\tilde{W}_i = [l_i^W, m_i^W, u_i^W]$, where

$$[l_i^W, m_i^W, u_i^W] = \left[\frac{\left(\prod_{j=1}^n l_{ij} \right)^{1/n}}{\sum_{i=1}^n \left(\prod_{j=1}^n u_{ij} \right)^{1/n}}, \frac{\left(\prod_{j=1}^n m_{ij} \right)^{1/n}}{\sum_{i=1}^n \left(\prod_{j=1}^n m_{ij} \right)^{1/n}}, \frac{\left(\prod_{j=1}^n u_{ij} \right)^{1/n}}{\sum_{i=1}^n \left(\prod_{j=1}^n l_{ij} \right)^{1/n}} \right], \quad i = 1, 2, \dots, n.$$

Then, the \tilde{W}_i , $i = 1, 2, \dots, n$ can be defuzzified as:

$$W_i = (l_i^W + 2 m_i^W + u_i^W) / 4, \quad i = 1, 2, \dots, n. \quad (8)$$

Finally, normalizing the W_i ($i = 1, 2, \dots, n$), the crisp local weight of the i th SFs can be obtained as:

$$\varpi_i = W_i / \sum_{i=1}^n W_i, \quad i = 1, 2, \dots, n \quad (9)$$

3.3.6. The global weights of the SFs

By the above steps in Sections 3.3.2~3.3.5, we can find all the local weights of the SFs in Table 1. The global weights of the SFs can then be found by multiplying their low level of local weights by their corresponding high level of global weights. Table 5 shows the results of all global weights of the SFs for the importance measurement of sample data. The global weights of the SFs in the first layer are shown in the second field, and those of the SFs in the second layer are shown in the last field. Likewise, the global weights of SFs for the frequency measurement of sample data are shown in Table 6.

Table 5. The importance weights (IWs) of safety factors for ship berthing operations

Layer 1: SFs	The global weights of Layer 1 SFs (%)	Layer 2: SFs	The local weights of Layer 2 SFs (%)	The global weights of Layer 2 SFs (%)
HF	32.19	HF1	28.076	9.04
		HF2	20.264	6.52
		HF3	26.797	8.63
		HF4	24.863	8.00
ME	29.04	ME1	29.523	8.57
		ME2	21.047	6.11
		ME3	23.117	6.71
		ME4	26.313	7.64
PM	20.24	PM1	33.225	6.72
		PM2	31.748	6.43
		PM3	35.027	7.09
DF	18.53	DF1	35.190	6.52
		DF2	34.195	6.34
		DF3	30.615	5.67

Table 6. The frequency weights (FWs) of safety factors for ship berthing operations

Layer 1: SFs	The global weights of Layer 1 SFs (%)	Layer 2: SFs	The local weights of Layer 2 SFs (%)	The global weights of Layer 2 SFs (%)
HF	39.69	HF1	6.46	2.56
		HF2	14.72	5.84
		HF3	24.04	9.54
		HF4	54.79	21.75
ME	24.90	ME1	26.39	6.57
		ME2	4.96	1.24
		ME3	13.41	3.34
		ME4	55.24	13.75
PM	16.02	PM1	9.14	1.46
		PM2	21.76	3.49
		PM3	69.10	11.07
DF	19.39	DF1	23.85	4.62
		DF2	62.50	12.12
		DF3	13.65	2.65

3.4. The Safety Index of SFs

Obviously, a SF with higher degrees of importance and frequency should be improved with higher priority. Based on such a concept, a Safety Index (SI) was proposed to determine the SFs' priorities. Let IW_i^n and FW_i^n denote the weights of the importance weight and frequency weight of the i th SF ($i = 1, 2, \dots, n$), which are obtained from Equation (9), respectively. Then, the SI of the i th SF is defined as:

$$SI_i = (IW_i^n * FW_i^n) / \sum_{i=1}^n (IW_i^n * FW_i^n), \quad i = 1, 2, \dots, n \quad (10)$$

For our sample, the SI indexes are shown in the fourth and the last fields of Table 7, in which the higher SI values are highlighted in boldface. Table 7 shows, for the first layer of SFs, the HF (*Human Factor*) construct has the highest SI; while for the second layer of SFs, the top five SFs with higher SI are HF4, ME2, HF3 and DF2.

Table 7. The Safety Index (SI) of safety factors for ship berthing operations

Layer 1: SFs	Importance (%)	frequency (%)	Layer1: SI (%)	Layer 2: SFs	Importance (%)	frequency (%)	Layer 2: SI (%)
HF	32.19	39.69	47.60	HF1	9.04	2.56	3.12
				HF2	6.52	5.84	5.14
				HF3	8.63	9.54	11.10
				HF4	8.00	21.75	23.46
ME	29.04	24.90	26.94	ME1	8.57	6.57	7.60
				ME2	6.11	1.24	1.02
				ME3	6.71	3.34	3.02
				ME4	7.64	13.75	14.17
PM	20.24	16.02	12.08	PM1	6.72	1.46	1.33
				PM2	6.43	3.49	3.02
				PM3	7.09	11.07	10.58
DF	18.53	19.39	13.39	DF1	6.52	4.62	4.07
				DF2	6.34	12.12	10.35
				DF3	5.67	2.65	2.02

4. Results and Implications

4.1. The importance weights of SFs

The results of Table 5 indicate, overall, the *Human Factor* (HP, 32.19%) is the most important construct to affect ship berthing safety. While, the top five SFs by importance weights are: HF1 (*Professional skills*, 9.04%), HF3 (*Emergency response*, 8.63%), ME1 (*The performance of main engine and steering engine*, 8.57%) and HF4 (*Work concentration*, 8.00%). The results imply the human factor (HF1, HF3 and HF4) could be the main determinant of the ship berthing safety. This result confirms previous relevant studies that the human factor is the most important determinant of vessel accidents in container shipping context (Lu and Tsai, 2008; Tzannatos and Kokotos, 2009), shipping safety in restricted waters (Kokotos and Linardatos, 2011) and ship navigation in port (Hsu, 2012).

Practically, the main operating staff for ship's berthing operations at dock include marine pilot, ship crews, turbot drivers and linemen. Thus, for improving ship's berthing safety, port authority may focus on strengthening those staff's literacy. In practice, most vessel accidents occur in an instant. Thus, the response capability for emergencies is particularly important for those staff. For enhancing their response capability in emergencies, this paper suggests the port authority may make policy to encourage or even force the staff to attend related trainings activities regularly, such as experience sharing, computer simulation for berthing operations, analysis of the causes of collisions, and how to prevent accidents etc. Further, the port authority may also make a license system to force those staff to participate in those trainings.

Further, in practice, the operating staff's mental and physical condition on duty is the main determinant of their work concentration. Generally, all of the staff have to work night shifts, which may lead to mental fatigue and decrease their work concentration. Relevant studies indicated human fatigue is one of the main causes of marine casualties (Hetherington, 2006). This paper suggests the port authority may make regulations to control the shift system of operating staff, such as the maximum work hours for a shift.

4.2. The Safe Indexes of SFs for Kaohsiung port

The result of the Safety Index (SI) for Kaohsiung Port, shown in Table 7, indicated the top five SFs with higher SI are: HF4 (*Work concentration*, 23.46%), ME4 (*The performance of mooring lines*, 14.17%), HF3 (*Emergency response*, 11.10%), PM3 (*The port policy for improving business*, 10.58%) and DF2 (*The berth's length*, 10.35%). Since the SF's Safety Index(SI) consists of importance weight and frequency weight, the SI may reveal the management performance of port authority and ship carriers. Based on the results, we conducted post-interviews with several of the surveyed marine pilots and made some suggestions for the Kaohsiung port authority and carrier managers.

1.) *Improving operating staff's work literacy*

As explained in section 4.1, several policies may be considered for Kaohsiung port authority and carrier managers to enhance their operating staff's work literacy, such as holding related training activities, making a license system and improving shift system.

2.) *Make regulations to supervise mooring line*

For the ship berthing operations, there are two specifics of mooring lines, ship line and tugboat line. The latter is regulated to be stronger than the former. However, for saving on cost, some carriers may adopt mooring lines instead of tugboat lines. This behavior should be strictly forbidden. Further, the mooring lines should also be maintained and checked regularly to prevent cracks from occurring during ship berthing operations. Generally, most ports in the world have regulations to supervise the performance of mooring lines. However, those regulations may not be actually implemented. Thus, how to ensure those rules to be performed should also be considered. In practice, port authorities may add some penalties in the regulations for violations.

3.) *Improving port's business policy*

In practice, port authorities may adopt policies to improve their port's business, such as utilizing terminals, speeding up logistical operations of terminals, etc. However, those policies may reduce the operating time of ship berthing, leading to more ship accidents. Thus, balancing business demands and ship safety is an important problem for port managers to consider. This paper suggests port authority may set an upper limit to control the ship density in port, by which the operating staff may have sufficient time to berth their ships, and to ensure the safety of ships.

5. Conclusion

Relevant statistics indicate collisions are the most frequent maritime accident. In practice, collisions most frequently occurs when ships berth at port dock. However, previous studies discuss such topics less. The purpose of this study was to explore the safety factors (SFs) of ship's berthing operations at dock. In this paper, a Safety Index (SI) with a fuzzy AHP model was proposed to assess those SFs. The Safety Index, consists of both SFs' importance and frequency weights, not only indicates the SF's priorities, but also the performance of port management. Compared with the relevant literature, the SI may provide more complete information for port authorities and carrier managers to improve their ship berthing safety at docks. The proposed model may provide theoretical references for further research on methodology and ship navigation safety.

For validating the practical application of the proposed model, the ship berthing operations at Kaohsiung Port in Taiwan were empirically investigated. The results indicated operating staff's literacy is the most important determinant of ship berthing safety. In practice, the main operating staff of a port include the marine pilot, ship crews, turbot drivers and linemen. Thus, those staff's personal literacy should be enhanced, including professional skills, emergency response and work concentration. Further, for Kaohsiung port, in addition to operating staff's work literacy, the port authority and carrier managers also need to pay more attention to the problems of regulating mooring lines and balancing business demands and ship safety. The results may provide practical information for Kaohsiung port and other port authorities to make policies in improving their ship berthing safety.

In this paper, 28 marine pilots at Kaohsiung Port in Taiwan were empirically surveyed to validate the proposed model. For enhancing the validity of the questionnaire investigation, this paper adopted an interview survey instead of a mailed survey. Thus, the validity and reliability of the findings in this paper could be endorsed. However, for better confirming the empirical results, more representative samples may be necessary in future research.

References

- Buckley, J.J., (1985), Fuzzy hierarchical analysis, *Fuzzy Sets and Systems*, 17 (3): 233-247.
- Cahit, I. (2007), Pilot, ship and VTC, International Marine Pilots' Association, <http://www.internationalpilots.org>.
- Celik, M., Lavasani, S.M. and Wang, J. (2010), A risk-based modeling approach to enhance shipping accident investigation, *Safety Sciences*, 48 (1): 18-27.
- Darbra, R.M. and Casal, J. (2004), Historical analysis of accidents in seaports, *Safety Sciences* 42 (1): 85-98.
- Darbra, R.M., Crawford, J.F.E., Haley, C.W and Morrison, R.J. (2007), Safety culture and hazard risk perception of Australian and New Zealand maritime pilots, *Marine Policy* 31 (2): 736-745.
- Hetherington, C., Flin, R., Mearns and K., (2006), Safety in shipping: The human element, *Journal of Safety Research* 37(2): 401-411.
- Hsu, K.Y., Chang Y.C. and Chou, H.P. (2008), An analysis of marine casualties of the international commercial port on the west coast of Taiwan, *Maritime Quarterly* 17 (1): 45-62.
- Hsu, W.K. (2012), Ports' service attributes for ship navigation safety, *Safety Science* 50 (2): 244-252.
- Hsu, W.K and Huang, S.H. Evaluating the service requirements of Taiwanese international port distribution centers using IPA model based on fuzzy AHP, *International Journal of Shipping and Transport Logistics*. (Forthcoming)
- Josten, E.J.C., Ng-A-Tham, J.E.E. and Thierry, H. (2003), The effects of extended workdays on fatigue, health, performance and satisfaction in nursing, *Journal of Advanced Nursing* 44 (6): 643-652.
- Knudsen, O.F., Hassler, B. (2011). IMO legislation and its implementation: Accident risk, vessel deficiencies and national administrative practices. *Marine Policy* 35 (2): 201-207.
- Kokotos D.X. and Smirlis G.Y. (2005), A classification tree application to predict total ship loss, *Journal of Transportations and Statistics* 8 (2): 31-42.
- Kokotos, D.X. and Linardatos, D.S. (2011), An application of data mining tools for the study of shipping safety in restricted waters, *Safety Sciences* 49: 192-197.
- Liu, C.P., Liang, G.S., Su, Y.L. and Chu, C.W. (2005), Analysis of navigation safety in Taiwanese, *Maritime Quarterly* 14 (1): 1-20.
- Lu, C.S. and Tsai C.L. (2008), The effects of safety climate on vessel accidents in container shipping context, *Accident Analysis and Prevention* 40 (2): 594-601.
- Oltedal, H.A. and McArthur, D.P. (2011), Reporting practices in merchant shipping, and the identification of influencing factors, *Safety Sciences* 49 (2): 331-338.
- Saaty, T.L. (1980), *The Analytic Hierarchy Process*. McGraw-Hill Companies, Inc., New York.
- Tzannatos E.R. and Kokotos, D.X. (2009), Analysis of accidents in Greek shipping during the pre-and post-ISM period, *Marine Policy* 33 (4): 679-684.
- Wang, J. (2002), Offshore safety case approach and formal safety assessment of ships, *Journal of Safety Research* 33 (2): 81-115.
- Yager, R.R. (1981), A Procedure for ordering fuzzy subsets of the unit interval, *Information Sciences*, 24 (2): 143-161.

Impact of Port Disruption on Supply Chains: Petri Net Modeling and Simulation

Jasmine Siu Lee Lam^{1*} and Tsz Leung Yip²

¹Division of Infrastructure Systems and Maritime Studies, School of Civil and Environmental Engineering, Nanyang Technological University, 50 Nanyang Avenue, Singapore 639798

²C.Y. Tung International Centre for Maritime Studies, Department of Logistics and Maritime Studies, Faculty of Business, The Hong Kong Polytechnic University, Hung Hom, Hong Kong

**Corresponding author*

Abstract

Ports play a key role as nodes for maritime and multimodal transport chains in both import and export logistics processes and as logistical platforms where cargo logistics are handled. In practice, any disruptions at a port can have direct impacts on the port's ability to continue operations, thus affect the supply chains and the parties served by the port. Therefore, a port can better serve the supply chains if it can manage these disruption risks properly. The paper aims to analyse the impact of port disruption on supply chains and the parties involved. A stochastic timed Petri Net model is developed to provide stepwise processes and an efficient environment for conducting simulation and analysis. A discrete-event simulation for a multimodal and multi-port supply chain system with a focus on the disruption of Shenzhen Port is performed. The results show significant variations in the maximum product delivery time when there are port disruptions. Risk mitigation in ports can help reducing such variations and uncertainties in supply chains efficiently.

Keywords: port, disruption risk, supply chain, logistics, Petri Net, simulation

1. Introduction

Ports play a key role as nodes for maritime and multimodal transport chains in both import and export logistics processes and as logistical platforms where cargo logistics are handled. Ports facilitate international trade and contribute to the effective and efficient management of flows of materials, products and information in supply chain management (SCM). A port that is able to meet the evolving requirements of SCM can ensure that its value chain system remains competitive and enables the comparative and competitive advantages of the system's hinterlands to be attained. In general, the role of ports in supply chains has been recognized from researchers and industry professionals alike. Correspondingly port research in such a context has grown significantly in recent years (Lam and Gu, 2013). Cost efficiency, productivity, connectivity, and service quality of ports are usually the research focus in the literature. Risk management about ports is relatively under researched.

Research suggests that ports and shipping are regarded among the most important causes for uncertainty in supply chains (Sanchez-Rodrigues et al., 2010). In practice, any disruptions at a port can have direct impacts on the port's ability to continue operations, thus affect the supply chains and the parties served by the port. In this paper, disruption is defined as an event that causes a sudden interruption on material or product flow in a supply chain, leading to a halt in movement of cargoes (Wilson, 2007). Such a port disruption is possible in many cases, for example, natural hazards (e.g. earthquake, typhoons), a port accident (e.g. ship collision), terrorist or political acts, and breakdown of port equipment. A port disruption may result in long delays of material flow at ports and then enormous adverse impacts on multiple elements of a supply chain simultaneously. A port can better serve the supply chains if it can manage these disruption risks properly. A major port disruption may even lead to a collapse of the entire supply chain system. Therefore, it is crucial for ports and stakeholders in the supply chains such as manufacturers, distributors, and inland transport providers to better understand and mitigate the risks involved. Nevertheless, relatively few studies address port disruption risks. To the authors' knowledge, we do not find any prior studies which specifically quantify the impact of port disruption on supply chains.

To narrow these research gaps, this paper aims to analyse the impact of port disruption on supply chains and the parties involved. This will be fulfilled by a modeling technique known as Petri Net (PN). Petri Net modeling can provide stepwise processes and an efficient environment for conducting simulation and analysis. The study conducts a discrete-event simulation for a multimodal and multi-port supply chain system using the port of Shenzhen and the supply chain involved as a numerical example. Serving the key manufacturing base in South China, Shenzhen handled 23.28 million twenty-foot equivalent units (TEU) in 2013 and is the world's third busiest port in terms of container throughput (AASOCKS, 2014). The port serves numerous global and regional supply chains and is an interesting case for analysing the impact of port disruption on supply chains. In particular, the study will address the following research questions:

1. If a major port encounters a disruption, to what extent will a manufacturer's supply chain be affected?
2. What are the impacts of port disruption affecting the import logistics versus the export logistics?
3. What risk mitigation strategies can be undertaken by ports and manufacturers involved?

After this introduction, the next section provides a literature review. Section 3 presents the PN model. Section 4 discusses the results and implications, and section 5 concludes the paper.

2. Literature Review

Disruption is an event that results in an impulsive interruption in a system. The system that links suppliers, manufacturers, distributors and customers is now known as supply chains. Disruptions of supply chains have become one of the most popular research topics after Kleindorfer and Sood (2005). They provided a conceptual framework to manage disruption risk of supply chains, and broadly categorised sources of disruptions into operational issues, natural hazards, and political instability. They further applied 10 principles to reduce the disruptive risks of supply chains.

Despite that port is a vital node of supply chains, not many research has been done on port disruption. Chang (2000) studied the port of Kobe which suffered severe damage in the 1995 earthquake. She further reported that the port disruption was costing USD 4 billion which included income loss in harbour-related industries, manufacturing, wholesale, and retail trade. It took 2 years for the port of Kobe to recover its facilities but port traffic did not return. Lewis et al. (2013) proposed to manage port disruption impact by managing the inventory or port capacity. They used Markov chain theory to analyze the macro effects of three generic strategies of disruption risk management. Their three generic strategies of port disruptions are: effective contingency plans, inventory management, and efficient capability.

From the shipping perspective, Gurning and Cahoon (2011) analysed 4 generic strategies for supply chain disruption which are: increase buffer inventory, develop contingency plans, re-structure the transportation network, and re-connect business relationships. However, re-structuring the transportation network may not be possible, particularly when gateway ports are involved. Gateway ports are an entry / exit point to / from a hinterland. Port disruptions could be resulted from different events, e.g. natural disasters, labour strike, onshore (transport) incidents, and marine (transport) casualties.

Efforts have also been spent on the prevention of disruptive events. Berle et al. (2011) discussed the failure modes of maritime transportation system. Fuzzy logic sets have been applied to assess system reliability of maritime transportation system (e.g. Gaonkar et al. 2011). Instead of the prevention of port disruptions, our study aims to understand the impact of port disruptions on supply chains. To consider the dynamic impact of port disruptions on supply chains, we attempt the problem by using the Petri Net modeling.

Petri Net modeling has been proved a very powerful method for modeling and analysing complex systems of discrete event systems. The PN modelling has been widely used in many engineering applications, such as manufacturing planning (e.g. Su, Wu, and Yu, 2014). Blackhurst, Wu and Craighead (2008) developed a PN model to study the supply chain disruption. They used the PN to model supply chain systems hierarchically and then evaluate the systems quantitatively. With the PN model, supply chains can be described in a graphical, concise and integrated manner, where disruption can be illustrated. Given the scant literature on port disruption, this research is among the first to assess the impact of port disruption on supply chains.

3. Stochastic Timed Petri Net Model and Simulation for Analysing Port Disruption

3.1 Model features

Petri Net (Petri, 1962) is a graphical and mathematical tool offering high flexibility to model and visualize the properties of complex systems. Timely material and information flows are desirable attributes of supply chains. To include the time factor, this study has chosen stochastic timed PN to model port disruption. In stochastic timed PN models, time is modelled as random variables or probabilistic distributions. As such, the models cannot be solved analytically for general cases (Zurawski and Zhou, 1994). This study conducts a discrete-event simulation. Importantly, simulation is suitable for studying the eventual effects of alternative scenarios in complex systems. The PN model can provide a uniform environment for simulating each individual process in the supply chain.

Disruption is a function of probability and consequences involving estimation (Sheffi and Rice, 2005). There are inevitably uncertainties in estimating risk exposure with regards to the precise likelihood of occurrence, timing and consequences since risk is unanticipated. Due to the inherent nature of uncertainty in risk studies, it is not our focus to predict port disruption, but to present a versatile model so that any risk level can be taken into consideration and any port can be studied. PN based simulation analysis will be able to achieve such objectives effectively.

3.2 Numerical example

As a numerical example, the focal seaport chosen is Shenzhen (SZ). As mentioned in the introduction, the port of Shenzhen plays an important role in serving the manufacturing base in South China and the supply chains involved. Moreover, there is evidence that the port is exposed to both natural and non-natural risks. Regarding natural disasters, they are seen as events having low probability of occurrence but very high consequences (Knemeyer et al., 2009). Shenzhen is in a typhoon-prone area especially in the summer season (EM-DAT, 2014). As for man-made risks, the port employees of Shenzhen called for more safety protection at workplace and an extended insurance coverage because of the potential danger of working in the port area (OCI, 2007). Port workers also expressed concerns on their salary and welfare along the years. In 2007, strikes occurred in the three major terminals, namely Shekou, Yantian, and Chiwan, involving 300 cranes operators and truck drivers and thus causing the delay of at least 10,000 containers (Tan, 2007). Labour strikes were on the rising trend in Shenzhen (CLB, 2009). There are also many other kinds of risks such as equipment breakdown, electrical outages and industrial accidents which can lead to port disruptions.

In the first step of the modelling, we translate a multi-modal and multi-port supply chain system into a PN model as shown in Figure 1. The entire process from the material supplier to the end product customer can be traced. The manufacturer involved is a machine producer located in Dongguan, the Pearl River Delta area. Raw materials such as pistons are imported from Kaohsiung as an example. The supplier is located in Kaohsiung (Taiwan) using the port for export. Maritime transport carries the cargoes (raw materials) to Shenzhen which is the focal port representing the import port for raw materials. Inland transport carries these cargoes to the manufacturer in SZ. After the manufacturing process, the finished products are carried by inland transport to SZ Port for export. In other words, SZ also serves as the port of export for finished goods. Then maritime transport carries the cargoes (finished goods) to a customer in Long Beach (USA) which is the import port for finished products. Figure 1 includes the logical functions and time factor of disruption events in the port network, which is very useful for the analysis of sequences and timing of events due to a disruption.

In the second step, for analyzing the impact of port disruptive events, we involve the risk factors into the PN model by specifying events in the port characterized by a probability of occurrence. Stochastic timed PN based simulation can observe the cause and effect relationships among port disruptive events and the supply chain process using performance measurement regarding different scenarios.

In a PN model, $PN = (P, T, I, O, M_0)$, where

$P = \{p_1, p_2, \dots, p_m\}$ is a finite set of places. In this example, $m = 15$ for there are totally 15 places.

$T = \{t_1, t_2, \dots, t_n\}$ is a finite set of transitions, $P \cup T \neq \emptyset$ and $P \cap T = \emptyset$, where $n = 17$ representing 17 transitions.

$I: (P \times T) \rightarrow N$ is an input function that defines directed arcs from places to transitions, where N is a set of nonnegative integers.

$O: (P \times T) \rightarrow N$ is an output function which defines directed arcs from transitions to places.

$M_0: P \rightarrow N$ is the initial marking.

Places are conditions whereas transitions are events. The directed arcs link up the transitions and places to show the process. In a stochastic timed PN, transitions have probabilistic firing conditions or stochastic firing times. Tables 1 to 4 illustrate the general execution process and the detailed interpretation of each place and transition in each stage of the supply chain system. Parameters including probabilistic distributions, average time taken, the minimum and maximum time range, probability of risk events, and trigger frequency are specified according to the practical situation.

As a major gateway port, Shenzhen serves the inbound and outbound logistics of numerous supply chains. As shown in figure 2 and table 1, we model that the occurrence of port disruption happening in SZ Port (transition 2 PD:SZP) after the raw materials are transported by sea, represented by P2:M(KHP-SZP):Sea in table 2. The flexibility of the method enables any types of risk to be modelled. We take typhoon as a more common example of natural hazard happened in South China. The potential impacts of port disruption on various parties in the supply chain are considered. The major parties are manufacturers, shipping companies, inland transport providers, and customers/consignees importing finished products. Safety is the utmost concern in shipping companies' operations and a key determinant whether they continue to call at a port (Lam, 2012). For serious port disruptions, carriers may bypass intended ports-of-call that are disrupted and have the option to re-route the ships to other ports.

In this example, the ship and cargoes arrive at SZ Port first before the typhoon becomes severe. There can be two possibilities as shown in figure 2. First, the materials may be damaged or lost if the disruption such as typhoon hits the cargo directly. Hence after P3:M(SZP), one directed arc leads to transition 3 (DLM:SZP). Then the impact of such a port disruption on the manufacturer's inbound logistics in the supply chain is: manufacturer has to use existing inventory to continue with the production. However, if there is insufficient inventory, the production schedule will be delayed. No matter if there is adequate inventory, the manufacturer will have to replenish inventory since the material is damaged/lost. Thus, after transition 3 in port (DLM:SZP), transition 8 in manufacturer (INTEL:M) happens which is setting up inventory level of material. All the possible actions required with regards to material inventory held by a manufacturer can be modeled in transition 8.

The second possibility after a port disruption by typhoon is no cargo damage but a halt in port operations and cargo flow. Thus the other directed arc leads to transition 4 (BCP:SZP) which is the time when the port tries to resume port operations. In this case, material will be staying in port which is represented by transition 5 (MS:SZP). Various effects on supply chains can be simulated with different number of days of port disruption. After the port backup time, the material can be delivered by inland transport to manufacturer for production. The inland transport is shown by transition 6 and place 6. For example, if there is a significant delay in production schedule due to a major port disruption, manufacturer can still fulfil customer demand on finished product if there is sufficient inventory. Otherwise, the overseas customer in Long Beach cannot receive the product on time. All the possible actions required with regards to finished goods' inventory held by manufacturer can be modeled in transition 9 (INTEL:FP). Inland transport operators are also inevitably affected and the adverse effects can be longer waiting time, re-routing, longer transit time, and missed connections among others.

Regarding outbound logistics for finished products after the manufacturing process, cargoes are sent by inland transport operators to SZ Port as indicated in transition 11 (DFP:Mfg-SZP) and place 10 (FP(Mfg-SZP):Inland). Transition 12 (PD:SZP) models port disruption that occurs in outbound logistics of the supply

chain. In order to compare the export side with the import side, the same port disruption parameters are set (T2 vs T12, T3 vs T13, T4 vs T14, T5 vs T15 in table 1). Similar to the inbound logistics portion, cargoes may be damaged/ lost (transition 13 DLFP:SZP) or there can be a halt in the product flow (transition 15 FPS:SZP). After the cargoes are damaged/ lost, the manufacturer has to manufacture the products again so the directed arc goes back to place 9 and then the inventory will be set up. The chain of events can be modeled like the illustrations as given above in inbound logistics.

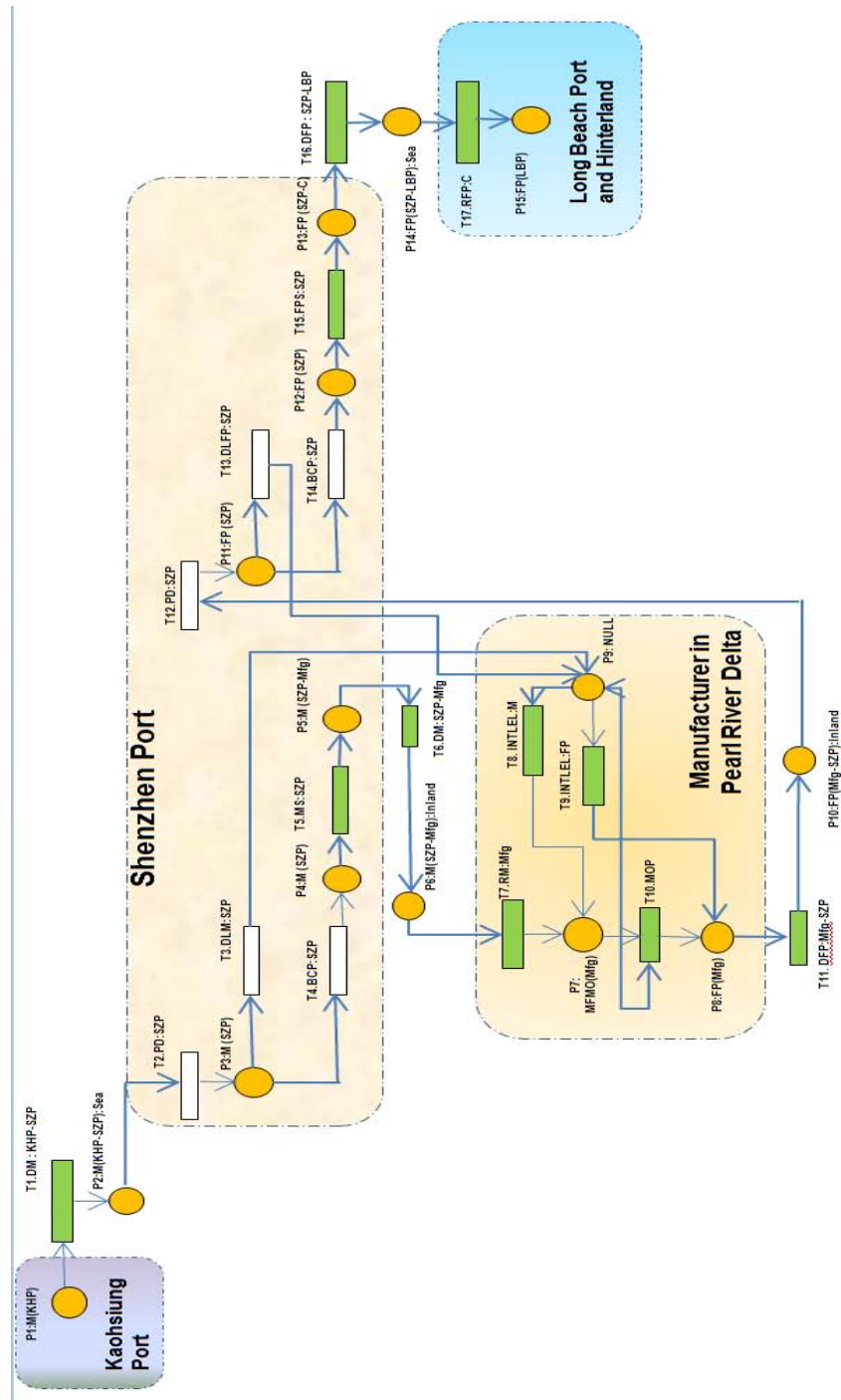


Fig 1. Petri Net Model of a Multimodal and Multi-port Supply Chain System
Note: circle = place; rectangle = transition (white/non-shaded rectangles = with disruptions)
Source: Authors

After setting up the PN model, we run the simulation with the following assumptions with the aim to mimic a practical situation:

1. Orders from customers in Long Beach are placed weekly, and every week 7 tons of raw materials are transported from P1.
2. Producing one ton of final goods requires one ton of raw material.
3. P9 is the place for backup inventory, and 1 ton of backup inventory will be used if port disruptions occur at T3, T13, or when the raw material is delayed (delivery time is greater than or equal to 21 days from P1) before it is transported to T10.

Table 1. Transitions involving Shenzhen Port and the associated parameters

Code	Transition Name	Description	Quantity (days)	Trigger Frequency
1	T1:DM:KHP-SZP	Deliver material: from Supplier in Kaohsiung to Manufacturer in Shenzhen	Uniform distribution [1, 3] days	Once per week (weekly shipment)
2	T2:PD:SZP	Port disruption in Shenzhen Port	Exponential distribution with mean 2 days, range [0.5, 60] days Probability = 0.01	N.A.
3	T3:DLM:SZP	Damage or loss of material in Shenzhen Port	Exponential distribution with mean 1 day, [0.5, 20] days Probability = 0.03	N.A.
4	T4:BCP:SZP	Back up the port disruption (attempt to resume port operations)	Exponential distribution with mean 2 days [0.5, 60] days Probability = 0.03	N.A.
5	T5:MS:SZP	Material staying at Shenzhen Port during the backup time of Shenzhen port disruption	Uniform distribution [3, 5] days	Once per day
6	T6:DM:SZP-Mfg	Deliver material: from Shenzhen Port to Manufacturer	Uniform distribution [1, 3] days	Once per week (weekly delivery)
12	T12:PD:SZP	Port disruption in Shenzhen Port	Exponential distribution with mean 2 days, [0.5, 60] days Probability = 0.01	N.A.
13	T13:DLFP:SZP	Damage or loss of finished product in Shenzhen Port	Exponential distribution with mean 1 day, [0.5, 20] days Probability = 0.03	N.A.
14	T14:BCP:SZP	Back up the port disruption (attempt to resume port operations)	Uniform Exponential distribution with mean 2 days [0.5, 60] days Probability = 0.03	N.A.
15	T15:FPS:SZP	Finished products staying at Shenzhen Port during the backup time of Shenzhen port disruption	Uniform distribution [3, 5] days	Once per day
16	T16:DFP:SZP-LBP	Deliver finished product: from Shenzhen Port to customer in Long Beach	Uniform distribution [20, 30] days	Once per week (weekly shipment)
17	T17:RFP:C	Receiving finished product at customer in Long Beach	Uniform distribution [1, 2] days	Once per week (weekly delivery)

Table 2. Interpretation of places connected to and from Shenzhen Port and operations in the port

Code	Place Name	Description
1	P1:M(KHP)	Material at Supplier's port (Kaohsiung)
2	P2:M(KHP-SZP):Sea	Material on the way from Kaohsiung Port to Shenzhen Port (Sea transportation)
3	P3:M(SZP)	Material staying in Shenzhen Port
4	P4:M(SZP)	Material waiting for backup in Shenzhen Port
5	P5:M(SZP-Mfg)	Material ready to be delivered from Shenzhen Port to Manufacturer
6	P6:M(SZP-Mfg):Inland	Material on the way from Shenzhen Port to Manufacturer (Inland transportation)
11	P11:FP (SZP)	Finished product staying in Shenzhen Port
12	P12:FP (SZP)	Finished product waiting for backup in Shenzhen Port
13	P13:FP (SZP-C)	Finished product ready to be delivered from Shenzhen Port to Customer
14	P14:FP(SZP-LBP):Sea	Finished product on the way from Shenzhen Port to Long Beach Port (Sea transportation)
15	P15:FP(LBP)	Finished product at Customer's port (Long Beach)

Table 3. Transitions involving manufacturer and the associated parameters

Code	Transition Name	Description	Quantity (days)	Trigger Frequency
7	T7:RM:Mfg	Receiving material at Manufacturer	Uniform distribution [0.5, 1] days	Once per week
8	T8:INTLEL:M	Setting up inventory level of material	Uniform distribution [1, 2] days	Once per day
9	T9:INTLEL:FP	Setting up inventory level of finished product	Uniform distribution [1, 2] days	Once per day
10	T10:MOP	Manufacturing operation for product	Uniform distribution [5, 10] days	Once per day
11	T11:DFP:Mfg-SZP	Deliver finished product: from Manufacturer to Shenzhen Port	Uniform distribution [1, 3] days	Once per week (weekly delivery)

Table 4: Interpretation of places in manufacturer

Code	Place Name	Description
7	P7:MFMO(Mfg)	Material for manufacturing operation in Manufacturer
8	P8:FP(Mfg)	Finished product in Manufacturer
9	P9:NULL	NULL
10	P10:FP(Mfg-SZP):Inland	Finished product on the way from Manufacturer to Shenzhen Port (Inland transportation)

4. Results, Sensitivity Analysis and Discussion

The simulation model is coded by Matlab and is run for 36500 days, i.e. 100 years for generating stable results. To answer the research questions, we set the base scenario as no port disruption; scenario 1 has port disruptions on both import and export; scenario 2 has a port disruption on the import side; and scenario 3 has a port disruption on the export side.

Table 5. Simulation results on product delivery time (days)

	Base scenario - With no disruption	Scenario 1 - With Disruption on both sides	Scenario 2 - Disruption on Import Side	Scenario 3 - Disruption on Export Side
MIN	42.20	42.45	42.31	42.19
MAX	74.61	158.13	100.40	94.31
MEAN	57.80	58.13	57.80	58.11
St.D	4.55	5.32	4.64	4.99

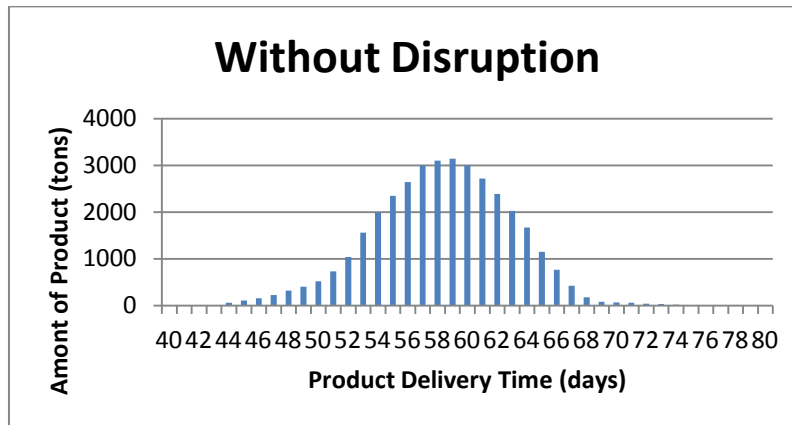


Fig 2. Base scenario - Product delivery time without port disruption

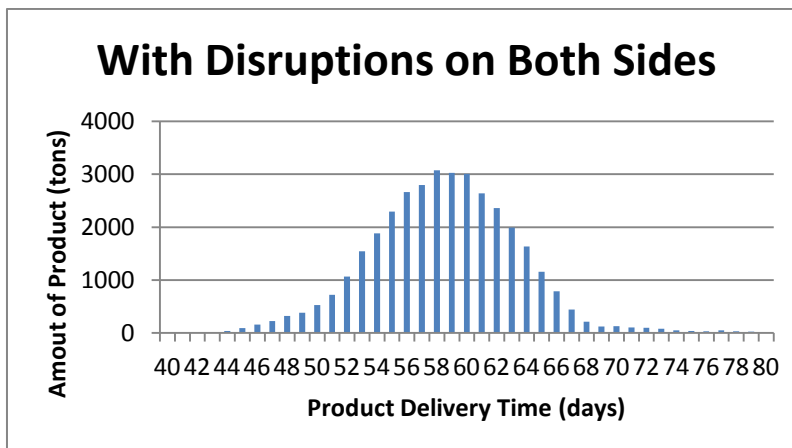


Fig 3. Scenario 1 - Product delivery time with port disruptions on both import and export

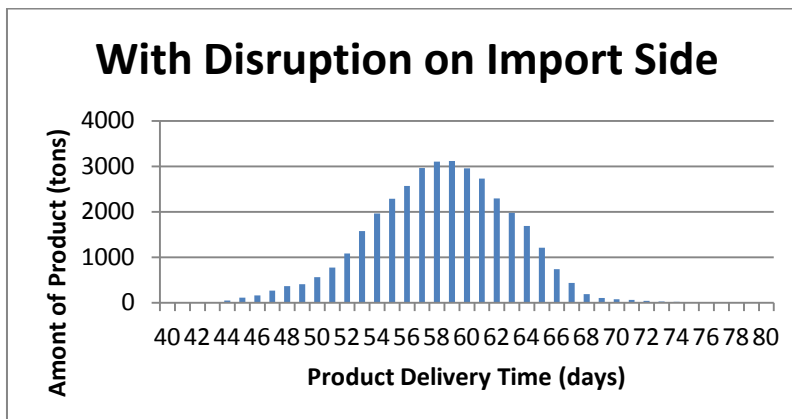


Fig 4. Scenario 2 - Product delivery time with port disruption on import side

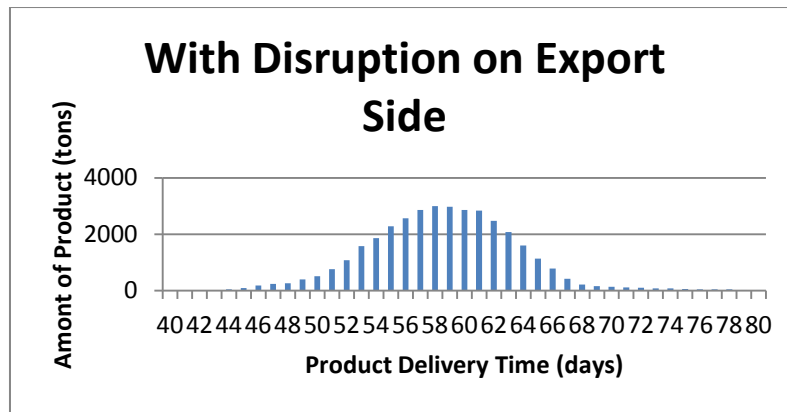


Fig 5. Scenario 3 - Product delivery time with port disruption on export side

Figures 2 to 5 and table 5 show the range of product delivery time in each of the scenarios. We can see that there are variations in product delivery time in normal circumstances regardless of port disruptions, as shown by the minimum and maximum number of days in delivery. Since the time taken for each transition is set to be stochastic instead of deterministic, differences exist in shipment time, inland transport time, and manufacturing operation among others. The simulation helps to imitate the behavior of supply chains in practice. The simulation results show that in the case of no port disruption, the mean product delivery time is 57.8 days with a minimum of 42.2 days and a maximum of 74.61 days. The standard deviation quantifies the extent of variations in product delivery time.

There are four observations worth pointing out with respect to table 5. First, the mean product delivery time regardless of disruptions on both import and export or either sides is rather similar, ranging from a low of 57.8 days to a high of 58.13 days. This means that regardless of disruptions, the mean time taken for product delivery is generally unaffected. Having a similar mean is due to the reason that the simulation was run for a very high number of times over 100 years with a low probability of port disruption (0.01). The simulation met the purpose of providing a real-life environment for analyzing the supply chain system. Second, the minimum product delivery time also exhibits relative consistency, ranging from 42.19 days to 42.45 days. This means that regardless of port disruptions, the minimum time taken to deliver the product is able to match up to the performance shown in the case of no disruptions. Since a port disruption can be as short as 0.5 day, the minimum time is not much affected. Third, the table shows significant variations in the maximum product delivery time. Taking reference to the product delivery time with no disruption, the maximum number of days shown is 74.61. However, where there are disruptions on both import and export sides, the maximum number of days increases significantly to 158.13, which is 2.12 times that of the case with no disruption. Where there are disruptions on either of the import or export side, the maximum number of days taken for product delivery are 100.4 and 94.31 days respectively. Compared to the scenario where there are no disruptions to product delivery, disruptions on the import side will result in maximum product delivery time being 1.35 times more. Where there are disruptions on the export side, maximum product delivery time will be 1.26 times more when compared to the case of no disruptions. The findings reveal that port disruptions that are extreme events can lead to very long delays in product delivery. In inbound logistics, such severe delays will particularly affect manufacturers' production schedule, while in outbound logistics, the effect will be largely on the consignees who require the products for sales. As can be seen in higher standard deviations with port disruptions especially on both import and export sides, results show that port disruptions create uncertainties for supply chains and stakeholders. Fourth, as compared to export, port disruptions happened on the import logistics affect the supply chains in terms of the high maximum delivery time. However, port disruptions on the export side lead to greater significance due to higher mean and standard deviation. These effects are undesirable since longer delivery time and higher uncertainties translate into lower supply chain efficiency and performance. We would like to highlight that a port disruption occurred in inbound logistics may affect outbound logistics and vice versa.

To understand the impact of risk mitigation on ports, we conduct sensitivity analysis by changing the parameters of T4 and T14. In scenarios 4 to 6 (see table 6), it takes longer time to resume operations by the port after the port disruption due to insufficient risk mitigation measures. Hence, the port suffers from lower

resilience and takes longer time to recover from the disruption. The mean time for resuming port operations is 1 day longer to be 3 days, and the range is [0.5, 70] days. According to the new simulation results, the product delivery time needed for all scenarios becomes higher. While the minimum and mean number of days slightly increase, the maximum time and standard deviation drastically increase, when it takes only 1 day more on average to resume port operations. The effect is especially significant when port disruptions affect both import and export. The maximum number of days in scenario 1 is 158.13 (table 5). However, it becomes 167.63 days or 9.5 days (6%) higher in scenario 4. The effect is even more obvious when compared to the base scenario where the maximum number of days is 74.61. This means, the maximum time needed is 2.25 times than that of a case having no port disruption. The standard deviation in scenario 4 is 7.76 while it is 5.32 in scenario 1. The results reveal the importance of risk mitigation strategies to enhance a port's resilience.

Table 6. Simulation results on product delivery time (days) with T4 and T14 mean 3 days, range [0.5, 70] days

	Base scenario - With no disruption	Scenario 4 - With Disruption on both sides	Scenario 5 - Disruption on Import Side	Scenario 6 - Disruption on Export Side
MIN	42.20	42.80	42.35	42.19
MAX	74.61	167.63	120.81	120.57
MEAN	57.80	58.47	57.85	58.22
St.D	4.55	7.76	5.00	5.54

As for managerial implications, supply chains and their members (e.g. manufacturers, distributors, customers) may suffer from a port disruption very significantly. The recovery period is relatively long. We suggest that inventory control would be an effective strategy to defend against port disruption, as discussed by Lewis et al. (2013). For instance, the Strategic Petroleum Reserve of USA is designed to reduce the disruptions of oil supply chains. A major problem for this strategy is that it demands for spare port capabilities and not all types of communities can afford such extra port capabilities to store inventory.

For any member of supply chains, re-structuring the supply chains is also an effective risk mitigation strategy. Therefore, in order to reduce the impacts due to port disruption, it is vital for a gateway port operator to develop some contingency plans with adjacent ports strategically. A contingency plan should be developed at the regional level, especially if a gateway port is concerned.

Our model is useful for different stakeholders to estimate the recovery of supply chains due to port disruptions. Simulations offer a more detailed prediction of the various indicators and factors along the supply chains. A study of port disruptions versus supply chain characters reveals latent strength or weakness along the supply chain systems. A good supply chain system should be not only effective but also survive against all disruptions.

5. Conclusions

This paper develops a stochastic timed Petri Net model for studying the dynamic behaviour of the supply chain system due to port disruptions. The investigation uses the PN model to combine two elements (a) the framework structure of supply chain, and (2) the cause-and-effect structure for analysis. The study generates new insights in supply chain system behaviour. The study shows that the PN model can provide stepwise processes and an efficient environment for conducting simulation and other analyses on the study topic. Based on the results from the discrete event simulation, it can be seen that the impact of port disruption propagates in the supply chain which can be very extensive. The study contributes by quantifying the impact which would be highly valuable to various supply chain parties for risk management purposes. The paper has illustrated a scientific and replicable research process on assessing and managing port disruptions. The approach undertaken by this study is widely applicable to any ports. The flexibility of the method also enables any types of risk to be modelled. Many future studies can be conducted, for example, on comparing different port disruption mitigation strategies and transshipment hub disruption.

Acknowledgements

This research is funded by Singapore Ministry of Education AcRF project, NTU ref: RF20/10 and The Hong Kong Polytechnic University under Grant Number: A-PL05.

References

- AASTOCKS (2014), Update: Container throughput of Shenzhen Port totals 23.28 mln TEU in 2013, ranking 3rd in the world, <http://www.aastocks.com/en/stocks/analysis/china-hot-topic-content.aspx?id=200000303210&type=2&catg=1> (Accessed 3 February 2014).
- Berle, O., Rice Jr., J. B., and Asbjornslett, B.E. (2011), Failure mode in the maritime transportation system: A functional approach to throughput vulnerability, *Maritime Policy and Management*, 38(6): 605-632.
- Blackhurst, J., Wu, T. T., and Craighead, C. W. (2008), A systematic approach for supply chain conflict detection with a hierarchical Petri Net extension, *Omega*, 36(5): 680-696.
- Chang, S. E. (2000), Disasters and transport systems: Loss, recovery and competition at the Port of Kobe after the 1995 earthquake, *Journal of Transport Geography*, 8: 53-65.
- China Labour Bulletin (CLB) (2009), *Going It Alone, The Workers' Movement in China (2007-2008)*, www.clb.org.hk (Accessed 10 December 2013).
- EM-DAT (2014), Natural Disasters Trends, <http://www.emdat.be/natural-disasters-trends> (Accessed 3 February 2014).
- Gaonkar, R.S.P., Xie, M., Ng, K.M., Habibullah, M.S. (2011), Subjective operational reliability assessment of marine transportation system. *Expert Systems with Applications*, 38(11): 13835-13846.
- Gurning, S. and Cahoon, S. (2011), Analysis of multi-mitigation scenarios on maritime disruption, *Maritime Policy and Management*, 38(3): 251-268.
- Kleindorfer, P.R. and Saad, G.H. (2005), Managing disruption risks in supply chains, *Production and Operations Management*, 14(1): 53-68.
- Knemeyer, A.M., Zinn, W. and Eroglu, C. (2009): Proactive planning for catastrophic events in supply chains, *Journal of Operations Management*, 27(2): 141-153.
- Lam, J.S.L. (2012), Risk management in maritime logistics and supply chains, in Song, D.W. and Panayides, P.M. (eds.), *Maritime Logistics: Contemporary Issues*, Emerald, 117-132.
- Lam, J.S.L. and Gu, Y. (2013), Port hinterland intermodal container flow optimisation with green concerns: a literature review and research agenda, *International Journal of Shipping Transport and Logistics*, 5 (3): 257-281.
- Lewis, B. M., Erera, A. L., Nowak, M. A, Chelsea, W.C.III (2013), Managing inventory in global supply chains facing port-of-entry disruption risks, *Transportation Science*, 47(2):162-180.
- Office of the Commissioner of Insurance (OCI). (2007), Extended insurance coverage to the Shenzhen Bay Port Hong Kong Port Area. (25 June, 2007), http://www.oci.gov.hk/download/pr_20070625.pdf (Accessed 10 December 2013).
- Petri, C. (1962), *Kommunikation mit Automaten*, PhD dissertation, University of Bonn.
- Sanchez-Rodrigues, V., Potter, A. and Naim, M.M. (2010), Evaluating the causes of uncertainty in logistics operations, *International Journal of Logistics Management*, 21(1): 45-64.
- Sheffi, Y. and Rice, J. B. (2005), A supply chain view of the resilient enterprise, *MIT Sloan Management Review*, 47(1): 41-48.
- Su, P., Wu, N.Q., Yu, Z.Q. (2014), A Petri net based heuristic for mixed model assembly line balancing problem of Type-E., *International Journal of Production Research*, 52(5): 1452-1556.
- Tan, X. (2007), Port salary dispute resolved, (9 April 2007), <http://www.newsgd.com/citiesandtowns/shenzhen/news/200704090026.htm> (Accessed 15 January 2014).
- Wilson, M.C. (2007), The impact of transportation disruptions on supply chain performance, *Transportation Research Part E*, 43(4): 295-320.
- Zurawski, R. and Zhou, M. (1994), Petri Nets and Industrial Applications: A Tutorial, *IEEE Transactions on Industrial Electronics*, 41(6): 567-582.

Examining the Linkages between Service Capabilities, Dynamic Capabilities, and Competitive Advantage in Container Shipping

Szu-Yu Kuo¹, Pei-Chun Lin² and Chin-Shan Lu³

¹Department of Transportation and Communication Management Science, National Cheng Kung University, Tainan City 701, Taiwan, ROC

²Department of Transportation and Communication Management Science, National Cheng Kung University, Tainan City 701, Taiwan, ROC

³Department of Logistics and Maritime Studies, The Hong Kong Polytechnic University, Hong Kong

Abstract

The purpose of this study is to examine the linkages between service capabilities, dynamic capabilities, and competitive advantage in container shipping. Using data provided by 134 respondents in container shipping companies in Taiwan. A structural equation modeling (SEM) was used to test the research hypotheses. The research findings indicated that service capabilities positively influenced on dynamic capabilities, whereas dynamic capabilities were positively related to competitive advantage. Results also indicated that dynamic capabilities mediates the relationship between service capabilities and competitive advantage. Practical implications from the research findings were discussed for container shipping firms.

Keywords: Service Capabilities, Dynamic Capabilities, Competitive Advantage, Container Shipping.

1. Introduction

In the field of strategic management, the resource-based view (RBV) suggests that organizational capabilities have been recognized as one core source for creation and development of sustainable competitive advantage (Barney, 1991; Schreyögg and Kliesch-Eberl, 2007). Specifically, the container shipping is an international industry that provides maritime transport service based on customer's needs and a regularly scheduled basis to predetermined ports (Tran et al., 2012). With the significant changes in global business environment, the shipping industry has become highly competitive and seeks to enhance its capabilities of services in order to meet various requirements of shippers (Lu, 2007; Lu et al., 2007). Service capabilities can be defined as the ability of service providers to employ their resources satisfies customers' needs (Lai, 2004; Huang and Huang, 2012). Service capabilities have been explained in container shipping service includes transit time, freight rate, and frequency of services that are the drivers for superior competitive advantage (Lu and Yang, 2006). Despite the notion of capabilities to a firm's competitive advantage have been discussed in prior research (Barney, 1991; Peteraf, 1993; Wernerfelt, 1984), many empirical problems remain existing while the environment changes (Drnevich and Kriauciunas, 2011). The RBV has not adequately interpreted how a firm has its competitive advantage in circumstances of rapid and unpredictable change (Eisenhardt and Martin, 2000), therefore, several studies have extended RBV to a dynamic conception (Teece et al., 1997; Helfat, 1997).

Under conditions of an uncertain environment with increasingly higher costs and risks (UNCTAD, 2013), container shipping companies have to focus on the dynamic capabilities for renewing and adjusting their management strategies (Helfat and Winter, 2011; Tsekouras, et al., 2011; Yang et al., 2009). The dynamic-capability view (DCV) of a firm can be defined as "the ability of a firm to renew itself in the face of a changing environment by changing its set of resources" (Danneels, 2010, p. 1). It can be disaggregated into these capabilities "(1) to sense and shape opportunities and threats, (2) to seize opportunities, and (3) to maintain competitiveness through enhancing, combining, protecting, and when necessary, reconfiguring the business enterprise's intangible and tangible assets" (Teece, 2007, p.1319). Romme et al. (2010) argued that dynamic capabilities can enhance organizational ability to change and adapt to new environmental

requirements. In a changing environment, therefore, dynamic capabilities have become a necessary source by which to sustain competitive advantage (Haleblian et al., 2012; Kor and Mahoney, 2005).

This study utilized theories related to the resource-based view to consider below questions. First, by focusing on the previous research of service in resource deployments, this study highlights and examines the role of dynamic capabilities in strategic management leading to development and sustaining of competitive advantage. Second, while prior studies have compared the difference of capabilities (Drnevich and Kriauciunas, 2011), few studies have empirically examined how service capabilities influence dynamic capabilities. Third, the RBV is often revealed empirical research streams related to service industry, it seems weakness to explain the situation of environmental dynamism in strategic management. Dynamic capabilities are thought have greater perform to sustain the competitive advantage than traditional RBV theory (Eisenhardt and Martin, 2000). Therefore, the objective of this study is to examine the relationship between service capabilities, dynamic capabilities and competitive advantage in the container shipping context.

There are five sections in this research. The first section introduces research motivation and background. In the following section, the literature on service capabilities, dynamic capabilities, and competitive advantage are reviewed to develop research hypotheses. Section three discusses the development of the research instrument, including the measurement constructs used in the survey, the sampling technique, and the research procedures. Section four presents the statistical results from the analyses relevant to the research hypotheses. Conclusions and implications from the research findings are discussed in the final section.

2. Theoretical Background and Hypotheses

2.1 Definition of Resource-based View

Resource-based view (RBV) was defined as a bundle of resources and capabilities (Nath et al., 2010). RBV was suggested for strategic management and it needs to be sustained by a firm's resources and capabilities (Hooley and Broderick, 1998). Barney (1991) summarised four characteristics of resources could sustain a firm's competitive advantage, namely, value, rarity, imperfect imitability, and imperfect substitutability. RBV could be divided into resources and capabilities (Teece, 1982). Amit and Schoemaker (1993, p.35) referred resources to "stocks of available factors that are owned or controlled by the firm". Resource comprised of tangible components such as financial and physical assets, equipment, land, and buildings, whereas intangible components include human resources, patents, client trust, firm reputation, and know-how (Clulow, 2007; Nath et al., 2010).

Capabilities were defined as "a complex bundle of skills and accumulated knowledge that enables firms to coordinate activities and makes use of their assets" (Day, 1990, p.38). Capabilities concern a firm's ability to combine and develop its resources to create competitive advantage (Wu, 2010). The characteristics of capabilities can be identified as being either functional based (Hafeez et al., 2002). Day (1994) divided capabilities into three types of processes, including outside-in processes (e.g. market sensing, customer linking, and technology monitoring), inside-out processes (e.g. financial management, technology development, manufacturing processes, human resources management), and spanning processes (e.g. customer order fulfilment, purchasing, strategy development). Capabilities can be thought as the organizational ability to using current resources to perform tasks or activities (Gavronski et al., 2011).

2.2 Definition of Service Capabilities

The term of service capabilities refers to "the process of delivering products in a way that creates added value to customers" (Liu and Lyons, 2011, p. 549). To fully satisfy the increasing requirements from customers, service capability is thought the footstone in container shipping (Lu, 2007). The service attributes in the shipping industry was selected from the related literature based on previous maritime and transportation studies. For example, Brooks (1985) examined the determinants affecting shipper choice of a container shipping carrier and discovered service cost was the most frequent concern related to selection criterion, followed by sailing frequency, reputation, transit time, and directness of routes.

Kent and Parker (1999) investigated that the difference in perceptions of 18 carrier selection factors between shippers and international containership carriers. The findings indicated that the five most important attributes includes claims processing, pickup and delivery service, special equipment, line haul services, and quality of carrier salesmanship. Lu (2000) evaluated logistics services in Taiwanese maritime firms and found there to be nine service attributes that were significantly different between implemented and non-implemented logistics companies. These service attributes included good financial condition, high frequency of sailing, on-time pick-up, courtesy of inquiry, prompt response to claim, good condition of containers, ability to provide computer system for cargo tracking, ability to provide door-to-door service, and ability to provide customs clearance services.

Lu (2003) assessed the impact of carrier service attributes on shippers' satisfaction from the perspective of shipper-carrier partnering relationships. Seven service factors were extracted by factor analysis that included timing-related services, pricing-related services, warehousing service, sales service, door-to-door service, information service, and advertising. The findings indicated that timing related services were necessary to increase shipper satisfaction in a partnering relationship, while the other relative service factors didn't significantly affect shipper-carrier partnering relationships. Subsequently, Lu (2007) evaluated key resources and capabilities for liner shipping services in Taiwan. Three resource dimensions (including marine equipment, information equipment, and corporate image) and seven capability dimensions were identified from factor analysis. The results indicated that operation capabilities are perceived as the most important dimension, followed by customer service, human resource management, information integration, pricing, purchasing, and financial management.

Yang et al. (2009) evaluated the impacts of resources and capabilities on container shipping services in Taiwan. Three resource attributes (e.g. corporate image, information equipment, and network resources) and four logistics capabilities (value-added service, service reliability, relationship building, and information integration and flexibility) were identified using factor analysis. The five most important resource attributes were financial stability, corporate reputation, low cargo damage or loss record, geographical coverage of service, and high frequency of sailings. On the other hand, the five most important logistics service capabilities included courtesy of sales representative, accurate price calculation, long term contractual relationship with customers, reliability with regard to booking space, and accuracy of documentation. Kannan et al. (2011) investigated the theory of reasoned action to determine important carrier service attributes from the shippers' point of view in India. An analytic hierarchy process (AHP) was used, and the results indicated that the most important criterion was low freight, followed by pricing flexibility, gifts and compliments, online booking, physical facilities, professional appearance, and trade announcements. The capability concept of the resource-based view recommends that superior organizational performance is depend on the manner in which shipping service providers' leverage their resources (Lai, 2004).

2.3 *Service Capabilities and Competitive Advantage*

Competitive advantage has been defined as "the implementation of a strategy not currently being implemented by other firms that facilitates the reduction of costs, the exploitation of market opportunities, and/or the neutralization of competitive threats, and performance is generally conceptualized as the rents a firm accrues as a result of the implementation of its strategies" (Newbert, 2008, p.749). Based on resource-based view, a firm's competitive advantage includes unique resources and capabilities, the ability to efficiently employ resources and capabilities to make right decisions (Talaja, 2012). Services and resources have been classed as assets and capabilities in the context of container shipping.

To know the key service capabilities of container shipping were considered, previous researches have discussed the importance of attributes for shipping carriers (Brooks, 1985; Lu, 2007; Kannan et al., 2011; Progoulaki and Theotokas, 2010). Kannan et al. (2011) used 45 criteria to evaluate the container carrier selection process from a shipper's perspective in India and found the most important criterion to be low freight. When firms have the low-cost capabilities, they can provide low freight to customers and build strongly competitive advantage. Progoulaki and Theotokas (2010) also presented the impact of resources on competitive advantage in the shipping industry. Results indicated the management of human resources in the shipping company as a powerful capability that can reduce cost to sustainable competitive advantage.

According to the resource-based view, container shipping companies can employ different resources to provide integrated shipping service for further competitive advantage. Accordingly, this study hypothesized that:

Hypothesis 1: The service capabilities will be positively related to competitive advantage in the container shipping industry.

2.4 *Service Capabilities and Dynamic Capabilities*

Teece et al. (1997, p. 515) defined dynamic as “the capacity to renew competences so as to achieve congruence with the changing business environment; certain innovative responses are required when time-to-market and timing are critical, the rate of technological change is rapid, and the nature of future competition and markets difficult to determine”. Further, Teece et al. (1997, p. 516) defined the dynamic capabilities as “The firm’s ability to integrate, building, and reconfigure internal and external competences to address a rapidly changing environment”. Accordingly, dynamic capabilities can be deployed to acquire, allot, integrate, and recombine resources to generate new value for firm (Eisenhardt and Martin, 2000). Dynamic capabilities can be divided into three dimensions including: (1) to sense and shape opportunities; (2) to seize opportunities; (3) to maintain competitiveness through enhancing, combining, protecting, and reconfiguring resources (Hodgkinson and Healey, 2011; Teece, 2007; Wilden et al., 2013). Sensing capability refers to a firm’s activities in scanning, searching, identifying and exploring new opportunities (Ellonen et al., 2009). Seizing capability is defined as strategic insight and denotes making the correct decisions and executing them (O’Reilly and Tushman, 2008). Reconfiguring capability refers to “the ability to recombine, to reconfigure assets, and organizational structures as the enterprise grows and markets change” (Teece, 2007, p. 1335).

A growing number of studies have demonstrated that the notion of dynamic capabilities was derived from resource-based view (Fawcett, 2010; Helfat and Peteraf, 2003; Newbert, 2007; Teece, 2007; Wu, 2006). Wu (2006) found that a firm’s resources positively affect its dynamic capabilities because the existing resources are a firm’s basis by which to construct dynamic capabilities. Fawcett et al. (2010) presented an integrated theoretical framework to examine dynamic capabilities in supply chain collaboration. This study considered that successful inventory management capabilities that provides high level of dynamic collaboration to obtain customer’s satisfaction. Results indicated that the information infrastructure between suppliers and customers were the key determinants influencing the dynamic collaboration leading to the creation of more inimitable value. A firm has different specific resources (e.g. complementary capability, financial capability, institutional assets, structural assets, research and develop capability, information technology capability, and marketing capability, etc.) with lead to the creation of the different effects on dynamic capabilities (Teece, 1997). Accordingly, this study hypothesized that:

Hypothesis 2: The service capabilities will be positively related to dynamic capabilities in the container shipping industry.

2.5 *Dynamic Capabilities and Competitive Advantage*

Dynamic capabilities have been considered to be important with regard to sustaining a firm’s successful competitive advantage (Zahra, 1999). Based on future competition and market are difficult to certain forecast, a firm specially needs to be flexible with regard to the timing of market entry and decision changes occurring in response to current environment (Sher and Lee, 2004).

Prior studies have demonstrated the effects of dynamic capabilities on competitive advantages (Marcus and Anderson, 2006; O’Reilly and Tushman, 2008; Sher and Lee, 2004). Marcus and Anderson (2006) found dynamic capabilities to have impacts on firm competence in supply chain management in the retail food industry because dynamic capabilities can help to flexibly solve the allocation problems in supply chain networks. O’Reilly and Tushman (2008) asserted dynamic capabilities can integrate organizational resources to keep costs low and asset utilization high that increasing competitive advantage rapidly responds to environmental changes. This finding revealed that the dynamic capabilities have a significant positive

influence on competitive advantages. Dynamic capabilities have been shown to improve competence for the delivery of business excellence and competitive advantage. Accordingly, this study hypothesized that:

Hypothesis 3: The dynamic capabilities will be positively related to competitive advantage in the container shipping industry.

3. Methodology

3.1 Sample

The sample of this study was drawn from employees working for companies registered by the National Association of Shipping Agencies and Companies in Taiwan. The sample includes container shipping companies and container shipping agencies, excluding port agencies, were identified. A total of 339 questionnaires were sent to target professional managers on 10th October, 2013 and 88 usable questionnaires were returned. A follow-up mailing was sent to the other respondents who didn't reply our questionnaires in the first time mailing to improve the response rate after two weeks. An additional 46 usable responses were returned. A total number of usable questionnaires of 134 with overall response rate of 39.52%.

3.2 Non-response Bias

In order to ascertain the representativeness of survey data, this study analysed responses from the first data set (88 respondents) and then compared the results with the second data set (46 respondents) for non-response bias testing. A simple across 32 measurement items paired t-test analysis presented that there were 2 items significant difference ($p < 0.05$) between the two sets of data on the key variables utilized in this study (Armstrong and Overton, 1977). Results of non-response bias suggested that it was appropriate to combine the two datasets as representative of the population that was accepted to take part in the survey.

3.3 Common Methods Variance

Since data were collected from a single person at a single point in time, common method variance (CMV) should be a threat to the validity of study results. To examine the extent to which CMV affects the empirical findings, this study carried out several post hoc tests of the data. This study conducted Harman's one-factor test (Podsakoff and Organ, 1986), one of the most widely used methods to that no one general factor accounted for the majority of covariance between the predictor and criterion variables (Podsakoff et al., 2003). Results of factor analysis demonstrated that there's no single factor, where the independent and dependent variables load on different factors with the first factor accounting for less than 50% (47.73%) of total variance (Podsakoff et al., 2003). This study can conclude that the results will not be inflated since the existence of CMV.

3.4 Measures

Data for this study were collected from a survey and it was designed based on the approach by Churchill and Iacobucci (2010). Three constructs of this study examined survey measurement items of service resources, dynamic capabilities, and competitive advantage. The items of questionnaire were adapted from the existing scales in the literature and shipping expert. According to the feedbacks from interviews and after revising, the final version of survey items consisted of 32 evaluation items in this study. The following items were measured on a five-point Likert scales from 1 (strongly disagree) to 5 (strongly agree) for range the agreement and evaluating scale. The proposed constructs and evaluation items and utilisation from prior studies can be found in Table 1.

Service capabilities- Service capabilities were measured as the level of the agreement from the capabilities of container shipping companies. 13 measures were adapted from the studies of Brooks (1985), Kannan et al. (2011), Kent and Parker (1999), Lu (2000, 2003, 2007), Lu and Marlow (1999), and Yang et al. (2009).

Dynamic capabilities- Dynamic capabilities were measured as the firm's ability to integrate, building, and reconfigure its competences to face a changing environment. There are 16 measurement items were adapted

from the prior studies of Agrwal and Selen (2009), Drnevich and Kriauciunas (2011), Hung et al. (2010), Lin and Wu (2014), Wilden et al. (2013), Wu (2007, 2010). Respondents were request to answer these attributes of dynamic capabilities in their company related to competitive advantage.

Competitive advantage- Competitive advantage was measured according to the level of competitive advantage from respondents' company. To identify the specific competitive advantage in container shipping, 6 items were adapted from the previous studies of Bharadwaj et al. (1993), Schilke (2014), and Spanos and Lioukas (2001).

Table 1. Measurement items for service capabilities, dynamic capabilities, and competitive advantage constructs

Measurement items	Prior studies
<i>Service capabilities</i>	Brooks (1985),
S1 My firm is good at cargo tracing.	Kannan et al. (2011),
S2 My firm can efficiently response to customer complaint.	Kent and Parker
S3 My firm is good at sales activity.	(1999), Lu (2000,
S4 My firm has rational freight rate.	2003, 2007), Lu and
S5 My firm provides flexibility service.	Marlow (1999), and
S6 My firm is good at information integration.	Yang et al. (2009).
S7 My firm provides high frequency of sailing.	
S8 My firm is good at on-time pick-up and delivery.	
S9 My firm provides short transit time.	
S10 My firm is good at purchasing (e.g. vessel or fuel)	
S11 My firm has good relationships with cooperative partners.	
S12 My firm has low damage or loss record for cargo delivery.	
<i>Dynamic capabilities</i>	
D1 My firm is good at customer information collection.	Agrwal and Selen
D2 My firm understands customers' specific needs.	(2009), Drnevich and
D3 My firm is good to evaluate my own firm's strength and weakness.	Kriauciunas (2011),
D4 My firm can rapid aware new business opportunity or threat possibility.	Hung et al. (2010),
D5 My firm has the ability to gather economic information on our operations and operational environment.	Lin and Wu (2014),
D6 My firm owns better learning capability.	Wilden et al. (2013),
D7 My firm can flexibly develop new services.	Wu (2007, 2010).
D8 My firm adopts the best practices in the industry.	
D9 My firm changes our practices when customer feedback gives us a reason to change.	
D10 My firm learns or acquires new skill from the partners.	
D11 My firm has the ability of rapid organizational response to market changes.	
D12 My firm has the ability of rapid organizational response to competitor's action.	
D13 My firm has the ability of efficient and effective communication with cooperative organization.	
D14 My firm has the ability of resource reconfiguration.	
D15 My firm has the ability to change various way of doing business.	
D16 My firm owns flexible competitiveness in the industry in the future.	
<i>Competitive advantage</i>	
C1 My firm has service differentiation.	Bharadwaj et al.
C2 My firm has cost advantage.	(1993), Schilke
C3 My firm has advantage of service innovations.	(2014), and Spanos
C4 My firm has fully using capacity utilization.	and Lioukas (2001).
C5 My firm has gained strategic advantages over our competitors.	
C6 Overall, my firm is more successful than our major competitors.	

3.5 Research Methodology

The aim of this study is to examine the linkages between service capabilities, dynamic capabilities, and competitive advantage in the container shipping industry. First, an exploratory factor analysis was employed to identify the crucial dimensions of service capabilities, dynamic capabilities, and competitive advantage. Subsequently, a confirmatory factor analysis (CFA) was performed to assess the convergent and discriminant validity of the measurement items. Third, a structural equation modelling (SEM) was used to examine the model of research hypotheses. Finally, explanation and application of the administration of these tools for evaluating mediation is further discussed. All analyses were carried out using the SPSS18.0 and AMOS 18.0 for windows statistical packages.

4. Results and Empirical Analysis

4.1 Characteristics of Respondents

The profile of respondents is presented in Table 2. Result indicates that 73% of respondents' job title was director or above, explaining most of respondents are the deciding makers that are suitable to answer our questionnaires. With regarding working experience, only 15% were under 10 years represented respondents had abundantly practices. Table 2 also shows that 31% of respondents' firm employed between 101 and 500 employees, followed by 28% that were less than 50 employees. The length of business operations of respondents' firm is 86% over 31 years. In terms of the ownership pattern, local-firm was 52%, followed by foreign-owned firm was 34%.

Table 2. Profile of respondents

	Number of respondents	Percentage of respondents
Job title		
Vice president or above	43	32
Manager	55	41
Director	20	15
General employee	12	9
Sales representative	4	3
Working experience (years)		
Less than 5	10	7
6-10	11	8
11-15	20	15
16-20	22	16
21 or above	71	53
Number of employees		
Less than 50	37	28
51-100	17	13
101-500	42	31
501-1,000	8	6
1,001 or above	30	22
Length of business operations (years)		
Less than 5	1	1
6-10	0	0
11-20	7	5
21-30	11	8
31 or above	115	86
Ownership pattern		
Local firm	70	52
Foreign-owned firm	46	34
Foreign-local firm	18	13

4.2 Exploratory Factor Analysis

Exploratory factor analysis was utilized to clarify the factors/dimensions underlying the measurement items and recommend conducting for scales that are development in advance while confirmatory factor analysis was used for more mature scales. Principal component analysis with VARIMAX rotation was employed to extract the factors with eigenvalues greater than 1.0 (Hair et al., 2010; Handley and Benton, 2012). Bartlett's Test of Sphericity (901, $p < 0.000$) and the Kaiser-Meyer-Olkin (KMO) statistic (0.898) confirmed the suitability of items for factor analysis (Hair et al., 2010). Results indicated that both service capabilities and dynamic capabilities measurement items performed two factors and competitive advantage revealed one factor underlying their items. Therefore, conducting an exploratory factor analysis for service capabilities and dynamic capabilities was necessary and results were performed as followed. This study found factor analysis of service capabilities indicated two factors accounted for 61.83% of the total variance in Table 3. They are described below.

- (1) Factor one consisted of seven items, namely, "my firm is good at information integration"; "my firm is good at purchasing (e.g. vessel or fuel)"; "my firm is good at on-time pick-up and delivery"; "my firm provides high frequency of sailing"; "My firm provides short transit time."; "my firm is good at cargo tracing"; "my firm has low damage or loss record for cargo delivery". Based on these items were regarding to operation capability, this factor was labelled an operation capability dimension. "My firm is good at information integration" had the highest loading on this dimension. This factor accounted for 53.38% of the total variance.
- (2) Factor two consisted of five items, namely, "my firm provides flexibility service"; "my firm can efficiently response to customer complaint"; "my firm has rational freight rate"; "my firm is good at sales activity"; "my firm has good relationships with cooperative partners". As these items were associated with marketing capability, this factor was labelled a marketing capability dimension. "My firm provides flexibility service" had the highest factor loading on this dimension. Factor two accounted for 8.45% of the total variance.

Table 3. Factor analysis of service capabilities attributes

Attributes	Factor one	Factor two
<i>Factor 1</i> Operation capability		
My firm is good at information integration.	0.83	0.15
My firm is good at purchasing (e.g. vessel or fuel).	0.75	0.12
My firm is good at on-time pick-up and delivery.	0.70	0.43
My firm provides high frequency of sailing.	0.70	0.38
My firm provides short transit time.	0.63	0.44
My firm is good at cargo tracing.	0.61	0.34
My firm has low damage or loss record for cargo delivery.	0.55	0.48
<i>Factor 2</i> Marketing capability		
My firm provides flexibility service.	0.14	0.79
My firm can efficiently response to customer complaint.	0.42	0.75
My firm has rational freight rate.	0.16	0.74
My firm is good at sales activity.	0.49	0.65
My firm has good relationships with cooperative partners.	0.44	0.62
<i>Eigenvalue</i>	6.41	1.02
<i>Percentage variance</i>	53.38	8.45

The initial factor for dynamic capabilities accounted for 62.96% of the total variance and indicated the item "my firm owns better learning capability", and "my firm has the ability of rapid organizational response to market changes" were eliminated due to their factor loading score was over 0.5 between two factors. Table 4 performed the subsequent analysis of dynamic capabilities items given two factors, which accounted approximately 63.17% of the total variance. Bartlett's Test of Sphericity is 1171 ($p < 0.000$) and the KMO statistic is 0.928. They are labelled as below:

- (1) Factor one consisted of eight items, namely, “My firm understands customers’ specific needs”; “My firm is good at customer information collection.”; “my firm learns or acquires new skill from the partners”; “my firm adopts the best practices in the industry”; “my firm changes our practices when customer feedback gives us a reason to change”; “my firm is good to evaluate my own firm’s strength and weakness”; “my firm has the ability to gather economic information on our operations and operational environment”; “my firm can rapid aware new business opportunity or threat possibility”. As these items were related to sense and seize capability, was therefore identified as sensing and seizing capability. “My firm understands customers’ specific needs” had the highest loading on this dimension. This factor accounted for 55.77% of total variance.
- (2) Factor two comprised six items, namely, “my firm has the ability to change various way of doing business”; “my firm has the ability of resource reconfiguration”; “my firm has the ability of rapid organizational response to competitor’s action”; “my firm has the ability of efficient and effective communication with cooperative organization”; “my firm owns flexible competitiveness in the industry in the future”; “my firm can flexibly develop new services”. “My firm has the ability to change various way of doing business” had the highest loading on this dimension. This factor accounted for 7.40% of total variance.

Table 4. Factor analysis of dynamic capabilities attributes

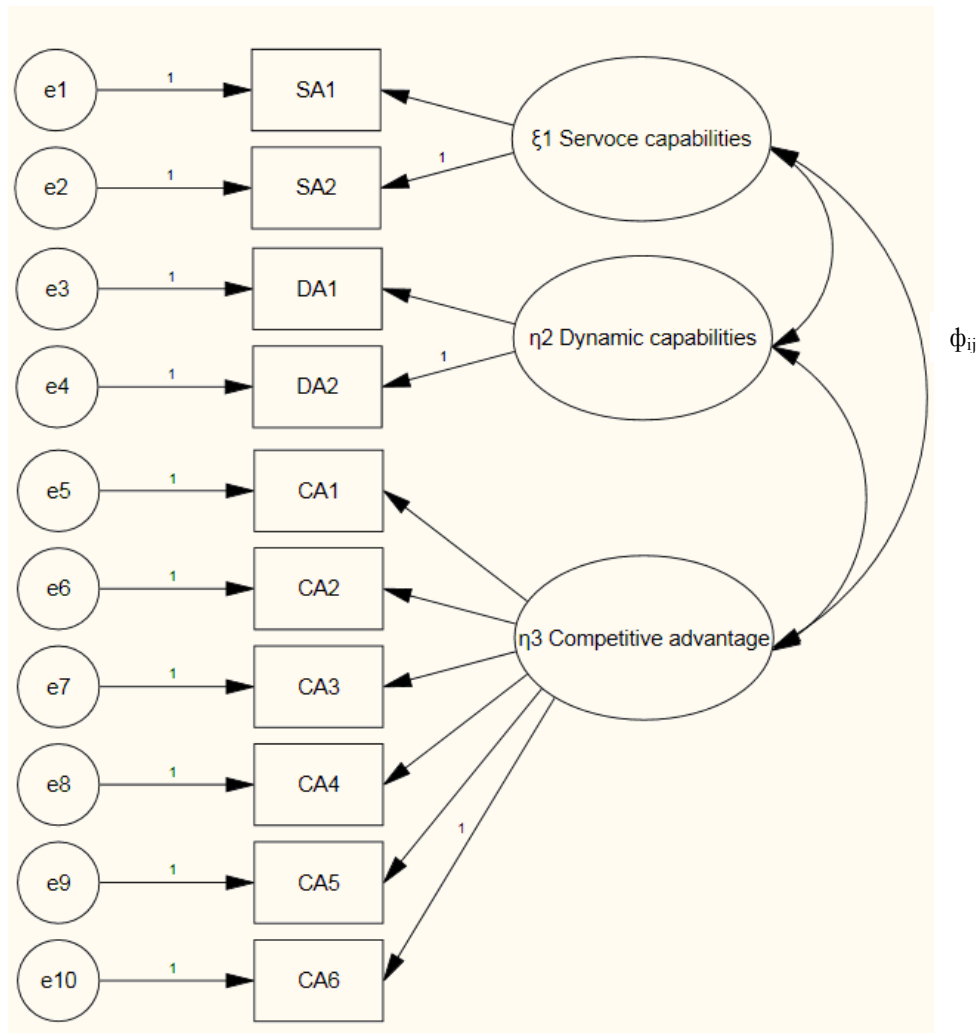
Attributes	Factor one	Factor two
<i>Factor 1 Sensing and seizing capability</i>		
My firm understands customers’ specific needs.	0.76	0.27
My firm is good at customer information collection..	0.75	0.28
My firm learns or acquires new skill from the partners.	0.72	0.35
My firm adopts the best practices in the industry.	0.71	0.28
My firm changes our practices when customer feedback gives us a reason to change.	0.70	0.27
My firm is good to evaluate my own firm’s strength and weakness.	0.68	0.34
My firm has the ability to gather economic information on our operations and operational environment.	0.63	0.40
My firm can rapid aware new business opportunity or threat possibility.	0.61	0.42
<i>Factor 2 Reconfiguring capability</i>		
My firm has the ability to change various way of doing business.	0.17	0.84
My firm has the ability of resource reconfiguration.	0.31	0.83
My firm has the ability of rapid organizational response to competitor’s action.	0.45	0.70
My firm has the ability of efficient and effective communication with cooperative organization.	0.48	0.69
My firm owns flexible competitiveness in the industry in the future.	0.40	0.69
My firm can flexibly develop new services.	0.42	0.59
<i>Eigenvalue</i>	7.81	1.04
<i>Percentage variance</i>	55.77	7.40

4.3 Reliability Test

This study conducted Cronbach’s alpha statistic and corrected item-total correlation coefficients to examine the reliability of the path loading of the measurement items (Nunnally, 1978). The high level of item reliability indicated the items are strongly affected by each measure construct and implied sets of items are unidimensional (Hair et al., 2010). Table 5 reveals the Cronbach’s alpha values and corrected item-total correlation coefficients of each measurement scale are all above the recommended threshold of 0.7 (Nunnally, 1978).

Table 5. Reliability test results

	No. of items	Mean	S.D.	Cronbach's alpha	Range of corrected item-total correlation
Operation capability	7	4.12	0.75	0.88	0.581-0.752
Marketing capability	5	4.20	0.69	0.85	0.595-0.777
Sensing and Seizing capability	8	4.03	0.71	0.90	0.464-0.732
Reconfiguring capability	6	4.00	0.76	0.90	0.639-0.792
Competitive advantage	6	3.87	0.68	0.87	0.613-0.795

**Fig 1. Path Diagram Representing the Measurement Model**

Note: SC1: Operation capability; SC2: Marketing capability; DC1: Sensing and Sizing capability; DC2: Reconfiguring capability; CA1: My firm has serve differentiation; CA2: My firm has cost advantage; CA3: My firm has rate of service innovations; CA4: My firm has fully using capacity utilization; CA5: My firm has gained strategic advantages over our competitors; CA6: My firm has gained strategic advantages over our competitors.

4.4 Confirmatory Factor Analysis

Confirmatory factor analysis was employed to test the model fit, reliability, and validity (Hair et al., 2010). Figure 1 performs a measurement model where there are three latent variables made up of their corresponding multiple indicators, namely, service capabilities, dynamic capabilities, and competitive advantage. Latent variables (common factors) are represented by circles and marked with Greek letters ξ and η . Ten observed variables were represented by squares. Two observed variables (SC1 and SC2) were loaded onto service

capabilities, two observed variables (DC1 and DC2) were loaded onto dynamic capabilities, and six observed variables (CA1-CA6) were loaded onto competitive advantage. The Greek letter ϕ_{ij} represents the correlation between the latent variables, whereas the coefficients are the factor loadings of the observed indicators on the latent variables.

The results from the CFA depicted acceptable measurement model validity. Acceptable overall model fit was reflected by the RMSEA= 0.043 and the Chi-square (χ^2) value were 39.82 at 32 of freedom and was significant ($p= 0.161$), above the minimum level of 0.05. Goodness-of-fit indices generally indicate the fit and unidimensionality of a measurement model (Bagozzi and Yi, 1988). The goodness-of-fit index (GFI) was 0.944, comparative fit index (CFI) was 0.991, and the adjusted good-of-fit index (AGFI) was 0.905, all values exceeded the standard recommend at 0.9 level. The root mean square residual (RMR) was 0.018, and the root-mean-square error of approximation (RMSEA) was 0.043, below the recommended level of 0.08. The normed Chi-Square (χ^2/df) was 1.24 (below 3.0) showing a good fit (Hair et al., 2010). The values of the goodness-of-fit indices thus suggested that the model acceptably represented the hypothesized constructs (see Table 6).

4.5 Convergent Validity and Item Reliability

Convergent validity can be measured by examining the critical ratio (C.R.) values (Dunn et al., 1994). The C.R. values should be greater than 1.96 or smaller than -1.96 for the model estimate to be acceptable (Hair et al., 2010). Table 6 performs that all C.R. values were significantly higher than the level of 1.96, all the indicators in each construct showed good convergent validity and unidimensionality (Anderson and Gerbing, 1988). The reliability of a particular item or variable can be estimated by the R^2 value. Table 6 shows the R^2 value of each measurement item was over 0.3 (Koufteros, 1999). Results indicated that the final model had convergent validity and item reliability (Hair et al., 2010).

Table 6. Parameter estimate, standard errors, critical ratios, and R2 values for the final model

Latent Variable Item	Completely standardized factor loading	Standard error ^a	Critical ratio ^b	R ²
ξ1 Service capabilities				
Operation capability	0.90	0.09	12.15	0.80
Marketing capability	0.84	- ^c	- ^c	0.71
η1 Dynamic capabilities				
Sensing and Seizing capability	0.89	0.07	13.65	0.80
Reconfiguring capability	0.87	- ^c	- ^c	0.76
η2 Competitive advantage				
CA1	0.69	0.12	7.65	0.47
CA2	0.63	0.14	7.01	0.39
CA3	0.88	0.11	9.89	0.78
CA4	0.87	0.12	9.64	0.76
CA5	0.64	0.14	7.16	0.41
CA6	0.72	- ^c	- ^c	0.52
Goodness-of-fit statistics				
$\chi^2(32)=39.82, p=0.161, \chi^2/df=1.24; GFI=0.944; AGFI=0.905; CFI=0.991; RMR=0.018; RMSEA=0.043$				

^a S.E. is an estimate of the standard error of the covariance.

^b C.R. is the critical ratio obtained by dividing the estimate of the covariance by its standard error. A value exceeding 1.96 represents a level of significance of 0.05.

^c Indicates a parameter fixed at 1.0 in the original solution.

Table 7 shows the computation of each construct. Construct reliability values provide a further assessment of internal consistency. The reliability of the constructs of service capabilities, dynamic capabilities, and competitive advantage were 0.86, 0.80, and 0.88, respectively. A minimum value of construct reliability should over 0.7 and all constructs reliabilities, which ranged from 0.80 to 0.88 were excellent (Bagozzi and Yi, 1988) indicated the evidence of convergent validity (Hair et al., 2010).

Table 7. Descriptive statistics and composite reliability for each measure

Measure	Mean ^a	S.D. ^b	Construct reliability ^c
Service capabilities	4.15	0.53	0.86
Dynamic capabilities	4.00	0.55	0.87
Competitive advantage	3.87	0.68	0.88

^a The tacit knowledge, transaction cost and knowledge transfer mean scores are based on a five-point scale, ranging from 1= strongly agree to 5= strongly disagree.

^b S.D. = standard deviation.

^c Construct reliability = (sum of standardized loadings)²/[(sum of standardized loadings)²+(sum of indicator measurement error)²]; Indicator measurement error is calculated as 1-(standardized loading)².

The Average Variance Extracted (AVE) indicators relative to measurement error and shows the amount of variance accounted for by a latent construct (Bagozzi and Yi, 1988; Hair et al., 2010). AVE should exceed 0.5 in advice to justify the use of a construct (Hair et al., 2010). Table 8 shows that service capabilities had the highest AVE value of 0.76, followed by dynamic capabilities (AVE= 0.77) and competitive advantage (AVE= 0.56), all the constructs had exceeded the level of 0.5 (Bagozzi and Yi, 1988). The AVE is subsequently employed to evaluate discriminant validity (Fornell and Larcker, 1981). Table 8 also indicates that the square root of the AVE for each construct is higher than all the other cross correlations. Overall, the goodness-of-fit results and assessment of the final model confirmed its reliability and acceptability.

Table 8. Assessment of average variance extracted

Measure	AVE ^a	Service capabilities	Dynamic capabilities	Competitive advantage
Service capabilities	0.76	0.87^c		
Dynamic capabilities	0.77	0.79 **	0.88^c	
Competitive advantage	0.56	0.66 **	0.72**	0.75^c

** Correlation is significant at the 0.01 level.

^a Average variance extracted (AVE) = (sum of squared standardized loading)/[(sum of squared standardized loadings)+(sum of indicator measurement error)]; Indicator measurement error is calculated as 1-(standardized loading)².

^c The square root of the shared variance between the constructs and their measures are provided in the diagonal (in bold).

4.6 Results of Hypotheses Testing

A structural equation modelling (SEM) was used to evaluate the relationship between service capabilities and dynamic capabilities on competitive advantage that framework as detailed in H1-H3. Figure 1 shows the final structural model. Hypotheses were tested using a latent variable model included both latent variables and observed variables. The latent variable measuring service capabilities toward service capabilities and competitive advantage is represented by the symbol η ; they are endogenous, that are, its value is determined within the model. The latent variables service capabilities were showed by the symbol ξ is exogenous, that is, their values are determined by factors outside the model. The factors of SC1 and SC2 form the survey instrument are accessed as indicators of service capabilities construct; factor of DC1 and DC2 are indicators of the dynamic capabilities construct; and questions CA1-CA6 are indicators of the competitive advantage construct. As above the loading estimates are the structural coefficients linking the latent variables and their indicators. The Chi-Square statistic $\chi^2(32)= 39.824$ was statistically significant. Results of H1 and H3 were supported in this study. The goodness of fit exceed the recommend level implied that the structural model provided a good fits in the data ($\chi^2/df= 1.24$; CIF= 0.991; RMR= 0.018; RMSEA= 0.043; AGFI=0.905; GFI= 0.944; NFI=0.956; RFI= 0.938; IFI= 0.991; TLI= 0.987).

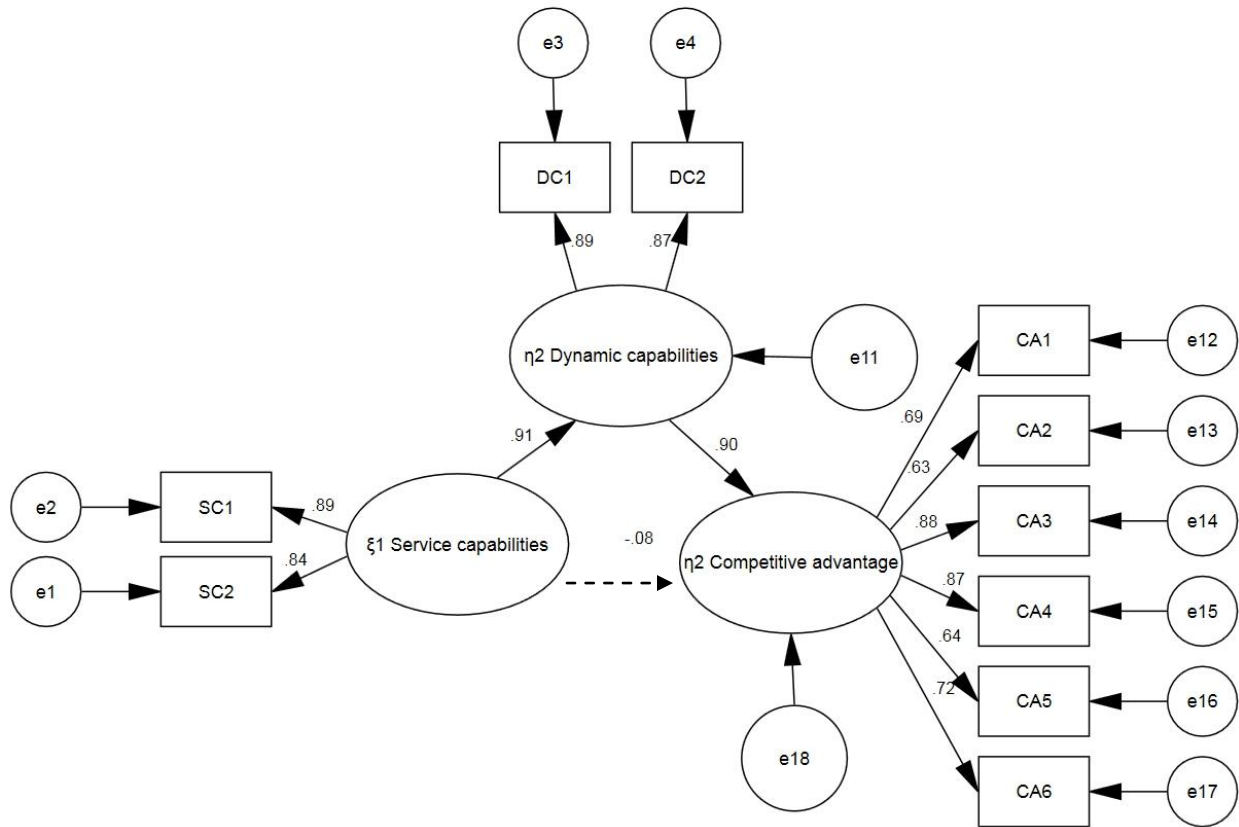


Fig 2. Structural equation model results

Note: Chi-Square = 38.824; P value= 0.161; Degrees of freedom= 32; CIF= 0.991; RMR= 0.018; RMSEA= 0.043; AGFI=0.905; GFI= 0.944; NFI=0.956; RFI= 0.938; IFI= 0.991; TLI= 0.987

Table 9 reveals the analysis results of the structural model. Service capabilities were found to have a positive influence on dynamic capabilities (H1) (estimate= 0.91, $p < 0.05$). Service capabilities were not positively related to competitive advantage (H2) (estimate= -0.08, $p > 0.05$). Dynamic capabilities were related to competitive advantage (H3) (estimate= 0.90, $p < 0.05$). No direct association was found between service capabilities and competitive advantage (C.R. < -1.96) and H2 was not supported in this study.

As a mediating effect existing, the relationship between the independent variable and dependent variable becomes less significant (Hair et al., 2010). This study subsequently examined the relationship between service capabilities and competitive advantage in this model. Figure 3 shows a direct relationship between service capabilities and competitive advantage and the structural equation model provided an acceptable fit with the data ($\chi^2_{(19)} = 20.480$; $\chi^2/df = 1.08$; CIF= 0.997; RMR= 0.018; RMSEA= 0.024; AGFI=0.932; GFI= 0.964; NFI=0.966; RFI= 0.949; IFI= 0.997; TLI= 0.996). Results indicated the path coefficient between service capabilities and competitive advantage was positive and significant, in accordance with the results concerning parsimony (see Figure 3), a fully mediated model existed. Figure 3 performs the model supported for dynamic capabilities being a mediator of the relationship between service capabilities and competitive advantage.

Table 9. Structural equation modeling results

Hypothesis	Estimate	S.E. ^a	C.R. ^b	P	Result
H1: Service capabilities→Dynamic capabilities	0.91 ^c	0.10	10.52	0.00	Supported
H2: Service capabilities→Competitive advantage	- 0.08	0.35	-0.288	0.77	Not Supported
H3: Dynamic capabilities→Competitive advantage	0.90 ^c	0.31	3.01	0.00	Supported

^a S.E is an estimate of the standard error of the covariance.

^b C.R. is obtained by dividing the covariance estimate by its standard error.

^c Underlined values are critical ratios exceeding 1.96 at the 0.05 level of significance.

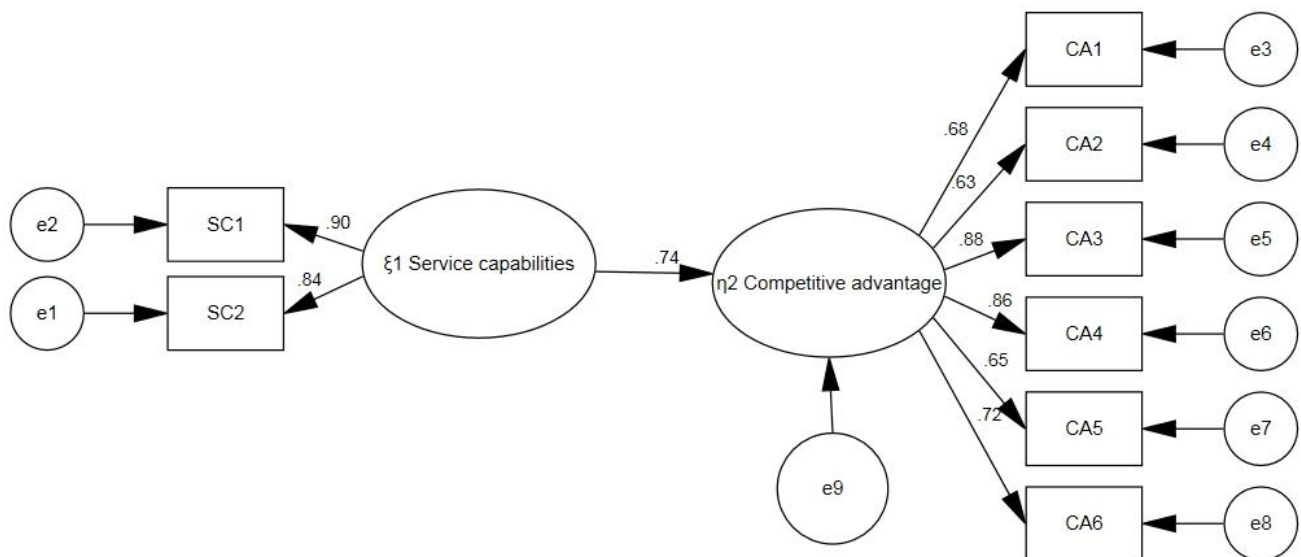


Fig 3. The relationship between service capabilities and competitive advantage

Note: Chi-Square = 20.480; P value= 0.366; Degrees of freedom= 19; CIF= 0.997; RMR= 0.018; RMSEA= 0.024; AGFI=0.932; GFI= 0.964; NFI=0.966; RFI= 0.949; IFI= 0.997; TLI= 0.996

5. Discussion and Conclusions

This study investigated the linkages between service capabilities, dynamic capabilities, and competitive advantage in shipping strategic management, especially considering the mediating effects of dynamic capabilities. While prior studies (Lu, 2007; Lu and Yang, 2006; Lu et al., 2007; Schreyögg and Kliesch-Eberl, 2007) have explained the relative studies of different capabilities based on RBV, but the study focused on dynamic capabilities are still lacking. To full up this gap, this study specifically demonstrated the effects of service capabilities and dynamic capabilities on competitive advantage in container shipping.

5.1 Interpretation of the findings

A number of findings are drawn from this study. Factor analysis was used to identify crucial service capabilities and dynamic capabilities in container shipping. Two service capabilities dimensions were identified, namely, operation capability, and marketing capability; two dynamic capabilities dimension were identified, namely, sensing and seizing capability, and reconfiguring capability. Based on the level of agreement, “my firm is good at cargo tracing” was considered as the most variable capability to container shipping, this finding implied to control the direction of cargo is the basic for container shipping. Grasping correct cargo location, container shipping companies can easily allocate cargo space on board and arrange all the activity regarding the cargo delivery. In the other words, it is yield to reduce cost and meanwhile achieve customer’s request. In the contrary, “My firm provides short transit time” had the lowest level of agreement. Results reflected that some container shipping companies consider the weak market fundamentals and prevent volatile oil prices have forced operators to change the strategy as slow steaming (UNCTAD, 2013).

Regarding the agreement of dynamic capabilities, “My firm understands customers’ specific need” had the highest level of agreement. Container shipping is the one of service industry. How to provide good service to customers become very important. The findings suggested that find the customers’ needs and fulfil it rapidly can bring the fruitful outcome. Adversely, “my firm can flexibly develop new services” was thought as the last agreement item for dynamic capabilities. Results indicated that container shipping companies need to develop new service to satisfy more customers’ request. For dynamic capabilities, realizing customers’ special and afterwards creating appropriate service for them need to be enhanced.

Consistent with expectations, this study found that service capabilities were positively related to dynamic capabilities, H1 was supported. Service capabilities are the important drivers of dynamic capabilities (Yang et al., 2009), thus, dynamic capabilities are critical capabilities that use original resources to develop more

effective responses to environmental uncertainty. Subsequently, service capabilities were not found direct effect of competitive advantage, H2 was not supported. Dynamic capabilities were positively related to competitive advantage, H3 was supported. This finding indicated that a firm has greater dynamic capabilities will enhance its competitive advantage. However, several studies also demonstrated service capabilities had influences on competitive advantage. Therefore, this study also investigated the mediating effect of dynamic capabilities. Results found service capabilities were positively related to competitive advantage, and dynamic capabilities plays the role of the mediator between service capabilities and competitive advantage. This result was consistent with prior studies (Lai, 2004; Lu, 2000; Lu, 2007).

5.2 *Managerial Implications*

This study has provided several important implications which are summarized below. First, operation capability was the most important factor of dynamic capabilities, container shipping may review and re-design their operational procedure themselves to fit the customer's actual needs. In order to keep highly operation capability on daily working, employees' training are also very important, we suggested that have training class or discussion on a regular schedule to confirm any appropriately adjustment for working content. Second, over 70% respondents were manager or above, they considered how can have a priority to sense the market and seize the correct decision is necessary. Due to maritime transportation was influenced by global economic, this study recommend that sufficiently collect information of global trade and competitor's action can assist to grasp the best decisive opportunity.

Third, the strategy analysis and decision must be situational. Although there is no algorithm for making decision in different circumstances for level of middle directors, prescription establishing that apply to groups of firms at best suggest overall direction, and may avoided the normal errors occurring. Moreover, from perspective of high level directors, seizing becomes a principal strategy which includes choosing among and committing to long-term paths of competence development. In this regards, high level directors may considered that know-how development, information collection, distinguishing capabilities from other competitors, reference of history path, overall cost, and owning resources tend to look for best strategic choice to face uncertain environment. While a firm looks inside itself, and deliberates the outside market environment, sooner or later it will find out new business opportunity (Teece et al., 1997).

Forth, dynamic capabilities were not only focused on a function of how one plays the game but also emphasize how to deploy and redeploy the assets in a changing market. Such dynamic capabilities cannot easily be bought and must be built in a long-term, dynamic capabilities need to be maintained for extending competitive advantage. Appropriately replicate or recombine a firm's resources to maintain special dynamic capabilities which can assist to face retrenchment or retirement in the future. Finally, this study specially focuses on the container shipping industry. The insights were into container shipping directors' viewpoint and the concept of dynamic capabilities also can be of interest to other relative transportation industries which provide a practice approach to sustain successful competitive advantage.

5.3 *Limitations and Direction for Future Research*

The limitations were drawing that should be recognized with the current study that provide direction for further research. First, because the budget was limited, this empirical investigation was carried out in Taiwan. According to the framework, it would be valuable to collect data from other respondents in other country or region to obtain a balanced view. The second limitation concerns the relatively limited sample size, because data collection of this study was at one point and time, therefore the hypothesised relationships were tested in a static fashion. Longitudinal research could be used to confirm how perceptions of service capabilities and dynamic capabilities change in short- and long-term.

This study raises the interesting linkages of service capabilities and dynamic capabilities on competitive advantage. First, while this study ascertained the relationships between service capabilities and dynamic capabilities, the other capabilities based on RBV such as innovation capabilities (Yang et al., 2009), logistics capabilities (Lu and Yang, 2006; Lu and Yang, 2010), and marketing capabilities (Nath et al., 2010) may also influence dynamic capabilities, further study might consider to investigate other latent variable. A second

direction for further research might consider the moderating effect of environmental dynamism. As the economic environmental changes, examining how the environmental dynamism moderates the relationship between dynamic capabilities and competitive advantage is a must (Drnevich and Kriauciunas, 2011). This evaluation may further find out the useful suggestion of strategic management to face the competitive environment. Finally, several studies (Drnevich and Kriauciunas, 2011; Ellonen et al., 2009; Teece, 2007) demonstrated that the effect of dynamic capabilities on firm performance (Chien and Tsai, 2012), or innovation outcomes (Ellonen et al., 2009). Further studies were suggested to add different observed variables to proposed model.

References

- Agarwal, R. and Selen, W. (2009), Dynamic capability building in service value networks for achieving service innovation. *Decision Sciences* 40(3): 431-475.
- Amit, R. and Schoemaker, P.J.H. (1993), Strategic assets and organizational rent. *Strategic Management Journal* 14(1): 33-46.
- Anderson, J.C. and Gerbing, D.W. (1988), Structural equation modelling in practice: a review and recommended two-step approach. *Psychological Bulletin* 103(3): 411-423.
- Armstrong, S.J. and Overton, T.S. (1977), Estimating nonresponse bias in mail survey. *Journal of Marketing Research* 14(6): 396-402.
- Bagozzi, R.P. and Yi, Y. (1988), On the evaluation of structural equation models. *Academic of Marketing Science* 16(1): 76-94.
- Barney, J.B. (1991), Firm resources and sustained competitive advantage. *Journal of Management* 17(1): 99-120.
- Bharadwaj, S.G., Varadarajan, R.P. and Fahy, J. (1993), Sustainable competitive advantage in service industries: a conceptual model and research propositions. *Journal of Marketing* 57(4): 83-99.
- Brooks, M.R. (1985), An alternative theoretical approach to the evaluation of liner shipping part two choice criteria. *Maritime Policy and Management* 12(2): 145-155.
- Chien, S.Y. and Tsai, C.H. (2012), Dynamic capability, knowledge, learning, and firm performance. *Journal of Organizational Change Management* 25(3): 434-444.
- Clulow, V. (2007), The resource-based view and value: the customer-based view of the firm. *Journal of European Industrial Training* 31(1): 19-35.
- Danneels, E. (2010), Trying to become a different type of company: dynamic capability at smith corona. *Strategic Management Journal* 32(1): 1-31.
- Day, G.S. (1990), *Market Driven Strategy: Processes for Creating Value*. Free Press, New York.
- Day, G.S. (1994), The capabilities of market-driven organizations. *Journal of Marketing* 58(4): 37-52.
- Drnevich, P.L. and Kriauciunas, A.P. (2011), Clarifying the conditions and limits of the contributions of ordinary and dynamic capabilities to relative firm performance. *Strategic Management Journal* 32(3): 254-279.
- Dunn, S.C., Seaker, R.F. and Waller, M.A. (1994), Latent variable in business logistics research: scale development and validation. *Journal of Business Logistics* 15(2): 14-172.
- Ellonen, H.K., Wikström, P., and Jantunen, A. (2009), Linking dynamic-capability portfolios and innovation outcomes. *Technovation* 29(11): 753-762.
- Eisenhardt, K.M. and Martin, J.A. (2000), Dynamic capabilities: what are they? *Strategic Management Journal* 21(10-11): 1105-1121.
- Fawcett, J.A. (2010), Challenges to apprehension and prosecution of East African maritime pirates. *Maritime Policy and Management* 37(7): 753-765.
- Fornell, C. and Larcker, D. (1981), Evaluating structural equation models with unobservable variables and measurement error. *Journal of Marketing Research* 18(1):39-50.
- Gavronski, I., Klassen, R.D., Vachon, S.V. and Nascimento, L.F.M.D. (2011), A resource-based view of green supply management. *Transportation Research Part E* 47(6): 872-885.
- Hair, J.F.Jr., Black, W.C., Babin, B.J. and Anderson, R. E. (2010), *Multivariate data analysis*, 7th edition. Prentice Hall, New Jersey, USA.
- Hafeez, K., Zhang, Y.B. and Malak, N. (2002), Determining key capabilities of a firm using the analytic hierarchy process. *International Journal of Production Economics* 76(1): 39-51.

- Haleblian, J., Mcnamara, G., Kolev, K. and Dykes, B.J. (2012), Exploring firm characteristics that differentiate leaders from followers in industry merger waves: a competitive dynamics perspective. *Strategic Management Journal* 33(9): 1037-1052.
- Handley, S.M. and Benton Jr, W.C. (2012), Mediated power and outsourcing relationships. *Journal of Operations Management* 30(3):253-267.
- Helfat, C.E. (1997), Know-how and asset complementarity and dynamic capability accumulation: the case of R&D. *Strategic Management Journal* 18(5): 339-360.
- Helfat, C.E. and Peteraf, M.A. (2003), The dynamic resource- based view: capability lifecycles. *Strategic Management Journal* 24(10): 997-1010.
- Helfat, C.E. and Winter, S.G. (2011), Untangling dynamic and operational capabilities: strategy for the (n)ever-changing world. *Strategic Management Journal* 32(11): 1243-1250.
- Hodgkinson, G.P. and Healey, M.P. (2011), Psychological foundations of dynamic capabilities: reflexion and reflection in strategic management. *Strategic Management Journal* 32(13): 1500-1516.
- Hooley, G., Broderick, A. and Möller, K. (1998), Competitive positioning and the resource-based view of the firm. *Journal of Strategic Marketing* 6(2): 97-115.
- Huang, C.J. and Huang, K.P. (2012), The logistics capabilities scale for logistics service providers. *Journal of Information and Optimization Sciences* 33(1): 135-148.
- Hung, R.Y.Y., Yang, B., Lien, B.Y.H., McLean, G.N. and Kuo, Y.M. (2010), Dynamic capability: impact of process alignment and organizational learning culture on performance. *Journal of World Business* 45(3): 285-294.
- Iacobucci, D. and Churchill, G.A. (2010), *Marketing Research: Methodological Foundation*, 10th edition. The Dryden Press, New York.
- Kannan, V., Bose, S.K. and Kannan, N.G. (2011), An evaluation of ocean container carrier selection criteria: an Indian shipper's perspective. *Management Research Review* 34(7): 754-772.
- Koufteros, X.A. (1999), Testing a model of pull production: a paradigm for manufacturing research using structural equation modeling. *Journal of Operation Management*: 17(4): 467-488.
- Kent, J.L. and Parker, R.S. (1999), International containership carrier selection criteria shippers/carriers differences. *International Journal of Physical Distribution and Logistics Management* 19(6): 398-408.
- Kor, Y.Y. and Mahoney, J.T. (2005), How dynamics, management, and governance of resource developments influence firm-level performance. *Strategic Management Journal* 26(5): 489-496.
- Lai, K.H. (2004), Service capability and performance of logistics service providers. *Transportation Research Part E* 40(5): 385-399.
- Lin, Y. and Wu, L.Y. (2014), Exploring the role of dynamic capabilities in firm performance under the resource-based view framework 67(3): 407-413.
- Liu, C.L. and Lyons, A.C. (2011), An analysis of third-party logistics performance and service provision. *Transportation Research Part E* 47(4): 547-570.
- Lu, C.S. (2000), Logistics services in Taiwanese maritime firms. *Transportation Research Part E* 36(2): 79-96.
- Lu, C.S. (2003), The impact of carrier service attributes on shipper-carrier partnering relationships: a shipper's perspective. *Transportation Research Part E* 39(5): 399-415.
- Lu, C.S. (2007), Evaluating key resources and capabilities for liner shipping services. *Transport Reviews* 27(3): 285-310.
- Lu, C.S. and Marlow, P. (1999), Strategic groups in Taiwanese liner shipping. *Maritime Policy and Management* 26(1): 1-26.
- Lu, C.S. and Yang, C.C. (2006), Evaluation key logistics capabilities for international distribution centres in Taiwan. *Transportation Journal* 45(4): 9-27.
- Lu, C.S. and Yang, C.C. (2010). Logistics service capabilities and firm performance of international distribution center operators. *The Service Industries Journal* 30(2): 281-298.
- Lu, C.S., Lai, K.H. and Cheng, T.C.E. (2007), Adoption of internet service in liner shipping: an empirical study of shippers in Taiwan. *Transport Reviews* 26(2): 189-206.
- Nath, P., Nachiappan, S. and Ramanathan, R. (2010), The impact of marketing capability, operations capability and diversification strategy on performance: A resource-based view. *Industry Marketing Management* 39(2): 317-329.
- Newbert, S.L. (2008), Value, rareness, competitive advantage, and performance: a conceptual-level empirical investigation of the resource-based view of the firm. *Strategic Management Journal* 29(7): 745-768.
- Nunnally, J.C. (1978), *Psychometric theory* (Second ed.), McGraw-Hill, New York.

- Marcus, A.A. and Anderson, M.H. (2006), A general dynamic capability: does it propagate business and social competencies in the retail food industry? *Journal of Management Studies* 43(1): 19-46.
- O'Reilly, C.A. and Tushman M.L. (2008), Ambidexterity as a dynamic capability: resolving the innovator's dilemma. *Research in Organizational Behavior* 28(1): 185-206.
- Peteraf, M.A. (1993), The cornerstones of competitive advantage: a resource-based view. *Strategic Management Journal* 14(3): 179-191.
- Progoulaki, M. and Theotokas, I. (2010), Human resource management and competitive advantage: an application of resource-based view in the shipping industry. *Marine Policy* 34(3): 575-582.
- Podsakoff, P.M., MacKenzie, S.B., Lee, J. and Podsakoff, N.P. (2003), Common method bias in behavioural research: a critical review of the literature and recommended remedies. *Journal of Applied Psychology* 88(5): 879-903.
- Podsakoff, P.M. and Organ, D.W. (1986), Self-reports in organizational research: problems and prospects. *Journal of Management* 12(4): 531-544.
- Romme, A.G., Zollo, M. and Berends, P. (2010), Dynamic capabilities, deliberate learning and environmental dynamism: a simulation model. *Industrial and Corporate Change* 19(4): 1271-1299.
- Schilke, O. (2014), On the contingent value of dynamic capabilities for competitive advantage: the nonlinear moderating effect of environmental dynamism. *Strategic Management Journal* 35(2): 179-203.
- Schreyögg, G. and Kliesch-Eberl, M. (2007), How dynamic can organizational capabilities be? towards a dual-process model of capability dynamization. *Strategic Management Journal* 28(9): 913-933.
- Sher, P.J. and Lee, V.C. (2004), Information technology as a facilitator for enhancing dynamic capabilities through knowledge management. *Information and Management* 41(8): 933-945.
- Spanos, Y.E. and Lioukas, S. (2001), An examination into the causal logic of rent generation: contrasting porter's competitive strategy framework and the resource-based perspective. *Strategic Management Journal* 22(10): 907-934.
- Talaja, A. (2012), Testing VRIN framework: resource value and rareness as sources of competitive advantage and above average performance. *Management* 17(2): 51-64.
- Teece, D.J. (1982), Towards an economic theory of the multiproduct firm. *Journal of Economic Behavior and Organization* 3(1): 39-63.
- Teece, D.J. (2007), Explicating dynamic capabilities: the nature and microfoundations of (sustainable) enterprise performance. *Strategic Management Journal* 28(13): 1319-1350.
- Teece, D.J., Pisano, G. and Shuen, A. (1997), Dynamic capabilities and strategic management. *Strategic Management Journal* 18(7): 509-533.
- Tran, H., Cahoon, S. and Chen, S.L. (2012), Quality management for seaports integrated in supply chains. *International Journal of Shipping and Transport Logistics* 4(4): 376-392.
- Tsekouras, G., Poulis, E. and Poulis, K. (2011), Innovation and dynamic capabilities in a traditional service sector evidence from shipping companies. *Baltic Journal of Management* 6(3): 320-341.
- United Nations Conferences on Trade and Development (2013), Review of Maritime Transport 2013. UNCTAD/RMT/2013: New York, US.
- Wernerfelt, B. (1984), A resource-based view of the firm. *Strategic Management Journal* 5(2): 171-180.
- Wilden, R., Gudergan, S.P., Nielsen, B.B. and Lings, L. (2013), Dynamic capabilities and performance: strategy, structure and environment. *Long Range Planning* 46(1-2): 72-96.
- Wu, L.Y. (2006), Resources, dynamic capabilities and performance in a dynamic environment: perceptions in Taiwanese IT enterprises. *Information Management* 43(4): 447-454.
- Wu, L.Y. (2007), Entrepreneurial resources, dynamic capabilities and start-up performance of Taiwan's high-tech firms. *Journal of Business Research* 60(5): 549-555.
- Wu, L.Y. (2010), Applicability of the resource-based and dynamic-capability views under environmental volatility. *Journal of Business Research* 63(1): 27-31.
- Yang, C.C., Marlow, P.B. and Lu, C.S. (2009), Assessing resources, logistics service capabilities, innovation capabilities and the performance of container shipping. *Int. J. Production Economics* 122(1): 4-20.
- Zahra, S.A. (1999), The changing rules of global competitiveness in the 21st century. *Academy of Management Executive* 13(1): 36-42.

Appendix A: Measurement scales

Items	Mean	S.D.
Service capabilities		
My firm is good at cargo tracing.	4.30	0.70
My firm has good relationships with cooperative partners.	4.28	0.69
My firm can efficiently response to customer complaint.	4.22	0.67
My firm is good at sales activity.	4.20	0.71
My firm provides flexibility service.	4.16	0.71
My firm has low damage or loss record for cargo delivery.	4.16	0.75
My firm is good at information integration.	4.15	0.81
My firm has rational freight rate.	4.11	0.68
My firm is good at purchasing (e.g. vessel or fuel).	4.10	0.82
My firm provides high frequency of sailing.	4.06	0.77
My firm is good at on-time pick-up and delivery.	4.03	0.70
My firm provides short transit time.	4.02	0.72
Dynamic capabilities		
My firm understands customers' specific needs.	4.16	0.69
My firm is good to evaluate my own firm's strength and weakness.	4.11	0.67
My firm has the ability of efficient and effective communication with cooperative organization.	4.07	0.72
My firm adopts the best practices in the industry.	4.07	0.68
My firm has the ability to gather economic information on our operations and operational environment.	4.04	0.70
My firm has the ability of rapid organizational response to market changes.	4.04	0.70
My firm owns flexible competitiveness in the industry in the future.	4.03	0.76
My firm has the ability of rapid organizational response to competitor's action.	4.00	0.76
My firm changes our practices when customer feedback gives us a reason to change.	3.98	0.72
My firm is good at customer information collection..	3.97	0.68
My firm has the ability of resource reconfiguration.	3.97	0.77
My firm owns better learning capability.	3.96	0.76
My firm learns or acquires new skill from the partners.	3.96	0.72
My firm has the ability to change various way of doing business.	3.96	0.79
My firm can rapid aware new business opportunity or threat possibility.	3.93	0.78
My firm can flexibly develop new services.	3.80	0.80
Competitive advantage		
My firm has gained strategic advantages over our competitors.	4.06	0.95
My firm has advantage of service innovations.	3.91	0.76
My firm has fully using capacity utilization.	3.89	0.80
My firm has service differentiation.	3.87	0.84
Overall, my firm is more successful than our major competitors.	3.84	0.86
My firm has cost advantage.	3.67	0.96

Study of Principal Operational Performance Indicators of Various Indian Ports for Imported Steam Coal

T. Bangar Raju¹ and B. V. Ramalingeswar Rao²

¹University of Petroleum and Energy Studies, Energy Acres, Bidholi via Premnagar, Dehradun, Uttarakhand State, India. Pin 248007. Email: bangarraju@gmail.com, Phone: +917895677779.

²Indian Maritime University, Gandhigram, Visakhapatnam, Andhra Pradesh, India. Pin 530005. Email: profbhavana@gmail.com, Phone: 09866808977.

Abstract

India being the largest importer of steam and it accounts for 54% of thermal energy in the country. The limitations of domestic production and supply have seen tremendous increase in imports of steam coal from Indonesia, South Africa and Australia. Understanding various bottlenecks and high costs which are incurring due to port congestion, poor infrastructure and poor port performance, there was a need to study port performance indicators for steam coal. From the literature survey, though number of studies were made to measure port performance indicators in general, but no specific research was made scientifically for specific bulk cargoes like steam coal. Therefore eight port performance indicators were taken based on UNCTAD guidelines and eleven east coast ports of India which handle steam coal were considered for study.

The data for these port performance indicators was collected and Principal Component Analysis was done to reduce the eight variables.

From the research study it was found that port draft and berthing time efficiency played major role to reduce berthing time efficiency and ocean freight costs.

Keywords: port performance indicators, Coal and IFSPA

1. Introduction

In India the power sector has installed capacity of 1,73,26 Megawatts as of as March, 2011 as per Ministry of coal (Report of working of Coal and Lignite, 2006). Out this the thermal power's share is 64% of the total installed capacity. The coal fired thermal plants contribute to 54% of India's electricity capacity. The hydro power accounts for 22% and natural gas for 10%. The share of nuclear is 2.8% and that of renewable is 10.6%.

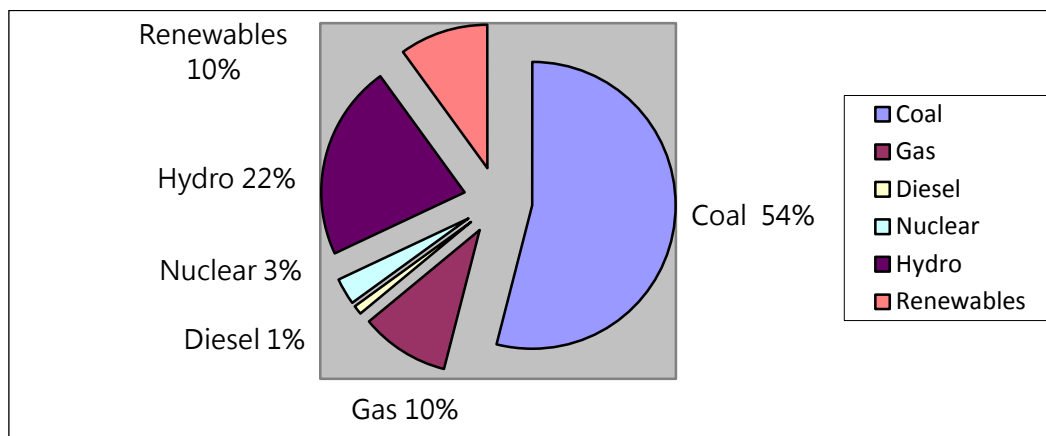


Fig 1. India's Power Sources

Source: Planning Commission

The above percentages do undergo a change when it is transformed in terms of energy generation for Hydro and renewable. Keeping in view the capacity factor which is less for Hydro power and renewable energy in the share in electricity generation would be 14% and 2.4% respectively. This clearly shows India is very much dependent on Coal fired thermal Power for its future requirement.

The Ministry of Shipping as stated (report of working group for Port sector for the 12th five year plan, 2011) that at the end of 12th five year plan India would import 336 million tonnes of steam Coal which would account for 25% of its total requirement which would be 842 million tonnes.

To calculate the productivity at ports as stated by UNCTAD (port performance indicators, 1976) there are various reasons to calculate various Port performance indicators. The UNCTAD has brought forward the need to calculate two kinds of Port Performance Indicators

1. Financial port performance Indicators
2. Operational Port Performance Indicators.

1.1 Need for study

India over period of time is increasingly depending on imported steam coal for its power requirements. Keeping in view the increasing demand and prices of steam coal for its thermal power requirements, it is high time it brings down the costs of handling and shipping at various Indian ports. Due to the high costs of handling, there would be great impact on trade in regard to increase in inflation due to high costs of fuel. In the 12th five year plan [4] the ministry of shipping has envisaged the need for investment for increasing port infrastructure in Indian Ports. Hence there is need to identify key areas where the coal ports and berths need the investment for better infrastructure and identify bottlenecks that lead to congestion, thereby high costs.

The Indian Power consumers mainly consist of agricultural sector and domestic sector which account for 21% and 25% in the year 2008-09 as per Planning commission (Annual report on working state power utilities and electricity departments, 2011). Thus cutting down costs of steam coal handling would lead lower power tariffs and thus farmers and consumers would benefit at the end.

2. Review of Research Work

There has been tremendous increase in India's steam coal imports as per figures from www.indiastat.com. From Figure 2 the steam coal imports have steadily risen from 12.03 million tons in 2004-05 to 44.28 million tons in 2009-10. This trend brings forth the need of imported steam coal for India power Sector.

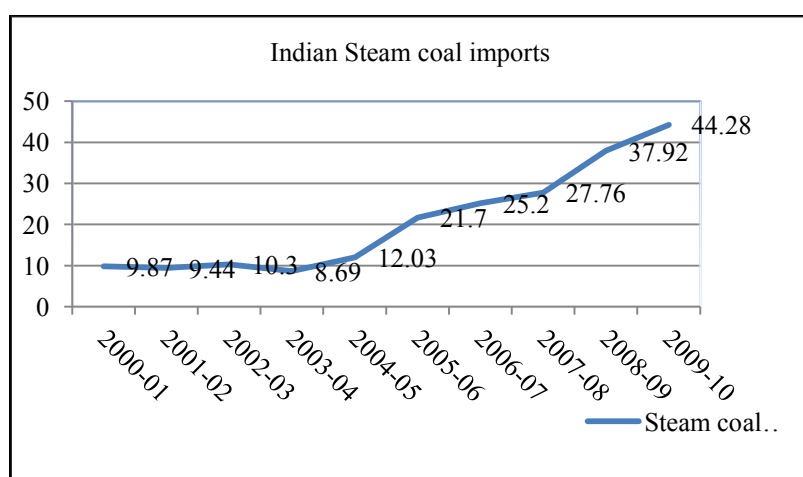


Fig 2. Steam Coal imports in India

Source: Indiastat.com

The import of steam coal has been increasing due to rapid growth in power sector and the inferior quality of domestic coal. Also the Power plant operators in coastal regions of southern Indian and western India preferred imported coal due to rail transportation challenges faced due to congested rail network. Also the coal

imported has higher GCV of around 4,750 to 6800 Kcal/Kg compared to Domestic coal with GCV at around 3,755Kcal/Kg.

In the report by Ministry of Shipping (Report of working group for Port sector, 2011) Steam Coal demand was assessed as shown below:

Table 1. Future Coal Demand and Coal availability scenario in Million tonnes

	2012-13	2013-14	2014-15	2015-16	2016-17
Steam Coal requirement	515	572	650	737	842
Indigenous Coal supply	416	436	471	521	550
Coal to be imported by Thermal power station designed on imported coal	32	40	47	49	50
Shortage	67	96	132	167	242
Coal to be imported for Thermal power stations designed on indigenous coal	45	64	88	111	161

From the above table at the end of twelfth five year plan the Thermal power stations designed on Indigenous coal would be importing 161 million tonnes and Thermal power stations designed on imported steam coal would be importing 50 million tonnes. Thus the total Imports of Steam coal would be 211 million tonnes.

Thus at the end of 12th five year plan, 25 % of the Coal demand would be met by imports. These imports would be routed through various existing Indian ports along east and west coast of India.

2.1 Research Work Examined

As discussed by UNCTAD (Port Performance Indicators, 1976), the Port performance Indicators have been brought forward and the following guidelines and importance of Port performance indicators were discussed.

There are various reasons for a need to calculate performance Indicators:

1. The Data can be used for improving port performance.
2. These can provide an appropriate basis for future.
3. Port performance Indicators are measures of various aspects of Port's operation. To fulfil the purpose, these indicators are easy to calculate and simplified to understand. They provide insight to the management of port in the operation of key areas. These can be used to compare the performance with a benchmark and also to observe trend in performance levels. These indicators can also be used for negotiations on port congestion surcharges, port development, port tariff considerations and port development.
4. The key purpose for collecting information to maintain performance indicators is to provide an ideal management information system for planning and control.
5. These Performance Indicators must exist for each category of cargo since the port provides different facilities for different set of cargoes. The following are suggested as a set of cargo categories
 - a. Coal
 - b. Ores
 - c. Unitized cargo
 - d. Grains
 - e. Liquid bulk
 - f. Dry bulk like grain, cement and fertilizers
6. The port performance indicators are attractive due to following reasons
 - a. Changing conditions: With the development of trade the port labour working rules, shipping lines change and port handling technology changes. The priorities assigned also change over a period of time. This makes it a necessary to build framework within which these changes can be measured and managed in consistent way.
 - b. Scarcity of management personnel: In developing countries the scarcity of trained and qualified middle management is a common feature. By developing the performance standards, by establishment

of reporting systems and standardising of methods for collection and analysis of information can minimize the problems created by this deficiency.

- c. Scarcity of capital resources: Port development is one among many strategic investments in a developing country. There is an opportunity cost involved in capital invested as it is obtained at the expense of other areas. In order to justify investments in these areas need justification. These performance indicators necessitate adequate information for development of long range plans.
7. Control of an operation is possible only if there is a feedback of performance. Feedback involves the measuring of an actual output and comparing it with desired output to determine what course of action to take.
8. Control is the complement of planning and neither element is useful without the other. The main step in control is the measurement of deviation from goals and standards that have been set during the planning activity. Thus the selection and the maintenance of Indicators is a necessary step for ports to obtain effective control. A set of indicators will allow management to make improvised utilization of resources by highlighting problem areas and thereby improve service to port users and reduce unit costs. There would be additional benefits which could be derived from the proper use of indicators
 - a. Highlighting the start and the cause of a congestion period.
 - b. The negotiation of a reduction in a port congestion surcharge as a result of monitoring and documenting port performance.
 - c. The timely adjustment of port tariffs.
 - d. The provision of a sound information base for port planning and justification for capital development.

Performance indicators were classified as:

1. Financial Port Performance Indicators.
2. Operational Port Performance Indicators.

The Financial Port Performance Indicators would deal with revenues generated from its operations and services.

Various Financial Indicators to be calculated are:

1. Total Tonnage worked
2. Berth occupancy Revenue per ton of cargo.
3. Cargo handling revenue per tonne of cargo.
4. Labour expenditure per ton of cargo
5. Capital equipment expenditure per ton of cargo.
6. Total contribution
7. Contribution per tonne of cargo.
8. Revenue produced from a service.
9. Cost of the service.

The report by I-maritime research and consulting division (India Port report, 2003), has brought forward need for ports, has discussed about berth occupancy, waiting time, service time, seasonal variations, cost considerations for every port investment and port planning. Special focus has been given for bulk cargoes like ores, coal, bauxite, phosphates, fertilizers and grains. The characteristics of these terminals, handling equipment performance specifications, types of various ship unloading equipments, storage of these bulk cargo and standby facilities have been discussed.

Geoffrey Poitras, Jose Tongzon and Hongyu Li have made study to make international comparisons of port efficiency. They have stated that available studies have not provided sufficient answer for calculating comparative port efficiency. They have used Data Envelopment Analysis and have ranked five Australian and Eighteen international container ports. They found this analysis easy as the calculations were nonparametric and do not require knowledge of prior weights for inputs and outputs.

The relative efficiency of container ports was done in South Korea by Hokey Min. The author has proposed a Hybrid Data Envelopment Analysis model by using real examples of major container terminals in South

Korea. The data analysis and TFP approach was done to measure the efficiency of Chinese container terminals by Bing-Lian Liu, Wai-Lin-Liu and Cheng-Ping Cheng.

There were studies in regard to scenario analysis for supply chain integration in container by Jasmine Siu lee lam and Eddy Van de Voorde. The authors have conducted their research for Indian Shipping scenario for container shipping.

Sushila Muniswamy and Gurcharan Singh did Data Envelopment Analysis to bench mark and evaluate the operating performance of 69 major Asian container ports and generate efficiency ranking. A regression model for vessel turnaround time for container vessels was calculated by Kasyapi Mokhtar and Dr. Muhhannad Zaly Shah (2006). Two ports in Port Kelang- West port and East port, data was collected to show that vessel turnaround time is highly correlated with crane allocation.

Studies with regard to logistics and supply chain management approach, to port performance measurement was discussed by K halid B ichou and R ichard Gray (2004). This approach could be beneficial to port efficiency by directing port strategy towards relevant value added logistics services.

The functional analysis of Port Performance as a strategic tool for strengthening port's competitive and economics model was brought forward by Diego Teurelinx, (2000). The methodology discussed was to provide an efficient tool for analysis of functional strengths and weaknesses in ports. The traffic analysis and bottleneck assessment stages were discussed.

The sensitive performance measures in container port were identified by Jie Wu, Hongyan and John Liu (2010). The results indicate that the number of berths and capital deployed are the most sensitive measures impacting performance of container ports. The analysis also reveals that container ports located in different continents behave differently.

A study on efficiency of iron ore and coal ports using Data envelopment analysis method was made by Gabriel figueiredo, De Oliveira and Pierre Cariou (2011). The paper shows that main source of inefficiency in bulk terminals is related to scale. The authors recommend that national efficiency can be achieved either through a limited number of large ports or by combining smaller ports with complimentary characteristics.

A great deal of significant studies were made in measuring port efficiency as a determinant of Maritime cost by Ricardo J. Sanchez, Jan Hoffman, Alejandro Micco, Georgina V. Pizzilitto, Martin Sgut and Wilmsmier (2003). The authors have calculated operational performance indicators for nine Latin American Countries and have done Principal Component Analysis. The conclusions are relevant for the policy makers which show that port performance indicators are relevant for determining port's competitiveness. The authors could collect data only containerized cargo and could not collect for bulk cargoes.

UNCTAD (Port development, 1985) has brought forward on ways of measuring and evaluating port performance and Productivity. The author has detailed the process and guidelines for calculating various possible Performance Indicators at various ports and various categories of cargo.

The importance of Operational Performance indicators and Asset performance indicators were brought forward by Kek C hoo C hung. The author has identified and defined various operational performance indicators, their importance and need.

One of the most significant contributions to the research studies for Indian port sector made by Prabir De (2009). The author has made studies related to port performance indicators and labour endowment in determining port traffic. Also has detailed about port productivity growth in Indian ports with their significance in globalization scenario. The author also has made studies related to technological change in terms of its power and ability to improve the productivity of labour at port in Indian Scenario. Also there has been an attempt to measure the concentration and competition in Indian port sector which would be beneficial for national economies, consumers and exporting/importing industries.

2.2 Research gap

We understand that India would importing 211 million tons at the end of 12th five year plan. Ports and Port infrastructure are of major concern for these imports due to high costs incurred. From the above literature survey we can find there is a huge research gap in regard to port and shipping studies. The Port Performance Indicators were calculated as a whole for all the commodities together but research work in regard to particular class of commodity like coal was not present. Also a lot of studies were done in regard to containers for which the data was easily accessible and the authors Richardo J. Sanchez, Jan Hoffman, Alejandro Micco and Georgina V. Pizzilitto, Martin Sgut, and Gordon Wilmsmier (2003), have mentioned the scope for studies in bulk cargoes like coal and iron ore.

The report by Ministry of Shipping (2011) have discussed some Port Performance Indicators in regard to Major ports without taking cargo class in to consideration. The authors have also brought forward absence of appropriate performance Indicators for bulk cargoes like iron ore, coal and fertilizers. Hence there is need for study in Port Performance Indicators for imported steam coal.

3. Objectives of the study

3.1 To study principal Operational Port Performance Indicators for coal handling along east coast of India

The primary data was collected for one year from April 2010 till March 2011. The ship file and productivity file records maintained by port authority for all import shipments along east coast ports were collected and operational Performance Indicators were calculated. The operational performance Indicators as suggested by UNCTAD (1976) were taken into consideration. The Operational Port Performance Indicators considered were shown below:

S no	Operational performance Indicator	Description	Units
1	Waiting time	The time a ship has to wait at an anchorage before getting entry into berth	Hours/ship
2	Pilotage time	The time taken from the vessel from anchorage till berthing of ship at port	Hours/ship
3	Service Time	The total time the ship has spent at the berth.	Hours/ship
4	Tons per ship hour at berth	The total tonnage handled towards ship berthing time.	Tonnes/hour
5	Effective working time at berth	The time effectively used for discharging of cargo at port	days
6	Average tonnage per ship	The average cargo carried by the ships at the port	Tonnes/ship
7	Average draft per ship	The vertical length of ship immersed in the water	meters
8	Ships arrival rate	The number ships arriving over a period of time	Ships/month

The performance indicators in regard to labour were not considered keeping in view that the focus was on to improve port infrastructure. All ports are not guided by any uniform labour laws and these indicators were not required for our objectives.

All the handling equipment, port location, port infrastructure, weather conditions and port topography was considered to be same for study. Factors related to environmental pollution and labour issues were not taken into consideration. All the time calculations other than documentation delays by the importer were considered to be in Port account.

4. Research design

4.1 Data collection

The Port Authority personnel and Shipping surveyors were requested to share their documents related to shipments. The Ship file and ship Data card documents were accessed and various operational performance indicators were calculated for each shipment. This method was obtained to gather accurate information from the facts recorded for every vessel which arrives to the port.

4.2 Sampling Frame

For the second objective the primary data was collected from all eleven ports which were handling steam coal along the East Coast of India were considered for study. The ship data card and ship files for all shipments pertaining to steam coal shipments from April 2010 till March 2011 were obtained. The average values of the Operational Port performance Indicators were calculated Port wise.

4.3 Tools for Analysis

The main idea of research was to form, from an existing set of Operational Performance Indicators a new set of reduced Indicators which would contain as much variability of the original data as possible. This could reduce the data which would be easy to handle and use it for further decision making purpose. For this Principal Component Analysis (PCA) was selected. SPSS version 19 software was used for analysis.

4.4 Analysis of Operational Port performance Indicators

The objective of the study was to find the principal Operational Port Performance Indicators for steam coal handling and shipping operations. Average values of eight operational Performance Indicators for eleven ports were calculated. The purpose was to form, from the existing set of Performance Indicators a new set of Indicators which are few in number as possible that contain as much variability of the original data as possible. These new Indicators would represent some sort of index of certain property that is measured by the original Indicators. For this the Principal Component Analysis was chosen.

4.5 Principal Component Analysis

Values of Eight Port Performance Indicators were calculated for eleven ports as per Table 2 below.

Table 2. Values of Port Performance Indicators

Port	Waiting time in days	Pilotage time in Hours	Service time in days	Tonnes per ship at berth in tonnes/hour	Effective working time at berth in days	Average tonnage in '000 tonnes /ship	Average draft per ship in metres	Ships arrival rate in ships/month
Haldia	5.95	7.80	2.77	395	2.21	20.30	9.15	4.33
Paradip	18.15	6.60	5.18	470	3.65	43.70	12.35	3.25
Gangavaram	0.60	5.20	2.85	1288	2.64	81.60	13.60	4.92
Vishakapatnam	4.22	6.30	6.25	485	4.31	45.40	12.18	4.75
Kakinada	6.30	7.50	3.83	605	3.10	44.30	10.60	4.25
Krishnapatnam	2.08	5.75	3.45	810	3.13	59.50	12.70	6.91
Ennore	0	4.95	3.41	760	3.08	54.90	12.40	2.30
Chennai	1.68	6.85	4.35	560	3.75	47.60	11.30	7.91
Karaikal	0	5.50	2.43	840	2.06	53.70	11.20	4.83
Chidambaranar	1.75	7.60	5.73	425	5.05	48.70	11.60	6.25
Cochin	0.90	9.60	1.87	445	1.34	20.00	8.30	0.16

Here the total variance of the data is considered for the analysis. The data was collected from all the ports along the east coast. Since the data was collected from the entire population was collected there is no need to test any hypothesis. The values of Kaiser-Meyer-Olkin and Barlett's Test of Sphericity were just calculated. The values were found to be Kaiser-Meyer-Olkin, Value= 0.595.

Barlett's test of Sphericity
 Approximate Chi-Square = 86.194
 Df = 28
 Sg = 0.000

To number of factors here were determined based on Eigen values. In this approach, only Performance Indicators (factors) with eigen values greater than 1.0 were retained. The other indicators (factors) were not included in the model. An eigen value represents the amount of variance associated with factor. Performance Indicators (factors) less than 1.0 are no longer better a single variable, because, due to standardization, each variable has a variance of 1.0.

Table. 3 Extraction of Components

<i>Total Variance Explained</i>									
Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	3.786	47.326	47.326	3.786	47.326	47.326	3.698	46.220	46.220
2	2.571	32.138	79.464	2.571	32.138	79.464	2.660	33.244	79.464
3	.964	12.046	91.510						
4	.415	5.184	96.695						
5	.216	2.704	99.399						
6	.029	.361	99.760						
7	.014	.176	99.937						
8	.005	.063	100.000						

Fig 3. Screen Plot for the Principal component Analysis

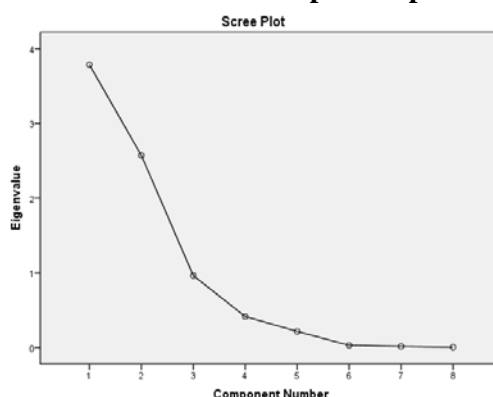


Table 4. Extraction Method: Principal Component Analysis

Component Matrix

	Component	
	1	2
average draft per ship	.961	.082
average tonnage per ship	.944	-.261
pilotage time	-.872	.217
ships arrival rate	.602	.298
service time	.349	.910
effective working time at berth	.495	.817
tonnes per ship hour at berth	.685	-.693
waiting time	-.112	.621

2 components extracted

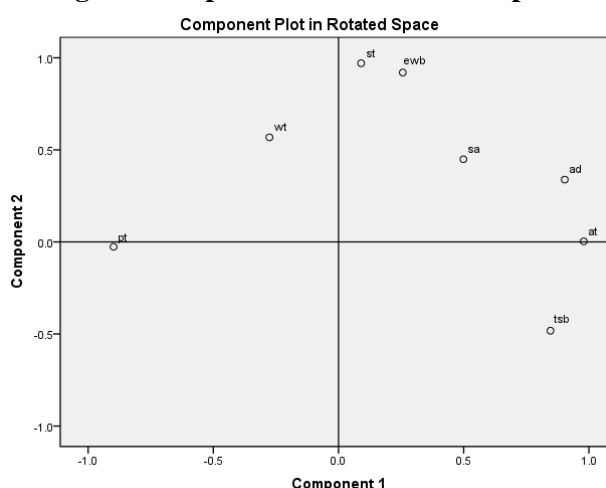
The PCA analysis reduced the eight variables into two components were extracted taking Eigen values greater than 1. The two components account for 79% of the total variance. Using the varimax rotation, an orthogonal rotation of the factor tends to maximize the variance of squared factor loadings of a factor on all variables. Thus it minimizes the number of factors, which have large factor loadings on the given factor.

Table 5. Rotation Method: Varimax with Kaiser Normalization.
Rotated Component Matrix^a

	Component	
	1	2
average tonnage per ship	.979	.003
average draft per ship	.903	.338
pilotage time	-.898	-.026
tonnes per ship hour at berth	.846	-.482
ships arrival rate	.499	.449
service time	.090	.970
effective working time at berth	.257	.920
waiting time	-.276	.568

^aRotation converged in 3 iterations.

Fig 4. Component Plot in Rotated Space



From the rotated component matrix two components extracted are:

Component 1	Average tonnage per ship (0.979)
Ship draft Index	Average Draft per ship (0.903)
Component 2	Service Time (0.970)
Berthing time Efficiency	Effective working time at Berth (0.920)

5. Conclusions and Recommendations

From the Principal component analysis, we arrive at two components:

1. Ship draft Index
2. Berthing time efficiency.

The two were the major components identified from statistical analysis. By improving the draft,

1. The size of vessel can be increased.
2. Parcel sizes could be larger thereby less number ships required.
3. The freight rates would less and cost per ton of coal would be reduced.

By improving berthing time efficiency

1. The ship turnaround time would be reduced.

2. Effective utilization of unloading equipment.
3. Decrease in waiting time of the ships.

5.1 *Shipping draft Index*

The draft at the port plays a critical role for the coal Imports. The approximate maximum drafts of various ships size are:

1. Handymax= 10.5 metres.
2. Panamax= 12.5 metres.
3. Capesize= 20 metres.

At present only two ports Krishnapatnam and Gangavaram have sufficient draft for handling capsize vessels. If the coal ports along the east through dredging upgrade for 20 m draft then all the coal imports could be carried by Capesize ships. The capsize have freight advantage of US\$ 5 over Panamax and US\$ 8 over Handymax considering imports from Indonesia and South Africa. Understanding from report [3] from Planning commission, at the India would be importing 211 million tons at the end of 2017. Then the total reduction in costs for this tonnage in terms of Ocean freight would be:

Total cost saved if cargo is carried by Capesize over Panamax = $211 \times 5 = 1055$ million US\$ per Year.

Total costs saved if cargo is carried by Capesize over handymax = $211 \times 8 = 1688$ million US\$ per Year.

5.2 *Berthing time efficiency*

In the in the period April 2010 till March 2011 there have been close to 600 shipments have been done along all the ports in east coast of India for steam coal. There has been high waiting time up to 18 days and also high Ship turnover time. There is a need to reduce the service or the berthing at the port. Even though we cannot exactly quantify the loss but still can estimate taking into view the time charter rates for the Ships of various sizes. Considering at the present time charter rate during this period the Panamax ship rates at around 14,000US\$/day, Capesize ship rates at around 19,000US\$/day and Handy max ship rates at around 9000 US\$ per day we can calculate the approximate amount that could be saved every day.

Number of Shipments by Capesize= 47: Approximate Costs saved= $47 \times 2 \times 21000 = 2$ million US\$.

Number of shipments by Panamax: 425: If reduction of Waiting time and ship turnover by two days, then Approximate Costs saved= $425 \times 2 \times 14,000 =$ US \$ 11.9 million per year.

Number of Shipments by Handymax = 126: Approximate Costs saved= $126 \times 2 \times 9000 =$ US\$ 2.2 million per year.

Total costs saved= US\$ 2 +11.9+2.2=16.1 million US\$.

Acknowledgement

We would like to thank Mr. A.J. Rao chairman Indian Port association for supporting for collecting various data. We also would like to express our gratitude to the Port Authorities of Major Ports who have helped in sharing the data of various Steam coal shipments along the East coast of India.

References

- Liu, Bing-Lian, Liu, Wai-Lin and Cheng Cheng-Ping (2006), Efficiency Analysis of Container terminals in China: An Application of DEA Approach, Asian-Pacific conference, August 17-19, 2006: 40-65.
- Teurelinx, Diego (2000), Functional Analysis of Port performance as a strategic tool for strengthening a Port's competitive and economic Potential, International Journal of Maritime economics 2(2):119-140.

- Figueiredo, Gabriel De Oliveira and Cariou, Pierre (2011), A DEA study of the efficiency of 122 iron ore and coal ports and of 15/17 countries in 2005, *Maritime Policy and Management* 38(7): 727-743.
- Poitras, Geoffrey, Tongzon, Jose and Li, Hongyu (1996), Measuring port efficiency: An application of Data envelopment analysis, www.bus.sfu.ca/homes/poitras/PORTS2.pdf (Accessed in July 2011).
- Min, Hokey (2004), A Hybrid data envelopment analysis and simulation methodology for measuring capacity utilization and throughput efficiency of containers terminals, www.ceb.nccu.edu.tw/proceedings/APDSI/2004/pdf/066.PDF (Accessed in August 2010).
- India port Report (2003), I-maritime research and consulting division 33-50.
- Lam, Jasmine Siu Lee and de Voorde, Eddy Van (2011), Scenario analysis for supply chain integration in container shipping, *Maritime policy and management* 38 (7):705-725.
- Wu, Jie, Yan, Hong and Liu, John (2010), DEA models for identifying sensitive performance measures in container port evaluation, *Maritime Economics and Logistics* 12: 215-236.
- Mokhtar, Kasyapi, Shah, Muhammad Zaly (2006), A Regression model for vessel turnaround time, Tokyo Academic, Industry and Cultural Integration Tour, Shibaura Institute of technology, Japan: 10-19.
- Bichou, Khalid and Gray, Richard (2004), A logistics and supply chain management approach to port performance measurement, *Maritime Policy and Management* 31(1): 47-67.
- Chung, Kek Choo (1993), Port performance Indicators, Infrastructure notes, Transportation, Water and Urban Development Department, The Worldbank.
- Ministry of Coal (2006), Report of the working of Coal and Lignite for formulation of eleventh five year plan, Government of India.
- Ministry of Shipping (2011), Report of Working Group for Port Sector for the Twelfth Five Year Plan (2012-2017), Government of India.
- Planning Commission (2011), Annual report 2011-12 on working of state power utilities and Electricity departments, Government of India.
- Prabir De (2009), Globalization and the changing face of port infrastructure - The Indian Perspective.
- Sanchez, Ricardo J., Hoffman, Jan, Micco, Alejandro, Pizzilitto, Georgina V., Sgut, Martin and Wilmsmier, Gordon (2003), *Maritime Economics and Logistics* 5: 199-218.
- Muniswamy. Sushila and Singh, Gurcharan (2011), Benchmarking the efficiency of Asian container ports, *African journal of Business management* 5(4): 1397-1407.
- UNCTAD (1985), Port development - A handbook for planners in developing countries, United nations.
- UNCTAD (1976), Port Performance Indicators, United nations.

Logistics Innovation Networks for Ports' Sustainable Development: The Role of the Port Authority

Marcella De Martino^{1*}, Luisa Errichiello¹, Alessandra Marasco¹ and Alfonso Morvillo¹

¹Institute for Service Industry Research (IRAT), National Research Council (CNR), Via G. Sanfelice 8, 80134 Naples, Italy.

*Email: m.demartino@irat.cnr.it (M. De Martino), Tel.: +39 081 2470963; fax: +39 0817618265.

**Corresponding author*

Abstract

In the context of ports, organizing for networked logistics innovation is a strategic response of port managers' to effectively tackle the increasing complexity of economic, social and environmental challenges. The paper proposes a conceptual framework to analyze the contribution of different public and private resources to a networked process of innovation that goes well beyond the port perimeter involving port-hinterland interactions and being embedded in the local economic context. In particular, it is emphasized how "Public-Private service innovation networks" (ServPPins) can be leveraged by Port Authority as a strategic tool for promoting and sustaining a culture of innovation in the port context. Indeed, ServPPins can be adopted not only for the goal of public-private risk sharing in seaport infrastructure investments, but they can be successfully chosen for the development of new and improved port-city logistics services. This framework aims at advancing existing knowledge about the nascent topic of logistics innovation in ports by embracing a managerial network-based perspective and its application is intended to support entrepreneurial ports in their efforts to grow business while preserving the social dimension of innovation.

Keywords: Logistics innovation networks; Port Authority; Sustainable development; ServPPins.

1. Introduction

Recent years have witnessed a profound evolution of ports, induced by a wide range of factors, such as: (a) technological developments in shipping, cargo-handling and storage equipment, and information and communication systems; (b) changing patterns of international trade; (c) a broadening complexity of global supply chains; and (d) a changing governance model of the port as a consequence of the process of privatization in Europe. The growing size and complexity of port functions have inspired an interesting and animated debate about the social, economic and environmental effects of these transformations, and, more specifically, on the relationship between the port and the city.

A crucial paradox characterizes port cities/areas: on the one hand, negative environmental impacts are produced by high level of energy and natural resources consumption for example in terms of air and water pollution; on the other hand, there is an increasing effort to preserve the specific cultural landscape while supporting business growth and economic development. This trade-off has been addressed through different perspectives by a number of authors, who have proposed a variety of innovative approaches to mitigate paradoxes and promote a win – win approach for the sustainable development of the port in the city. From an urban planning perspective, Girard (2012) suggests to consider the social economic systemⁱ as the engine for sustaining the synergistic development of port – city interactions. From a regional economic perspective, other authors look at ports as geographically localized sources of innovation and regional growth: Hall and Jacobs (2010), in particular, emphasize the role played by spatial and non-spatial dimensions (institutional and social) of proximity in influencing the development and diffusion of innovation, while Cahoon et al. (2013) point to the crucial role of specific and regional port's resources to stimulate innovation capabilities and competitiveness of firms and territories. Coherently to their policy-oriented nature, both contributions assume that the Port Authority (PA) can play a key role in fostering the sustainable development of the port and its

territory. Finally, from a managerial perspective, ports' sustainable development would benefit from a deeper understanding of the features and dynamics of complex innovation networks involving a variety of local stakeholders and their potential impact on the examined trade-off that characterize port cities/areas. However, research addressing networked logistics innovation in seaports from a managerial perspective is still in an initial phase of development. Among the main contributions in this area, De Martino et al. (2013) propose an initial conceptual framework for investigating the role of relationship networks in supporting logistics innovation in ports. In the present paper, this framework is further developed by emphasizing the nature and the role of Public-Private service innovation networks (ServPPINs) as a strategic tool for spreading a culture of innovation in the port context. These are a very specific type of innovation networks that differ from technology- and market-oriented manufacturing networks as well as from traditional Public-Private partnerships (PPPs) that are set up by government actors to fund and manage infrastructures and/or services in a more efficient way. ServPPINs dynamics and outcomes have been analyzed in transport, tourism, public services and recently also in relation to the development of new services in smart cities. It is believed that they can provide a useful construct to advance the understanding of networked innovation also in the port context and thereby provide PA with useful knowledge for the development of innovation in the port city area.

The paper is structured as follows. The next section addresses the issue of logistics innovation, which is central for ports' sustainable development. In this respect, the potential role of ServPPINs in the development of new and improved logistics services is considered in order to advance the understanding of logistics innovation in ports. Section 3 focuses the attention on the port context and presents a conceptual framework for analyzing logistics innovation from a managerial network-based perspective. The framework considers the contribution of public and private resources to the process of innovation in the port-hinterland interaction by focusing on two specific service network configurations, respectively oriented to the development of intermodality (α) and of value added logistics services (β). Based on this framework, section 4 addresses the role of landlord Port Authority's actionsⁱⁱ in promoting logistics innovations through a network-oriented approach, namely piloting and encouraging the development of ServPPINs. This is exemplified by some successful initiatives developed in European ports. Finally, in the last section some conclusions and directions for future research are provided.

2. Logistics Innovation: The Role of Relationships Network

Logistics innovation includes any logistics related service - from the basic to the complex - that is seen as new and helpful to a particular focal audience that could be internal, where innovations improve operational efficiency, or external, where innovations better serve customers (Flint et al., 2005). At one extreme there is the case of radical innovations at the industry-wide level, i.e. logistics services that are new to the world/industry, as it is the case of the initial shift to inter-modal containers. At the other extreme there would be incremental innovations, such as a change in package design or implementation of a new warehouse management system. In between these two extremes, there are a range of potential innovations, such as development of an improved customer relationship management system to better serve customers. In the current competitive scenario in order to gain market leadership through innovation, logistics firms need to carefully exploit the potential of three interrelated "factors" - technology, knowledge and relationship networks - that are essential to operate effectively (Kandampully, 2002; Chapman et al., 2003; Grawe, 2009).

In the last two decades, a plethora of studies has suggested that the adoption and successful implementation of available Information and Communication Technology (ICT) applications is a prerequisite for logistics success, allowing providers to set apart from their competitors (Closs et al., 1997; Tether and Metcalfe, 2003; de Vries, 2006). However, non-technological innovation is an emerging and challenging issue in innovation studies on services (Gallouj, 2002). Service innovation scholars have highlighted that innovation cannot be restricted to the adoption of new technologies; instead it is to be conceived as a creative use of technology in order to interpret the market or integrate the knowledge of the supply chains (Tether and Metcalfe, 2003). In this regard, the term "soft" or "invisible" innovation is currently used to refer to its non-technological dimensions - i.e. related to organization, processes, people behavior, relations, knowledge - that seem to better ensure to firms new levers for a sustainable competitive advantage.

Knowledge has been considered the primary source of competitive advantage for firms, including logistics operators. Beside horizontal and vertical alliances, which are acknowledged to be basic vehicles to gain access to new knowledge (Grawe, 2009), the whole set of relationships within the supply network is to be considered as a potential locus and source of innovation for logistics providers. Indeed, external knowledge flows shared within “knowledge networks” represent vital opportunities to recombine the internal stock of knowledge, create new knowledge and develop innovations. According to this perspective, a collaborative approach to managing strategic relationships upstream and downstream the supply network can allow logistics providers to access the latest technology and marketing intelligence and combine knowledge and resources to develop collective innovation activities (Szeto, 2000; Hakansson and Persson, 2004). This requires openness and commitment to collaboration instead of rivalry and mistrust within the supply chain (Christopher, 2005). The potential for innovation associated to advanced technologies and knowledge networks relies on adequate supportive inter-organizational structures, which, therefore, are an important facilitating factor for logistics innovation (Chapman et al., 2003). Definitively, logistics operators need to place considerable importance on the strategic management of inter-organizational relationships (*networking*) as a lever for improving their innovation capability and performance.

2.1 *Public-Private Innovation Networks in Logistics Services*

Against this background, the concept of Public-Private Innovation Networks in Services (ServPPINs) emerges as a useful construct to advance the understanding of inter-organizational collaborative arrangements for the development of new and improved port-city logistics services. The literature on innovation in services has emphasized the role of interactive structures and processes in relation to the general perspective of open innovation, within the context of tourism, knowledge-intensive services, public services and transport (Djellal et al., 2013; Rubalcaba et al., 2011). In particular, it is highlighted that innovative solutions to the challenges of value creation for service users, citizens and society as a whole can be effectively developed, promoted and maintained through multi-actor collaborative structures that enable public, private, third-sector and civil society actors to interact in a complementary and synergistic way in joint innovation processes (Weber *et al.*, 2014). In this viewpoint, ServPPINs have been suggested as a viable alternative for realizing innovations to existing models, such as traditional manufacturing- and technology oriented networks as well as contractual public-private partnerships for public service provision. This type of innovation networks involves collaborative partnerships between public, private and third-sector actors for developing, producing and delivering new and improved services. They are flexible inter-organizational structures that support the exploitation of complementarities and synergies among different organizations, the integration and sharing of dispersed knowledge, technology, competences and potential risks in uncertain innovation processes. ServPPINs are a specific type of innovation networks, being characterized by three fundamental features (Gallouj et al., 2013): firstly, the interaction between public and non-market actors and private actors occupies a central role; secondly, service providers as the main actors in the networks; and, finally, they build upon a broad conceptualization of innovation, including also non-technological forms (i.e. organizational, process, cognitive, conceptual, network-based). Moreover, they are “naturally” characterized by customer/user interactivity and involvement in innovation processes, given the endogenous role of customers in service co-production. The relational configuration of ServPPINs can widely vary depending on the actors involved, their role and the degree of formality of relationships among them. Further, it is subject to change during the networks’ lifecycle, which can be described in terms of the three main phases of initiation, emergence and wider implementation or uptake. Recent research has investigated the structure and operation of these networks in transport, health, tourism, knowledge-intensive and public services, highlighting the main sources of their success. These include internal and external drivers, such as trust, pro-innovation culture, leadership, a right strategy between bottom-up or top-bottom approaches, financial and political support, technological opportunities and innovation policies; their integration within wider systemic and social networks; their ability to overcome barriers in areas such as the rigidity of public administrations, the existence of different interests and incentive systems, asymmetric information and networking competences; and the reduction of evolutionary inefficiencies, concerning the risk of not being efficient enough to adapt to the changing phases of networks’ lifecycle (Rubalcaba et al., 2011). Research on ServPPINs has also shown that these structures represent a suitable organizational mode for social innovation (Djellal et al., 2011; Rubalcaba et al., 2013). Based on their relevance to the development of new solutions to public and societal needs, Errichiello and Marasco (2014) leverage the interpretive potential of ServPPINs in the Smart City context in order to advance

the understanding of the drivers, structure, dynamics and outcomes of innovation networks involved in the development and diffusion of innovative city services.

Based on extant research, it is argued that ServPPINs can be seen as a valuable concept to understand inter-organizational collaborative arrangements also in the context of ports. Indeed, for their specific features these innovation networks allow to address, in a more comprehensive way, the complex nature of open innovation processes in ports, offering an effective response to tackle paradoxes and trade-offs in the port-city/territory relationships, as well as to identify key factors influencing their effective operation in realizing innovations for ports' sustainable development.

3. Logistics Innovation in Ports from a Network Perspective: A Framework for Analysis

In addressing logistics innovation in ports from a managerial network-based perspective, De Martino *et al.* (2013) consider the contribution of public and private resources to the process of innovation in the port-hinterland interaction by focusing on two specific service network configurations: the first (α) is aimed at developing complementary services, namely intermodality; the latter (β) is oriented to the development of value added logistics services. Each of these configurations is characterized by different bundles of resources that are required for sustaining logistics innovation in the seaport. Specifically, with reference to intermodality (α , figure 1), interorganizational collaborative arrangements aim at expanding the port's core business to include the supply of complementary services (inland transport and warehousing). The bundles of resources necessary for developing new intermodal services are: the physical resources allocated by the Landlord Port Authority that allow the port to be interconnected with the local transport system; and the knowledge based resources, that can be related to training and educational services, networking activities and technology development. Once developed, the provision of intermodal services would rely on different forms of new inter-organizational relationships that would constitute innovation *per se* (interorganizational innovation) for the control and sharing of resources directly influencing end customer's satisfaction, such as the assets for the provision of supplementary services (mainly inland waterway and railways transport).

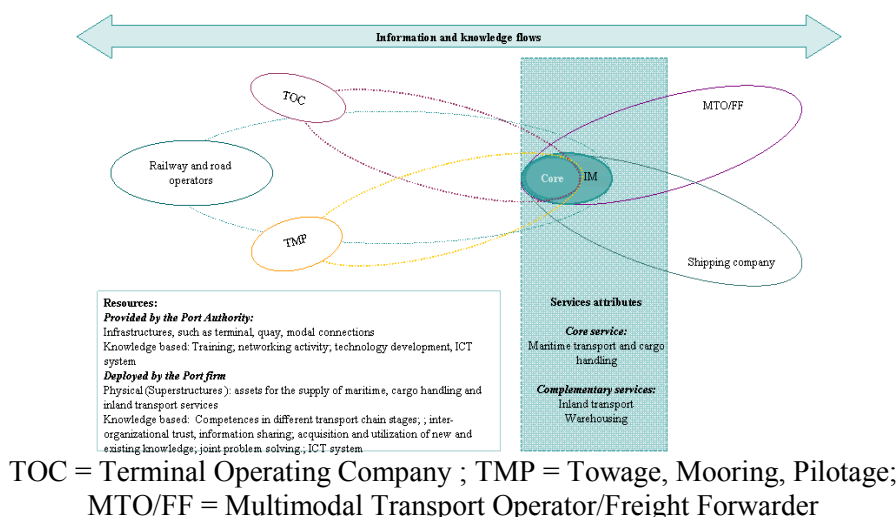


Fig 1. Port service network α : developing complementary intermodal services

Source: De Martino et al., 2013

In particular, although the development of new railways connections represents a strategic objective for the integration of ports with the market, it is highly complex and requires substantial investments. For these reasons, rail operators are often reluctant to start new connections unless perceived risks are limited; in this respect, the Port Authority can play a strategic role not only to guarantee the financial sustainability of these services by making direct investments in the hinterland but also to foster knowledge transfer and firms' competences development by forming partnerships with the main local railways operators. For example, in an increasing number of ports such as Le-Havre, Genoa, Barcelona, Rotterdam, Antwerp, Trieste, the Port Authorities have invested in an adequate network of railway and road connections in order to favour the

growth of container traffic and overcome the lack of space within the port perimeter. In the port of Le Havre, the shipping companies CMA-CGM and MOL supply intermodal services. CMA-CGM has opted for controlling internally the provision of handling and inland transport services by having capital shares of GMP - the stevedoring company controlling the terminal of France - and of RSC and Rail link (road and rail operators). On the contrary, MOL's supplies intermodal services by contractual relationships with GMP for the handling of containers and by stipulating other contracts with haulers for the distribution of cargoes.

With reference to the second service network configuration (β , Figure 2), the port can further extend its influence beyond the traditional boundaries towards the hinterland, including activities, resources and actors of the regional economic system, with the objective of providing value-added logistics services. In this case, Port Authority has an active role in the innovation process. Specifically, it invests in new physical resources such as logistics area, dry port, distripark and processing area. Moreover, PA drives the innovation process, sustaining the initiation, consolidation and institutionalization of a great number of interactions among port actors and others firms of the regional economic system (shippers/manufacturing firms), for the provision of core (maritime transport and handling) and supplementary services (inland transport and warehousing; value added logistics, manufacturing and distribution). In this representation, port is the springboard for the economic development of the hinterland and strategic options are oriented to the development of strategic partnerships with inland ports, dry ports and logistics platforms located in the hinterland.

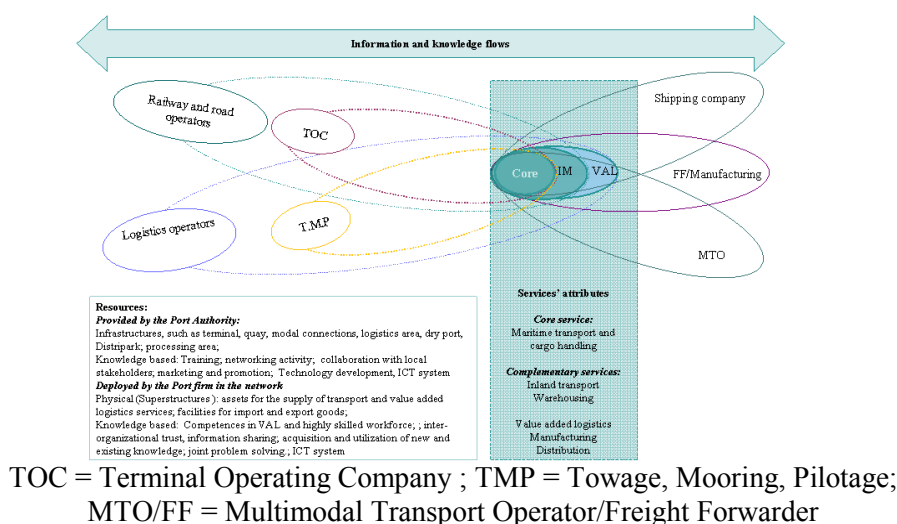


Fig 2. Port service network β : supporting broader economic development through value added logistics

Source: De Martino et al., 2013

For example, the Port Authority of Rotterdam established three distriparks in order to develop value-added logistics services with comprehensive facilities for distribution operations at a single location, connected directly to container terminals and multimodal transport facilities for transshipment, employing the latest in information and telecommunication technologies. In the same way, the Port Authority of Le Havre created different logistics parks for developing a complete range of logistics services, from bulk logistics to supply chain's optimization. Innovation is realized through the involvement of a number of companies located in the logistics areas that are connected to the Port Authority's community information system that plays a key role in accelerating all the procedures for goods transit, especially those related to Customs formalities. For example, in the port of Le Havre, CMA-CGM supplies also value added logistics services to European retailers (Carrefour and Danone) through a strategic alliance with SDV international logistics.

In the cases shown, different interorganizational collaborative arrangements can develop and different governance mechanisms can be implemented, varying from more hierarchical approaches to more relational ones, most of them driven by the Port Authority's intervention. The activation of a process of value generation through innovation in the port depends on a set of resources (public and private) that will increasingly

integrate the ports with its territory; however, the benefits of these investments could be shared and diffused in the port and in the territory through the development of relationship networks. This, even more, supports the need to investigate the nature of relationship networks shaping the competitive and cooperative dynamics of the port-market interactions.

4. Port Authority Policy Actions for Boosting Logistics Innovation Networks

The core idea of this paper is that in order to identify Port Authority's actions coherently with the potential role of the port for its market/hinterland, it is important to integrate a market-oriented approach with the macro-economic and "aggregated" perspective commonly used in defining the Port planning process. In this regard, port service networks can represent potential stages of a development path that Port Authority could follow in order to catch the opportunity offered by its economic and social context. In particular, innovation in port service networks can be generated, specifically, through: (1) the development of new logistics services, such as intermodality, warehousing, distribution, value added logistics and manufacturing; (2) the involvement of a great number of specialized operators in the field of land and inland transport and logistics; and, (3) the use and combination of different typologies of public and private resources for the development of innovation networks (ServPPINs) involving the port and the other relevant actors of the regional economic system.

Table 1: Port Authority's policy actions

		PORT SERVICE NETWORK α	PORT SERVICE NETWORK β
DRIVERS OF LOGISTICS INNOVATION	Networks and Networking	Private Public Partnership. Concession agreements for inland terminal management. Partnership with service business providers for the provision of road and railways services. Partnership with transport policy makers at local, national and European levels. Partnership with other neighboring ports.	Private Public Partnership. Concession agreements for logistics area management. Partnership with service business providers for the provision of logistics services.. Partnership with logistics platforms and others nodes of the regional and national logistics systems. Interactions with local stakeholders.
	Knowledge	Knowledge and intermodal chain learning; Education and Training programs.	New knowledge generation and acquisition through developing value added logistics services; Education and Training programs.
	Technology	Custom informatization; Oriented to the transport chain integration; Electronic Data Interchange (EDI).	Highly specialized and customized; Port community information system (PCS).

Source: reworked version of De Martino et al., 2013

The table 1 shows possible Port Authority's actions in boosting the development of multiple interactions between the port and its territory. In particular, the port service networks α and β reflect a progressively increasing number of resources that Port Authority should develop and allocate so that port operators could interact and develop innovative logistics networks that expand the port's boundaries towards the regional economic system. In the service network configuration α , the concession of terminal, inland terminal and other logistics resources to port operators is one of the most important Port Authority's tool to affect value creation in the port city. Through concession policy, Port Authority can retain some control of the organization and structure of the supply side of the port market, while optimizing the use of scarce resources such as the land. Pivoting a networked governance (β), Landlord Port Authorities can embrace concession policy not only as a mean to promote competition between port operators, but also to enhance the collaboration and coordination of port activities through resource allocation and create economical, relational

and social connections between the port and the marketplace. At this regard, traditional Public-Private Partnerships can be used to share the risks associated with huge investments in the hinterland and to pool different resources and skills. In this respect, an appropriate legislative framework is required to allow the balance between the management of physical resources to the private sector and the economic, social and environmental of these resources with respect to various local stakeholders.

The active role of the Port Authority should also be directed to making port actors aware of the existence of a network of interdependencies between the activities they perform and those of the firms of the regional economic system, and hence of the opportunities of developing collaborative relationships to improve business performance and securing a long lasting competitive advantage. Policy formulation and implementation should be the result of intensive communication, close interaction and consensus building among all local Institutions and Government. The Port Authority can play a facilitating role in this respect by stimulating the dialogue and the development of strategic partnerships with inland ports, dry ports and other neighboring ports. Knowledge is progressively being perceived as the core driver of port sustainable development and competitiveness. Shifting to the broader networked configuration (β), the variety and complexity of knowledge flows increases in terms of actors involved in the learning processes as well as domains of application. In this regard, the Port Authority can play a crucial role not only in facilitating intermodal learning processes within the port's networks, but also in fostering the generation and exchange of new logistics related knowledge. A large variety of specialized port operators in the port, such as cargo handling firms, warehouse operators and transport companies could benefit from high quality standards of education. A suitable training and education program could be determined by a set of collaborative initiatives taken by the relevant actors in the port with the aim of improving the quality and availability of labor. In this respect, education is considered as a public service in many countries and Port Authority and Education Institutes can play a major role. The ability of Port Authority to create coalitions that invest in training and education infrastructures is nowadays crucial. Many European Port Authorities are increasingly investing in education and training thorough the development of specific research programs with Universities and Research centers. Just to mention few examples, a number of courses and workshops are directed to strategic issues such as: risk management strategies; freight mobility policy; sustainability strategy; yard management best practices; latest gate technologies; security and safety in the port and in the supply chain. Finally, technology represents a further point of Port Authority's agenda. The Port Community information System (PCS) is an example of technology that has allowed the port to expand its boundaries toward the hinterland. In this system, generally managed by the Port Authority, each network actor (shipping companies, terminal operating companies, port service providers, maritime agents, MTO, freight forwarders, logistics operators, distributors, retailers and manufacturing firms) shares customized information on inbound and outbound flows, increasing the communication efficiency and effectiveness in the port.

4.1. The servPPINs: some embryonic initiatives

Several Port's successful cases such as Barcelona, Rotterdam, Le Havre, Antwerp and Amsterdam, highlight that innovation involving the port/hinterland integration have been increasingly the result of intensive communication, close interaction and consensus building between all local stakeholders in the port network. In these cases, the role that Port Authority plays in encouraging collaboration is directed towards stimulation, intermediation, promotion of regional dialogue and the building up of social capital. In this direction, servPPINs can be developed and sustained with the objective of integrating the different competencies required for logistics innovation and sharing the risks involved in large-scale innovative projects as well as to meet wider social needs. . The case of Amsterdam is a case in point, at this regard. The Port of Amsterdam has the ambition to become one of the most sustainable harbors in Europe by 2020 and has invested in several innovation projects to achieve this objective. Among the main initiatives, the Port Authority has led the development of new ship-to-grid solutions that allow inland ships in the harbor to use green energy from the grid instead of their own stationary diesel generators. This project was funded with support of the European Fund for Regional Development of the European Commission and aimed at reducing Co2 emissions, in line with EU Innovation 2020 objectives in the environmental area. In this case, the technology itself is not innovative, but rather it is the development of an effective collaboration among a wider range of port and city stakeholders the major challenge and outcome of the project. Indeed, for the deployment of the new solution, a close collaboration among many stakeholders from the municipality and several service providers with

complementary competences (ICT infrastructure, engineering, grid operator) was required. Moreover, to obtain the standardization for the ship to grid solution, the port of Amsterdam worked closely also with the National Port Council and the World Port Climate Initiative (Amsterdam Smart City, 2011; European Parliament/ITRE, 2014). Thus, the logistics innovation pursued by the Port Authority of Amsterdam does not primarily involve novel technological solutions, but is centered on the development and promotion of an effective collaborative innovation network allowing the combination of different specialized competencies and resources, the sharing of risks, the increased awareness for sustainability issues, and the spread of a culture of innovation. In this regard, the Port Authority has played a key role as the initiator and coordinator of the ServPPIN involved in the development and diffusion of the ship-to-grid connections. It is also to be noted that the establishment of a new collaborative arrangement between a number of organizations (both private and public) with different levels of commitment was the main outcome of the project. Thus, in line with the service innovation perspective, organizational innovation (i.e. a new interorganisational structure) and social innovation (i.e. increased awareness about environmental issues of energy saving and lower Co2 emissions) were, in this case, strictly combined with the technological dimension of innovation.

Another case is the Port of Barcelona that defines itself as a Smart Port. Like the Smart City, the Port Authority aims at defining development strategies that are sustainable for the citizens. In particular, the Port Authority has invested in technological and management tools to achieve an environment in which innovation and knowledge sustain the development of the port in the city of Barcelona. From automatic lighting management systems to automatic terminal entry and exit controls solutions (also removing the need for paper documents in container deliveries and collection), the Port Authority is constantly working to sustain businesses' growth and to increase the citizens' quality of the life. In the context of Barcelona Smart Port, particular importance is given to participatory initiatives, as it is evident in a number of projects, such as: the PortIC telematics platform that serves the entire port community; the Port Management System project, located in the Control Tower, which provides coordinated management systems for all the services provided in Port waters (pilots, tugs, berths, supplies, etc); or the storm forecasting system developed in conjunction with Puertos del Estado (State Ports). The Port's telecommunications networks are also shared by the various companies that operate in the area. On the environmental side, the Port Authority performs systematic controls of all activities and promotes actions to minimize their environmental impacts. At this regard, the PA has placed atmospheric sensors to monitor the air quality in the various areas of the Port. The environmental data are shared with the Barcelona City Council and the Government of Catalonia with the aim to draw up a map of emissions and to define different actions respect to the levels of pollution. The huge importance attached to environmental issues, is also visible in an online tool, called the *Ecocalculadora*, that is being developed for calculating CO2 emissions and will soon be made available to companies for quantifying the carbon footprint generated by their logistics activities, both inside and outside the Port.

As for the cases briefly described, several innovation programs and initiatives at European level, in relation to EU Innovation 2020 strategy or the Horizon 2020, consider Societal Challenges as one of the main priorities and address the need to gear the innovation process to societal needs. At this regard, the issue of "responsible innovation" appears to be a future challenge for managers in the port business. The diffusion of responsible innovation initiatives and the dissemination of best practices and paradigm cases within an online port community could be an effective way of fostering responsible innovation processes. Port authorities and relevant companies could publish their responsible research and innovation results in a collective online directory. This initiative could raise the level of trust and support within society and favor a combined effort of Port Authorities, companies and local stakeholders towards responsible innovation processes. Another way to foster a culture of innovation within the port is the active participation of Port Authorities to European Union funded projects. The objective of these projects is to enhance the participation of the different stakeholders of the port and transport industry and local community, and to define shared and specific actions of implementation of the innovation processes. For example, under the title "Aspects of future port strategies in Europe", the INTERREG IV-C project Port Integration, led by Hamburg Ministry for Economy, Transport and Innovation, brings together port experts from 9 different European countries and Russia to exchange their experiences in European and regional strategies for maritime transport and port strategy. Through exchanging experiences and good practices among the regions, the project aimed at creating a culture of sustainable innovation on specific issues such as "Maritime Transport and Port Interfaces" (PCS) and "Hinterland Transport, Gateways, Dry ports and other innovative logistic concepts".

Finally, the recent born of spontaneous and no-profit associations, the so-called “*think tank*”, is a further response of the port and transport communities to the need to promote a shared and sustainable vision of innovation for the future years. The aim of these “*think tanks*” is to build a common vision on the future challenges envisioned, for example, in the EU development agenda and to propose effective actions for the achievement of the sustainable development’s objectives. In this respect, the BTj Think tank, a breeding-ground for the discussion of the TransBaltic Macroregional Transport Action Plan is a very interesting case. This think tank, constituted in 2012 by academics, industry operators and institutions, supports the EU in the process of creation of an integrated multimodal transport system around the Baltic by proposing an optimum scenario (path) to achieve in the year 2030 and laying down a number of policy actions instrumental in following this path.

5. Conclusions and Future Research Direction

The recognition of the interactive nature of relationships among port actors in the port service networks represents a critical and fundamental issue for spreading a culture of innovation and sustainability in the port, since it allows to view collaboration as a means for value creation. Collaborative spirit and mutual trust are fundamental to create reciprocal benefits and a higher level of involvement of the port actors in the network. Only through a proper understanding of the features and rationale for the formation of relationships between actors of port community and all actors involved in the process of value creation for the final customer, Port Authority can foster new and more effective forms of logistics innovation networks. These inter-organizational arrangements should be characterized by the development of collaborative activities among all port actors, including manufacturing companies in its own hinterland. In this respect, it is critical that the Port Authority owns the leadership and vision attributes that are required to effectively coordinate these efforts and promote a culture of innovation and sustainability in the port. Building on a collaborative view of port’s inter-organizational networks, many initiatives can be realized that bring together policy, business, government procurement and research perspectives and resources to generate innovative solutions to existing and future economic, competitive and social challenges. A culture of innovation and sustainability can be nurtured on a continuing basis by encouraging the creation of dedicated innovation networks developed around specific projects and oriented to achieve long term goals of learning and social capital building through the cooperative exchange of knowledge, technologies and resources among port operators, industrial and technology partners. Finally, a better understanding of the role and the functioning of ServPPINs is a necessary step for implementing a successful innovation strategy that is based on sustainable collaboration structures among port actors and on local stakeholders’ involvement in the development of value added logistics services. In this regard, a multiple case study analysis would provide useful insights for the effective set up and management of public-private service innovation networks that are functional to the development and diffusion of logistics innovations in the port-territory interactions.

References

- Amsterdam Smart City: Smart Stories (2011), www.amsterdamsmartcity.com.
- Cahoon, S., Pateman, H., and Chen, S. -H. (2013), Regional port authorities: Leading players in innovation networks? *Journal of Transport Geography*, 27: 66–75.
- Chapman, R.L., Soosay, C. and Kandampully, J. (2003), Innovation in logistic services and the new business model - A conceptual framework. *International Journal of Physical Distribution & Logistics Management*, 33 (7): 630–650.
- Christopher, M. (2005), *Logistics and Supply Chain Management. Creating value-adding networks*, Third Edition, Prentice-Hall.
- Closs, D.J., Goldsby, T.J. and Clinton, S.R. (1997), Information technology influences on world-class logistics capability. *International Journal of Physical Distribution & Logistics Management*, 27 (1): 4-17.
- De Martino M., Errichiello L., Marasco A. and Morvillo A (2013), Logistics innovation in Ports: an inter-organizational perspective, in *Research in Transportation Business & Management*, Volume on Port Performance and Strategy 123-133.
- Errichiello L. and Marasco A. (2014), Open Service Innovation in Smart Cities: A Framework for Exploring Innovation Networks in the Development of New City Services, paper accepted to the 1st International

- Symposium "New Metropolitan Perspectives, The integrated approach of Urban Sustainable Development through the implementation of Horizon/Europe2020" (ISTH2020), Reggio-Calabria, 6-9 Maggio.
- de Vries, E. J. (2006), Innovation in services in networks of organizations and in the distribution of services, *Research Policy*, 25: 1037-1051.
- Djellal F. and Gallouj F. (2011), Social innovation and service innovation, Conference Challenge Social Innovation, Vienna.
- Djellal F., Gallouj F. and Miles I. (2013), Two decades of research on innovation in services: Which place for public services? *Structural Change and Economic Dynamics* 27: 98-117.
- European Parliament Committee for Industry, Research and Energy/ITRE (2014), Mapping Smart Cities in the EU, Directorate General for Internal Policies, Policy Department A: Economic and Scientific Policy.
- Flint, D.J., Larsson, E., Gammelgaard, B. and Mentzer, J.T. (2005), Logistics innovation: A customer value-oriented social process. *Journal of Business Logistics* 26 (1): 113–147.
- Fusco Girard L. (2012), The urban future, *Bollettino del Dipartimento di Conservazione dei Beni Architettonici ed Ambientali*, 12: 19-33.
- Gallouj F., Rubalcaba L. and Windrum P. (2013), *Public–Private Innovation Networks in Services* (Edward Elgar Publishing Ltd, Cheltenham).
- Gallouj, F. (2002), *Innovation in the Service Economy: The New Wealth of Nations*. Edward Elgar, Cheltenham.
- Grawe, S.J. (2009), Logistics innovation: a literature-based conceptual framework, *International Journal of Logistics Management*, 20 (3): 360 – 377.
- Hakansson, H., Persson, G. (2004), Supply Chain Management: The Logic of Supply Chains and Networks. *International Journal of Logistics Management*, 15 (1), pp.11 – 26.
- Hall, P. V., and Jacobs, W. (2010), Shifting proximities: The maritime ports sector in an era of global supply chains. *Regional Studies*, 44(9): 1103–1115.
- Kandampully, J. (2002), Innovation as the core competency of a service organization: the role of technology, knowledge and networks. *European Journal of Innovation Management*, 5(1): 18-26.
- Rubalcaba L., Di Meglio G. and Gallego G. (2013), Public-private Innovation networks and social innovation in the service economy, in: *Social Innovation: New Forms of Organisation in Knowledge – Based Societies*, edited by C.R. Viñals, C. Parra Rodríguez, Routledge.
- Rubalcaba L., Windrum P., Gallouj F., Di Meglio G., Pyka A., Sundbo J. and Webber M. (2011), ServPPIN. The contribution of public and private services to European growth and welfare and the role of public – private innovation networks, ServPPIN project final report, Universidad de Alcalá.
- Szeto, E. (2000), Innovation capacity: working towards a mechanism for improving innovation within an inter-organisational network, *The TQM Magazine*, 12 (2): 149-58.
- Tether, B. S. and Tajar, A. (2008), The organisational-cooperation mode of innovation and its prominence amongst European service firms, *Research Policy*, 37: 720–739.
- Weber K. M., Heller-Schuh B., Godoe H. and Roeste R. (2014), ICT-enabled system innovations in public services: Experiences from intelligent transport systems, *Telecommunications Policy* (in press), Available online 27 January 2014, <http://dx.doi.org/10.1016/j.telpol.2013.12.004>.

ⁱ Social economic system is characterized by value creation processes that are different from conventional economic ones. It is able to increase cultural resilience in the local context (city, region and nation) because it produces, in its exchanges, virtuous circular processes: reciprocity, social responsibility and public spirit. Social economy replaces and regenerates the social capital that makes the economy and democracy work; it stimulates culture, economy and also employment in the local context.

ⁱⁱ The ownership structure of seaport can be represented by four types of models: Public Service Port; Tool Port; Land Lord Port and Fully Privatized Port. Each of these models is characterized by a different power of regulation and administration of the public body, i.e. the Port Authority. In this paper, the focus is on the Land Lord Port model, typical ownership structure of the most of the European Seaports.

Issues Involved When Introducing Shore Power: A Critical Mixed Methods Study in the Port of Kaohsiung

Po-Hsing Tseng^{a*} and Nick Pilcher^b

^aDepartment of Logistics and Shipping Management, Kainan University, No. 1, Kainan Road, Taoyuan 33857, Taiwan. Email: phtseng@mail.knu.edu.tw.

^bSchool of Marketing, Tourism and Languages, Edinburgh Napier University, Edinburgh, UK

*Corresponding author

Abstract

To reduce ship emissions in port and city environments, shore power has been suggested and implemented in some global advanced ports. However, numerous challenges regarding its implementation remain. This paper uses quantitative and qualitative approaches to focus on Kaohsiung Port as an exemplar for introducing shore power. Quantitatively, simulation analysis compares the annual cost of conventional terminal and shore power. Qualitatively, in-depth interviews with key stakeholders are presented and discussed. Key focal points and issues for discussion related to introducing shore power in the practical arena are highlighted. These focal points are used to generate a list of key issues to help stakeholders consider the key issues in any future discussion around the implementation of shore power.

Keywords: Shore Power, Port, Emission, Issues.

1. Introduction

With international shipping now carrying over 80% of world trade by volume, the industry's greenhouse gas emissions attract increasing public attention (Gilbert and Bows, 2012; Yap and Lam, 2013). Ships are recognized as major air polluters, with associated climate change, global warming, acidification and eutrophication. Shipping activities at port are highly pollutive (Ng and Song, 2010), and over 95% of the world's shipping fleet is diesel engine powered, with even modern marine engines producing higher emissions per power output than regulated on-road diesel engines. When docked at berth (in hotelling), ships still need internal generators for basic function, such as lighting, chilling, refrigeration, cooling, heating, pumps, fans, emergency equipment, elevators and so on. In Taiwan, most ships at berth use heavy fuel oil for both main and auxiliary engine power and boiler operations, creating dangerous air pollution (Liu and Tsai, 2011). In the long-term this is not sustainable and needs to adopt effective mitigation and control strategy to reduce emission from the ship (Ko and Chang, 2010; Vergara et al., 2012).

One recently suggested solution to increase sustainability and reduce the environmental impact of shipping activities at berth is shore power. Shore power involves ships plugging into much cleaner power sources at berth and switching off their diesel engines. Such a system, as we show here, has great potential for improving port sustainability and reducing environmental impact in Kaohsiung, yet many implementation barriers within the practical policy arena exist, financial and technical (e.g. voltage, plug standardization and regulation). To date, however, surprisingly little effort has been devoted by port authorities and port operators to suggest ways forward to reduce such implementation barriers. We add to the research field by drawing up a list of key areas for discussion by policy makers and key stakeholders when introducing shore power. This is a list based on both quantitative and qualitative data, and thus generated and developed using an interpretivist approach which we believe is new to the field. We hope this list can help reduce implementation barriers.

The objective of this paper is twofold. First, we overview the nature of shore power in terms of emission reduction from ship at port. Second, through a quantitative cost analysis and qualitative in-depth qualitative interview with key stakeholders in the port management field and government officials, we use Kaohsiung

port as an exemplar to highlight issue for discussion. After this brief outline of the problem here, shore power and a background to the research site are described in section 2. In section 3, some recent and current literature is reviewed. Section 4 describes the methodology used in the data collection and analysis. Section 5 presents and discusses the quantitative cost analysis and qualitative interview results. Finally, conclusions drawing together the key issues are presented in section 6, and key points for discussion in any introduction of shore power systems are brought together in Appendix One for practical use by policy makers.

2. The Background of Research Site

2.1 The overview of shore power

Shore power, also known as ‘cold ironing’, ‘alternative power supply’, ‘shoreside power’, and ‘onshore power’, is a possible way to reduce air pollution from ships in the port area through electric feed to the ships from onshore. It is a land-to-ship electricity connection that allows ships to switch off onboard diesel-powered generators while docked. Shore power consists of three basic components: shore-side electrical system and infrastructure, cable management system and ship-side electrical system. Implementing shore power is a strategic choice as, although it has environmental benefits, issues remain. Environmental benefits are improved air quality, reduction in noise, and reduced health concerns from shipping activities at berth.

However, four key issues with introducing shore power exist. First, the cost of installing shore power is unattractive for port authorities: construction cost involves power lines, cables, reel, transformers deployment, extra electrical capacity, conduits and the plug infrastructure. This is a significant financial burden compared to traditional ship diesel and differs considerably by location. Second, shore power capacity is problematic as power requirements differ greatly, depending on ship type, size, and number of refrigerated containers on board. Also, connectors and cables are not internationally standardized and voltage issues also arise when designing shore-to-ship connection in port as no global uniform voltage and frequency requirement and standardization of electricity exists. For example, the port power system in Taiwan is usually 50 Hz, but is 60 Hz in America and Japan (Jia-Sheng et al., 2012). Third, system design and safety are key, and IEEE/ISO/IEC standard P80005-1 (engineering and electrical standard) must be followed. Fourth, no global regulations and legislation of shore power exist, and advanced ports (e.g. Los Angeles and Long Beach) have stricter legislation to regulate air quality. Thus, cost estimations cannot be exact and can only be a ‘guesstimate’.

2.2 Kaohsiung port

Kaohsiung port, located in the middle of the Western Pacific, is a pivotal point for shipping lines crossing the Pacific Ocean. It is the largest container port in Taiwan, accounting for about 70% of total container traffic in 2013. According to Taiwan International Port Corporation,¹ there were 17,250 ship calls in Kaohsiung port in 2012, equivalent to 47 ships per day. Currently, three shipping companies have installed shore power equipment (in terminals 96, 108-111 and 115-117) there. Generally, in Kaohsiung port, it takes 1-2 hours for shore power connection procedures, including shutting down ship engines (diesel generators), getting power cable from or to ships, plugging in connectors, pushing buttons and testing (e.g. voltage).

3. Literature Review

Port electricity is viewed as a useful strategy to reduce emission in the port (Kim et al., 2012; Lam and Notteboom, 2014). In order to reduce ship emissions and health risk, shore-side power has been suggested to replace auxiliary engines (Khersonsky et al., 2007; Ferrara et al., 2011; Yang et al., 2011; Theodoros, 2012). In some advanced ports (e.g. in California, US), ship owners must follow strict environment protection regulations and port authorities do not allow ships to operate their prime movers while at berth (Khersonsky et al., 2007). Traditionally, ships’ diesel auxiliary engines continue to provide electricity for lighting, ventilation, pumps, cranes, and essential equipment while they are berthed (called “hotelling”) (Hall, 2010), but shore power provides electricity from the land instead (Salomon, 2009). Shore-side electrical power has achieved significant CO₂ reductions: 99.5%, (Oslo, Norway) 85.0% (France) and 9.4% (Fort Lauderdale, US) (Hall, 2010). Shore power systems have been established in North America (Los Angeles, Long Beach, Juneau, Vancouver and Seattle) and Europe (Gothenburg, Lubeck, Antwerp) in the past decade. Key providers are

ABB (Swiss company), SCHNEIDER Electric (French company) and SIEMENS (German company). Theodors (2012) investigated the implementation of shore power and strategically analyzed its benefits in an environmental and financial point of view. Although environmental benefits are significant when adopting shore power, cost consideration and managing the complex and varied grant requirements are two main challenge barriers.ⁱⁱ

4. Methodology

Quantitatively, we conducted a cost analysis based on data from our interviews and from sources such as the Taiwan International Port Corporation. Qualitatively, we spoke to 7 government officials and 5 port operators. We interviewed many people twice, once about emissions tax, and second about shore power. Shore power was the main focus of interview two but also arose in one. We draw on a combined total of 18 interviews. Interviewees were chosen strategically from port management (including private and public shipping companies) and government. To ensure participants were able to convey information in a linguistic medium they were comfortable with, interviews were conducted in participants' native language (Cortazzi *et al.* 2011). To ensure accuracy these interviews were recorded and transcribed verbatim so no details were omitted or selected by the interview (who transcribed them). Then, considering the need for an appropriate translation, the interviews were translated into English using a goal oriented or 'skopos' approach (Vermeer, 2004) to reach as natural a translation as possible. To ensure as far as possible that participants were protected and therefore felt at ease to give what would be more valid data, ethical approval was granted from the appropriate bodies and anonymity assured (Christians, 2011). Further, Interviews were 'active' (Holstein and Gubrium, 1995) in the sense that negotiation of meaning was allowed through the use of 'spider diagrams' (*cf.* Pilcher *et al.*, 2013) focused on key issues rather than a list of questions which could have biased the meaning according to the linguistic form and perceptions of the interviewer. Transcripts were analyzed using a constructivist grounded theory approach (Charmaz, 2011) where themes and issues emerged rather than being pre-determined. This approach ensured that, rather than trying to pigeonhole the data into pre-arranged categories as an objectivist grounded theory approach would have done, we were able to see themes emerge that we had not anticipated but which were often of fundamental importance to consider.

5. Results

5.1 Quantitative cost analysis

To understand the cost comparison between conventional terminal and shore power terminal, we consider fuel and electricity cost (with extra cost when adopting shore power). Assuming 300 containerships (in 8,200 TEUⁱⁱⁱ) calling at one terminal in Kaohsiung port in one year. Fuel consumption for containership is 0.8 ton/hour and average time at berth is 16 hours/ship. The fuel consumption would be 12.8 (=0.8*16) ton/ship-hour. The estimation of fuel cost is 8,960 (=12.8*700) US\$/ship/year, assuming fuel price is 700 US\$ dollars/ton.^{iv}

Regarding shore power, electricity rate is negotiated case-by-case, based on result of interviews^v, we assume the electricity rate is 0.1US\$ (per WH^{vi}) for users. It is estimated that each containership uses 50,000 WH. The electricity cost would be 5,000 (=50,000*0.1) US\$ dollars/ship. The extra costs for shore power include infrastructure, operation/maintenance and extra charge when electricity volume exceeds contract quota. Assuming design life for containership is 20 years and infrastructure cost of shore power is 1.3 million US\$,^{vii} the construction cost of shore power is about 222 US\$ (=1.3 million/20/300) dollars/ship, assuming an annual 300 containerships calls at one terminal. The operation/maintenance cost is estimated to be 233 dollars/ship/year.^{viii} The extra charge for exceeding quota is variable cost and uncertain since it is difficult to estimate and is not included in our cost comparison. In sum, the cost comparison between conventional terminal and shore power terminal is shown in Table 1. The result shows that 3,505 US\$ benefit could be obtained if containership adopt shore power terminal and replace conventional terminal.

Table 1: Annual cost comparison of conventional and shore power terminal

Comparison	Conventional terminal	Shore power terminal
Fuel cost (US\$/ship)*		
Electricity cost (US\$/ship)		5,000
Infrastructure cost (US\$/ship)		222
Operation/maintenance cost (US\$/ship)		233
Sub-total	8,960	5,455
Difference		3,505

Note: * Fuel consumption for ship is 0.8 ton/hour and average time at berth is 16 hours/ship.

Fuel consumption is 12.8 ton/ship-hour and fuel price is 700 US\$ dollars/ton

These quantitative data show that currently shore power is not adopted in the terminal as ship owners would not use shore power in older ships due to the high expense of installing ship-side equipment.^{ix} Thus, capital costs of shore power make it unattractive. Also, overall life-cycle costs are not easily evaluated. To complement and contextualize these quantitative results in the practical arena we now present and discuss perspectives of key stakeholders.

5.2 Qualitative analysis and discussion.

We divide this section into *motivation and timescale*, and *issues and concerns*. The issues and concerns section we subdivide into: *costs, profits, and funding*; *specific electricity costs* and; *technical issues and solutions*. We present government (named, or denoted as GO) and port officials (named, or denoted as PO) together but highlight differences where pertinent. In the attempt to achieve a narrative, we interweave the results with the discussion. We aim to generate key focal points and issues for authorities and stakeholders. We also highlight suggestions for solutions. We thus adopt a critical approach by aiming to facilitate change through helping catalyze the introduction of shore power by highlighting these points for discussion.

5.2.1 Motivation and timescale

Our data show a main challenge to the introduction of shore power in Kaohsiung has already been overcome in that motivation to introduce it (despite the high costs the quantitative data shows) already exists. Port operators felt shore power part of an international trend, for example *“This is the important trend for developing green port and green ship.”* And sometimes expressed urgency regarding its introduction: *“It should be done early. It has already developed in Hong Kong, Singapore, LA and Seattle port. Our pace is too slow... If we do not do it today, we will regret tomorrow.”* Many government officials also saw shore power similarly, both locally, as *“it is the green port trend and must reduce air pollution (e.g. SO₂)”* and globally, as *“it is also the international trend.”* Shore power was thought to reduce air pollution, noise pollution, and improve port safety. Nevertheless, it was believed essential to introduce shore power ‘globally’ and not simply to a certain place as *“if we just do it in certain place, it is not enough... otherwise, we can not achieve the significant effect,”* and that *“the ship emission at port just one part of total pollution.”* Yet there was also the concern that *“it must not affect trade and economic development in Taiwan.”* There were thus a number of tensions here: firstly between specific and wider coverage, the need to start somewhere, but also to have a wide impact, a desire to be environmental but also profitable. Most significantly perhaps though, no-one was opposed to introducing shore power. Nevertheless, these issues would need to be taken into consideration when introducing any shore power systems.

Regarding timescale, and as to exactly when shore power would be operational in Taiwan, Government officials felt on average about 10 years, for example, *“it may be 10 years later,”* or simply, *“in the future.”* One port operator felt, *“It may take 7-8 years.”* Often, provisos were added, that it would depend on new ships or laws, or that it would be too expensive to equip old ships, which, *“can be used for 20-30 years”* (PO). One government official spoke of technical issues: *“It depends on the deployment progress of shore-side equipment.”* Other government officials spoke of purely political drive: *“It depends on governmental department’s arrangement and attitude,”* or the idea that political and global factors would be of importance, *“It is difficult to say. It depends on the rule of law. Also, it must consider the foreign ship’s inclination. We do not know it now.”* Here then, the importance of both technical and political factors was noted in terms of how

fast shore power would be introduced. Notably, the interconnectivity of these aspects was clear, thus, in terms of which specific people were involved in any discussions, in any shore power project it is therefore essential to involve experts from the technical field as well as those involved at the political end of decisions.

Regarding the likelihood of shore power being introduced, it was often felt that the introduction of shore power was inevitable. Government officials felt, *“it is the trend of world... Taiwan will also do it in the future,”* or that *“New ship construction will equip with shore power facility.”* Port Operators that, *“It is OK in technical issue. Our new ships which are built by Taiwan Ship Construction Company are already equipped with shore power now.”* Yet, there were many underlying tensions and issues. Firstly, if ships called only at developing countries ports and not those of Europe or the US, *“they do not care about environmental issues, we will not worry about shore power question.”* (PO) Further, from a technical perspective, although new ships were equipped to access shore power, to refit older ships so they could access shore power was unfeasible: *“the engineering cost is huge when renewing old ship... It is not worth doing it after evaluating the installment cost”* (GO). There was thus a tension between ‘inevitable’ introduction versus ‘no need’, and between technically advanced new ships versus continued use of older ships. Again, this shows a need to carefully and thoroughly consider whether any shore power system should indeed be introduced. This in turn is, we argue, inextricably connected with the feasibility and likelihood of the success of any shore power project as, without the justified or desired motivation for such a system, its implementation will be severely hampered.

5.2.2 Issues and concerns

5.2.2.1 Costs, profits, and funding

Understandably, the issues of the cost, and the resultant impact upon profit, of introducing shore power were key. Generally, costs were noted to be both fixed and variable: *“The fixed cost includes shore facility, the variable cost include electricity fee, operators cost and maintenance cost.”* (GO). One government official believed ship owners should pay some of the fixed costs, on the ship side: *“the fixed cost includes electricity facility on shore, ship-side electricity facility, and reel facility. The ship owner usually is responsible for ship-side facility and reel.”* Regarding the amount of these fixed costs, occasionally an actual price was put to these, for example: *“The installment cost of ship-side shore power facility about one million NT dollars”* (GO). Yet this was not felt to be as expensive as the shore side, for example: *“The shore-side facility is more expensive than ship-side facility.”* (PO). It was noted how fixed costs could be divided into, *“ship facility, terminal facility and line pipe and electricity factory... further maintenance and human cost.”* (GO).

In terms of how port operators approached the issues of costs, understandably, profitability was key, for example that *“Public welfare policy is always conducted when the corporation has made a profit.”* Port operator perspectives with regard to cost were to combine affordable fuel with discounts: *“We can not expect very low fare, but it should compete with other ports (e.g. Hong Kong, Singapore, LA)... Fare benefit and discount would increase more adoption rate. LA port in US already did it”* or that, *“Yes, business concern revenue and cost issue... We hope the government can subsidy for shore power users and low sulphur fuel users.”*

Regarding profit, government officials also focused on the key issue of not wanting to discourage shipping companies from calling at Taiwanese ports due to prohibitive costs. For example, *“if we have too many regulation and produce extra cost, the shipping operators will choose other countries...it should subsidy the operators. Otherwise, very fee operators will do it”* (GO). Yet, another official believed that the ports would still be profitable and that shipping companies should follow regulations: *“It still has market competitiveness in Taiwan. If the ship owners would like to run a business, it must obey the port regulation in Taiwan.”* The sensitivity of cost was therefore a key issue and something that must be decided on before the implementation of any system. Government officials were clearly aware of the need to be very careful in not discouraging ships from calling at ports due to prohibitive costs, as were port operators. The idea of costs being competitive and comparable with those of costs elsewhere in the world was noted, and the idea was also mentioned that in order to help create a ‘cultural’ change in the uptake of shore power (see above) discounts and subsidies would greatly help.

On the funding of shore power, many government officials felt an emissions tax could provide subsidies to set up shore power. For example that, *"It must rely on governmental subsidy. For example, using emission tax to subsidy shore power operators."* Yet, as well as subsidy, government officials also leaned toward regulations. For example that a schedule must be introduced with a 'sunset clause' for ships to adhere to, as had been done with truck regulation in Taiwan's ports, and that, *"If the expiration date is due, it can not continue to use it in port."* or that *"we must adopt environmental protection rule to ask ship owner to install shore power in the future."* It was also felt that without regulating to create the 'convention' for shore power, even if new ships were equipped to use shore power, they would not: *"Even all old ships are replaced, they would not conduct shore power overall. If there is no convention to conduct shore power, it is difficult to conduct it. If this is necessary policy, everyone will conduct it."* Yet, regulation for shore power is highly complex, one government official noted that different departments needed to coordinate more effectively: *"The Transportation Administration thinks it should be subsidized from Environmental Protection Administration. Environmental Protection Administration thinks it involves the electricity issue and which is subordinate to Economic Affairs Administration. These three parts do not have consistency common view. Harbor and Marine Technology Center (Government department) has investigated this issue now."* Thus, here again the complexity of the introduction of any shore power system is clear. Echoing the idea that shore power was 'not necessary' (above), here, the possibility of it not being used even if available was noted. This would involve a complex 'cultural' change in berthing practices which would need to be carefully considered. Further, much discussion around how to fund it is clearly needed, and the decisions made regarding whether to subsidize shore power, or whether to facilitate it through regulation alone. Further, given the different views of the different agencies, decisions need to be made exactly who should fund shore power, i.e. which government department should be responsible for it. Arguably, this is a decision that would have to be made above these departments, unless it was agreed that the costs be split between the three of them. Yet, amongst government officials, there was a general feeling that although the cost was high, the importance of following the 'international green port trend' was greater: *"In fact, it is cheaper to use ship fuel compare to shore power system, but, we must follow international green port trend to adopt shore power. We must invest lots of money to do it."* (GO).

5.2.2.2 Specific electricity costs

More specifically related to cost, the actual cost of the price that would be charged for the electricity was also a key issue. For many government officials, this was an unknown, or as yet, uncalculated cost. For example *"We do not know it now"* or *"the fare of electricity is not decided because it must consider overall cost, including instalment and maintenance. It is quite difficult to do it and it is under research period."* Regarding whether the cost would be higher than traditional electricity fare, one government official noted it would be higher than household electricity, whereas one port official felt it would be, *"cheaper than traditional electricity fare."* Also, one government official felt it would be cheaper than conventional ports: *"Generally, cost of adoption shore power is just 25% of conventional terminal. The cost difference of between them is the benefit of adopting shore power"* (GO). Notably, both voices amongst the government officials and port operators felt there needed to be further discussion. For example: *"The electricity fare standard should be discussed among ship owners, port authorities and power suppliers"* (GO) and *"the total cost is difficult to estimate and need further discuss with different departments"* (PO). Thus, the variable cost of the electricity is as yet undecided, this needs to be considered, and, we argue, considered in light of other issues discussed here, such as the need to retain profitability, encourage a 'cultural' change toward the use of shore power, to involve all stakeholders in any discussion, and to decide beforehand on which department is to be responsible, and how much should be given in terms of subsidies. The decisions taken on all these issues will inevitably affect the uptake of any shore power system and be of critical importance to its success.

5.2.2.3 Technical issues, and solutions

In addition to issues related to costs, a number of technical issues arose. With these issues, there was often one side, or 'voice' of caution, that championed caution and challenges, but another 'voice' of calm that felt the issue to be not serious. For example, regarding plugs and connection types, the 'voice' of caution noted that *"the connection between ship and shore is not unified... as I know, there are four types of connections. Maybe more, it would be great if there is only one type of connection."* (GO) Similarly, that such variety in

connection types was “*dangerous for facility and operators in the terminal*” (GO) and that ship length would determine where the connector could be placed and where the ship could berth. Yet, the ‘voice’ of calm said of plug and connection standards differing, that, “*this problem is not serious*” (GO). Further, regarding voltage, one port operator noted a ‘voice’ of caution: “*Voltage can be separated into 280V, 385V, 445V and so on. Therefore, the power supplies should be different. Different types of ship must be provided by various voltage powers.*” (PO) In contrast, a government official more of a ‘voice’ of calm: “*Based on trend of international shore power installment, the power voltage could be 6.6KV or 11KV. Therefore, this kind of power is high voltage for Taiwan’s case*” (GO). Similarly, the voices of caution noted with regard to ship facilities that new ships were able to access shore power, for example, “*it is very common in new ship. But, old ship would not adopt it due to cost consideration*” (GO) and also, “*Our new ships which is built by Taiwan Ship Construction Company is already equipped with shore power now*” (PO). Regarding the technical issue of the time required to set up the shore power supply after berthing, a voice of caution noted that, “*it needs the operation time to plug in the facility. It usually takes 1-2 hours. I even hear 5-6 hours if there are some problems when ships plug it.*” Or that “*each side (ship and shore) must test electricity power before plug in the facility, for the safety reason.*” In contrast, a voice of calm noted that: “*It will not spend much time if the port facilities are good.*” Thus, technically, a number of areas need to be clarified: voltage types, connection types, connection lag times. These need to be considered in the context of costs and responsibility.

In addition to issues and concerns, solutions were also suggested. One was to use solar energy and sell extra power to Taiwan Power Company: “*It should tie in solar energy facility to storage electricity and then sell it to Taiwan Power Company.*” (GO) Also, the steps to introduce were suggested: “*The public terminal could do it first. Do it first and make a fine example. The containership could do it first. The new terminal will prepare line pipe for future shore power construction.*” (GO). Or even that it may not be necessary if LNG ships become the norm: “*maybe the Liquefied Natural Gas ship become popular in the future, the situation of adopting shore power becomes not-important.*” (GO). One port operator also underlined the need to consider the introduction of shore power as one of six key factors: “*The first is cargo source. The second is port facilities must be good. The third is shore power. The fourth is port fare must be reasonable. The fifth is ship can be refueled and water refilled and provide secure environment (no terrorist). The sixth is cargo transshipment is good. The example is Singapore*” (PO). There were therefore numerous solutions suggested: to introduce step by step, to sell extra power, and to consider shore power as part of a total solution. It was also noted that it may not be necessary should LNG ships be used more, this could either be a partial or total solution.

6. Discussion and Conclusions

Through a mixed method investigation using the port of Kaohsiung as an exemplar, the above paper aimed to cast light on ways forward to help facilitate the introduction of shore power in Taiwan. The quantitative cost analysis shows that currently shore power is not adopted in the terminal as ship owners would not use shore power in older ships due to the high expense of installing ship-side equipment. Thus, capital costs of shore power make it unattractive. Yet, our qualitative data from interviews with key stakeholders show, significantly, that, although not all people, almost everyone was in favor of shore power and were aware of its benefits (*cf.* Hall 2010; Theodoros 2012). The qualitative data also show a number of issues that stakeholders need to discuss and resolve to help implement shore power focused around the desire to be environmental yet remain profitable. Cost wise, issues of whether to subsidize shore power or to regulate (*cf.* Khersonsky *et al.* 2007) for it; and whether to subsidize through an emissions tax or otherwise; further, exactly who should pay for what aspect of the facilities; what the exact cost for the electricity will be, and the desire to maintain port competitiveness yet be environmental. Technically, many issues remained unclear: voltages; connectors; connection lag times. Procedurally, the issue of balancing the need to have a wide impact with the need to start somewhere; the issue of wanting to start to introduce shore power but to remain competitive globally, and the issue of needing to establish effective communication between the different departments. We have listed these issues in Appendix One in the hope that such a list will help in the planning for and introduction of a shore power system. We do not imagine this list to be exhaustive nor complete, but hope it provides a useful starting point to help contextualize the introduction of shore power within other areas our interviewees highlighted.

Our stakeholders were split between the ideas that shore power would be ‘inevitable’ yet that without

establishing a 'convention' for it, shore power would not be used even if facilities existed. Yet, desire for shore power is clearly here, and although the cost is high, the importance of following the 'international green port trend' was greater. In one interview, one stakeholder said in relation to introducing policy: "*Researchers (like you) must think how to design an effective method... if the government must conduct this policy*" (GO). We hope that in this paper we have presented issues for discussion and brought them together in a practical format in Appendix One to enable such discussion to happen for the introduction of shore power in Taiwan, and also, we hope, for the introduction of shore power elsewhere.

Acknowledgement

Financial support for this research was provided by National Research Council, Taiwan, ROC (NSC 101-2410-H-424-015).

References

- Charmaz, K. (2011), Grounded Theory Methods in Social Justice Research. In Denzin, N. K., & Lincoln, Y. S. (Eds), *The Sage handbook of qualitative research*, Thousand Oaks, Calif: Sage 359-380.
- Christians, C. G. (2011), Ethics and politics in qualitative research, In Denzin, N. K., & Lincoln, Y. S. (Eds). *The Sage handbook of qualitative research*, Thousand Oaks, Calif: Sage 61-80.
- Cortazzi, M., Pilcher, N. and Jin, L. (2011), Language choices and 'blind shadows': investigating interviews with Chinese participants. *Qualitative Research*, 11(6): 505-535.
- Ferrara, P. J., Uva, M. A. and Nowlin, J. (2011), Naval ship-to-shore high temperature superconducting power transmission cable feasibility, *IEEE Transactions on Applied Superconductivity* 21(3): 984-987.
- Gilbert, P. and Bows, A. (2012), Exploring the scope for complementary sub-global policy to mitigate CO₂ from shipping, *Energy Policy*, 50: 613-622.
- Hall, W. (2010), Assessment of CO₂ and priority pollutant reduction by installation of shore power, *Resources, Conservation and Recycling* 54: 462-467.
- Holstein, J. A. and Gubrium, J. F. (1995), *The active interview*. Thousand Oaks, CA: Sage.
- Jia-Sheng, L. I., Jiang, L. J., Qiu, B. and Yang, W. M. (2012), Electronic shore power station based on matrix-style frequency algorithm, *Physics Procedia* 24: 932-937.
- Khersonsky, Y., Islam, M., Peterson, K. (2007), Challenges of connecting shipboard marine systems to medium voltage shoreside electrical power, *IEEE Transactions on Industry Applications* 43(3): 838-844.
- Kim, J., Rahimi, M. and Newell, J. (2012), Life-cycle emissions from port electrification: a case study of cargo handling tractors at the port of Los Angeles, *International Journal of Sustainable Transportation*, 6: 321-337.
- Ko, T.T. and Chang, Y.C. (2010), Integrated marine pollution management: a new model of marine pollution prevention and control in Kaohsiung, Taiwan, *Ocean & Coastal Management*, 53: 624-635.
- Lam, J.S.L. and Notteboom, T. (2014), The Greening of Ports: A Comparison of Port Management Tools Used by Leading Ports in Asia and Europe, *Transport Reviews*, 34(2):169-189.
- Liu, T.K. and Tsai, T.K. (2011), Vessel traffic patterns in the Port of Kaohsiung and the management implications for preventing the introduction of non-indigenous aquatic species, *Marine Pollution Bulletin*, 62: 602-608.
- Ng, A.K.Y. and Song, S. (2010), The environmental impacts of pollutants generated by routine shipping operations on ports, *Ocean & Coastal Management*, 53: 301-311.
- Pilcher, N., Smith, K.L. and Riley, J. (2013), International Students' first encounters with exams in the UK: superficially similar but deeply different. *International Journal of Teaching and Learning in Higher Education* 25(1): 1-13.
- Salomon, M. (2009), Recent European initiatives in marine protection policy: toward lasting protection for Europe's seas? *Environment Science & Policy* 12: 359-366.
- Theodoros, P.G. (2012), *A Cold Ironing Study on Modern Ports, Implementation and Benefits Thriving for Worldwide Ports*, Master Thesis, School of Naval Architecture & Marine Engineering, National Technical University of Athens, Greece.
- Vergara, J., McKesson, C. and Walczak, M. (2012), Sustainable energy for the marine sector, *Energy Policy*, 49: 333-345.
- Vermeer H.J. (2004), Skopos and commission in translational action. In: Venuti L (ed.), *The Translation*

Studies Reader (2nd Edition), London: Routledge 221-232.

Yang, X., Bai, G. and Schmidhalter, R. (2011), Shore to ship converter system for energy saving and emission reduction, 8th International Conference on Power Electronics-ECCE Asia, May 30-June 3, 2011, The Shilla Jeju, Korea.

Yap, W.Y. and Lam, J.S.L. (2013), 80 million-twenty-foot-equivalent-unit container port? Sustainable issues in port and coastal development, *Ocean & Coastal Management*, 71: 13-25.

Appendix One: Issues for discussion with regard to Shore Power systems

Prior to introducing Shore Power

- List, and then involve, all stakeholders in discussion
- Use the discussion to decide whether shore power is desired and feasible
- Gather data on pricing systems where shore power exists (e.g. ports in the States)
- Decide which government departments will be responsible for introducing and regulating shore power.
- Consider technical solutions to issues of voltage, connection types, set up times, and others.
- Decide on whether to subsidize and if so how, and to what extent to subsidize
- Consider whether to fund shore power through initiatives such as emissions taxes
- Consider how to regulate and also to what extent regulation should be the driving force behind the introduction of shore power.
- Consider how strict regulations should be and to whether to introduce ‘sunset’ type clauses to force ships to adopt shore power.
- Within the context of the above, and through the use of quantitative means, calculate a pricing for the electricity costs of shore power.

During the implementation of shore power

- Consider how to publicize the use of shore power, and to justify its introduction
- In order to help achieve green port, consider the implementation of shore power within the wider context of other initiatives such as emissions tax policies
- Consider and map out the implementation of shore power in both geographical stages (port by port) and also temporal stages (year by year) so it is phased in gradually.
- Establish bodies to carefully monitor the impact of shore power on port competitiveness and overall green port trends

ⁱ <http://163.29.117.5/english/index.htm>

ⁱⁱ Jill, B.B., Ibrahim, M. Leong, T., Prevost, D., Sandifur, M., Sinkoff, R. Port of Oakland completes shore power project's first phase, Port Technology International, <http://www.porttechnology.org/>

ⁱⁱⁱ Twenty-foot Equivalent Unit

^{iv} Assuming 30 NT dollars is 1 US\$ dollar. Based on interview from Chinese Petroleum Corporation in Taiwan.

^v The actual electricity rate is undecided, but it is similar for general commercial or industrial use.

^{vi} Watt-Hour (WH). Based on interview from Taiwan Power Company in Taiwan.

^{vii} From interviews with Taiwan International Port Corporation.

^{viii} From interviews with Taiwan International Port Corporation.

^{ix} From interviews with Taiwan International Port Corporation, expense of installing ship-side equipment per ship is about 3.3 million US\$ in Kaohsiung port.

Energy Saving Effect of Roof Shade at Reefer Container Storage Yard

Takeshi Shinoda¹ and Muhammad Arif Budiyo²

¹Department of Marine Systems Engineering, Kyushu University, Japan

²Graduate School of Engineering, Department of Urban and Environmental Engineering, Kyushu University, Japan

Abstract

The Kyoto Protocol came into effect in 2005, and actions for prevention of global warming are strongly desired in container terminals. Although energy saving will be significant impact on reduction in CO₂ emissions, electric power consumption by stored reefer container seems to make up about 50% of total power consumption in a container terminal. To reduce heat penetration on walls of reefer container by a load of strong solar insolation in summer will enable an improvement of energy consumption of reefer container. In this paper, we clarify the effect of reducing energy consumption of reefer container due to installing of roof shade that covers the reefer container storage yard to protect from solar insolation.

Key word: Container terminal, Greenhouse gas, Reefer container, Energy-saving, Roof shade

1. Introduction

The Kyoto Protocol came into effect in 2005, and actions for prevention of global warming are strongly desired in many industry sectors in Japan. A greenhouse gas with physical distribution activity in port and harbor is discharged by ships at anchorage in port and by cargo handling operations for ships and so on. Some control measures against these problems of greenhouse gas emission in port are being tackled in Kashii Park Port Container Terminal (KPPCT) and Hakata Island City Container Terminal (HICCT) in Fukuoka city in Japan. These container terminals introduced some measures for green house reduction such as electric power supplied system to RTG (Rubber Tired Gantry Crane), hybrid model straddle carriers instead of conventional straddle carriers and a trial system of roof shade for reefer container to reduce a load of solar insolation. Introducing these measures could be effective in energy saving, but these are difficult to estimate an amount of effect in energy-saving because the effects are not always so much and have strong deviation.

Especially, looking at the breakdown of electric power consumption in HICCT, the power consumption for storing reefer container makes up about 50% of total power consumption in the terminal. The major cause of energy consumption of reefer container is compressor driven with a compression refrigeration cycle system. This refrigeration system is controlling a frozen condition through monitoring thermal condition inside reefer container by the thermal sensor system. To reduce heat penetration on walls of reefer container by outside air temperature and the load of strong solar insolation in summer will enable an improvement of electric energy consumption of reefer container. In this paper, we attempt to establish an objective and quantitative evaluation method concerning the effect of roof shade over storage yard in reefer container stock yard.

2. Measuring Experimentation to Test the effectiveness of Roof shade over Reefer Container

Port of Hakata located in Fukuoka city in Japan has many container shipping lines that are connected to all around the world. About 850,000 TEU containers in one year are traded here and these are detailed 48% of export containers, 49% of import containers and 3% for transshipment by trade statistics data of Port of Hakata in 2012. Major trading partners are China (41%), Korea (20%) and US (8%). Besides the amount of handled container is increasing about 8% a year and this port was adopted the special major port by Japanese government in 1990.

There are two main container terminals in Port of Hakata, and one of these terminal is Hakata Island City Container Terminal (HICCT) in Fukuoka in Japan. Figure 1 shows a layout of HICCT. HICCT has 2 major berths that are 14 m and 15 m depth and 680 m berth length, yard area of 284,000m², 5 units gantry crane with outreach 50.0 m for 18 container columns span, full electric drive 17 units rubber tier-mounted transfer crane that can manage 8 container columns span, the container storage capacity of 19,296 TEU and 336 plugs for reefer container (Hakata Port Corporation).

Statistical data investigated by Hakata Port Corporation tell us that the monthly average of electricity consumption is 475 MWh, but reached 560 MWh in summer in 2011. The part of reefer container consume about 50 % of all electric consumption in this container terminal, and the act of energy-saving is one of most important issue in this terminal because shutdown of all nuclear power plants in Japan causes severe shortage of energy especially in summer after the Great East Japan Earthquake in 2011.

Installing the roof shade over reefer container stock yard will enable improvement to protect thermal condition of reefer container from bad thermal effect by solar insolation. HICCT initially set up the roof shade over two bays of reefer container storage yard as demonstration equipment in 2011, and HICCT and Kyushu University have been carrying into verification test for the effects of roof shade until now.

Figure 2 shows the outline of measuring experimentation to evaluate present performance of the roof shade over reefer container storage yard. The container plugs in container rack are arranged here in 8 columns and 3 tiers. Therefore, we prepared 6 reefer containers, and made two pairs of tiered 3 containers. Furthermore, these pairs for measuring experimentation are stored in the same storage slot in the bays with and without the roof shade as shown in Figure 3. The measuring experimentation has been carried out through comparing both pairs of temperature changes of reefer containers in the same slot with and without the roof shade.

3. Results of Measuring Experimentation on the roofshade over Reefer Container

The measuring experimentation was conducted at HICCT from August through October in 2013 with shifting the experimental pairs of reefer containers to another storage yard. Figure 4 shows the change of solar insolation power on the each surface of reefer container on 27th August in 2013. The power of solar insolation is strong on the east surface and the south surface of reefer container in the morning, and then the peak of power moves to the ceiling surface and the west surface in the afternoon. These features of solar insolation adversely affect a thermal condition of stored reefer container.

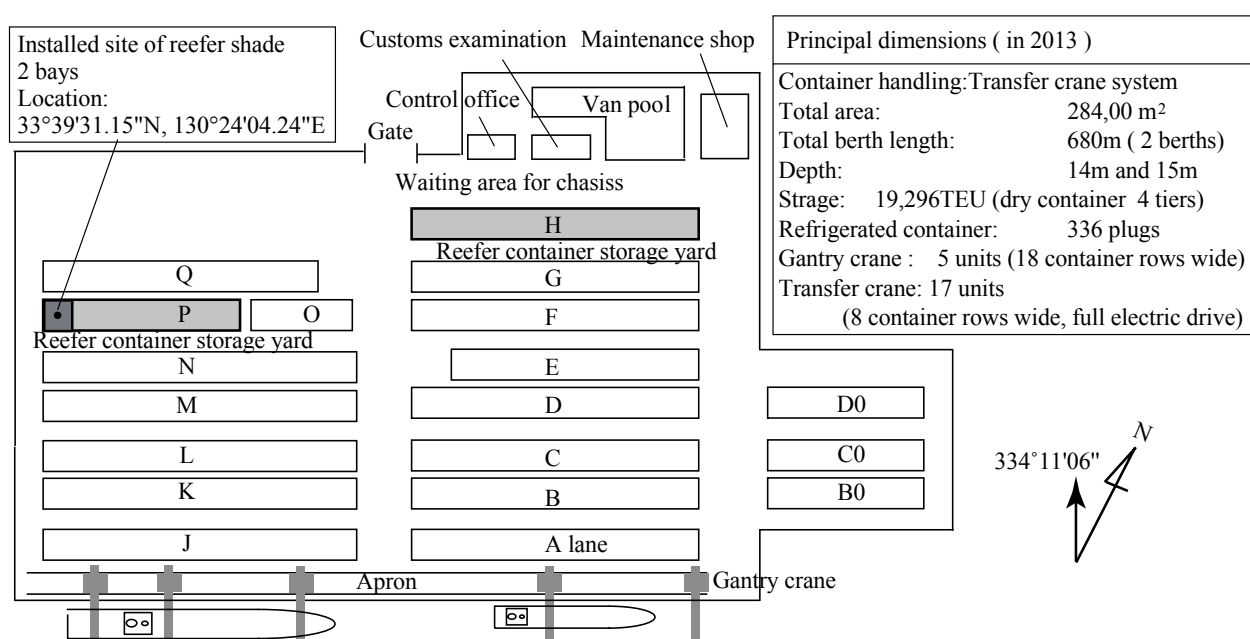


Fig 1. Layout of HICCT and experimental site for the roof shade

The reefer container is mainly composed of the freezing store unit and the refrigerating machine unit. The ceiling and the south side of reefer container have a large surface area for the freezing store unit, also are receiving a strong solar insolation from both sides. Moreover, the refrigerating machine unit faces the west side in this container storage arrangement, and the strong solar insolation from the west side make a negative impact on the refrigeration cycle system in the afternoon. These factors are associated with ill effects on the electric energy consumption of stored reefer container.

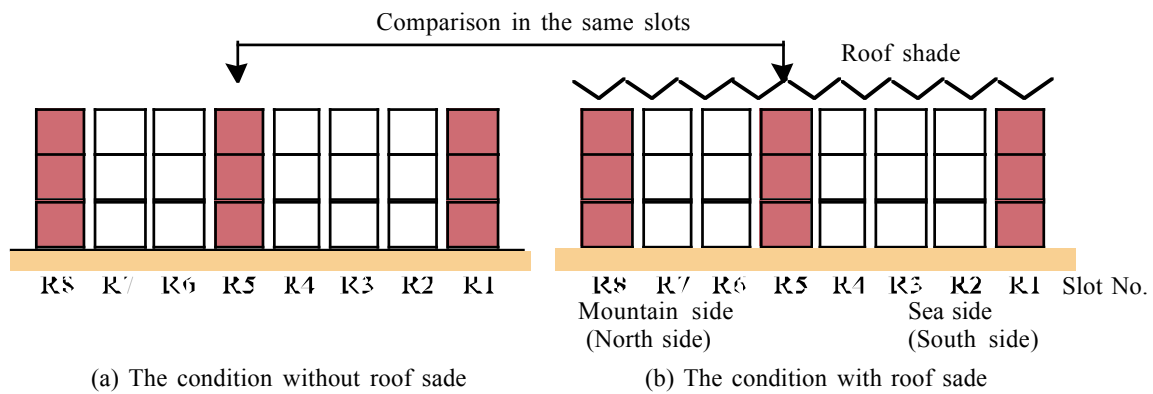


Fig 2. Concept of measuring experimentation on effect to reefer container by installing roof shade



Fig 3. Photo of experimental units in the reefer container storage yard

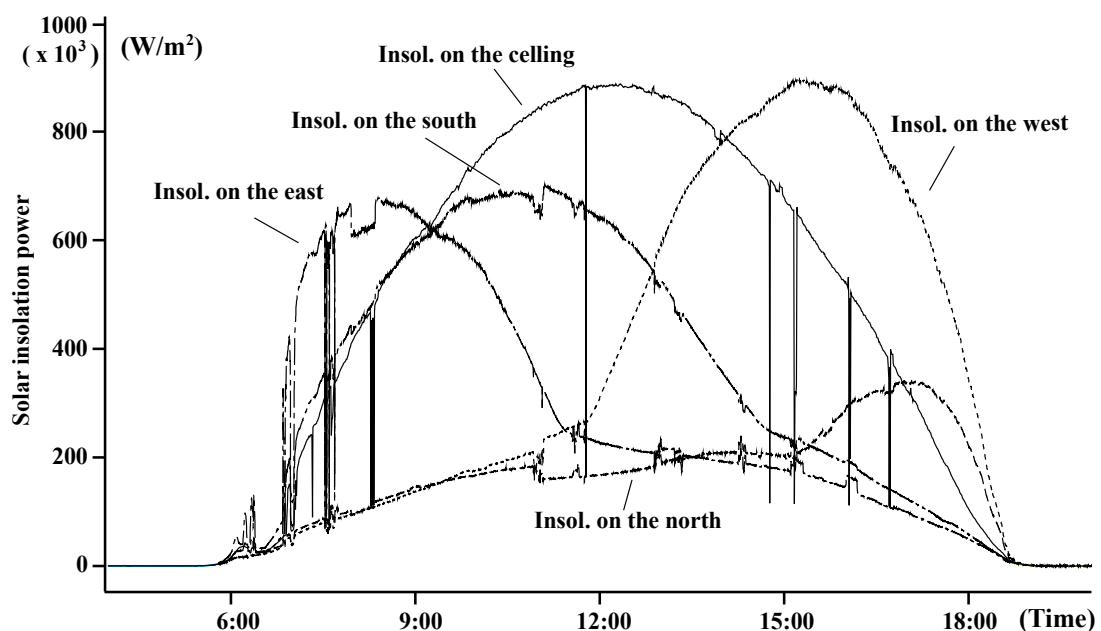


Fig 4. Change of solar insolation in the day time (on August 27th, 2013)

Figure 5 shows results of measuring experimentation on the top of reefer container when the experimental set of containers are stored in the slot of R4 without roof shade. Surface temperatures on the south side, the ceiling side, and the west side increase linearly with increasing the power of solar insolation, also accompanying these increase in surface temperatures, an increase in electric energy consumption is caused until sunset. Each temperature inside refer container keeps near 0 degrees C that is the preset temperature, but slightly increases with increasing of surface temperatures outside container. The electric energy consumption remains in high range between 7.8 kW and 8.8 kW. Thus the electric energy consumption is strongly associated with increase of surrounding temperature by solar insolation in order to keep the preset temperature of refer container.

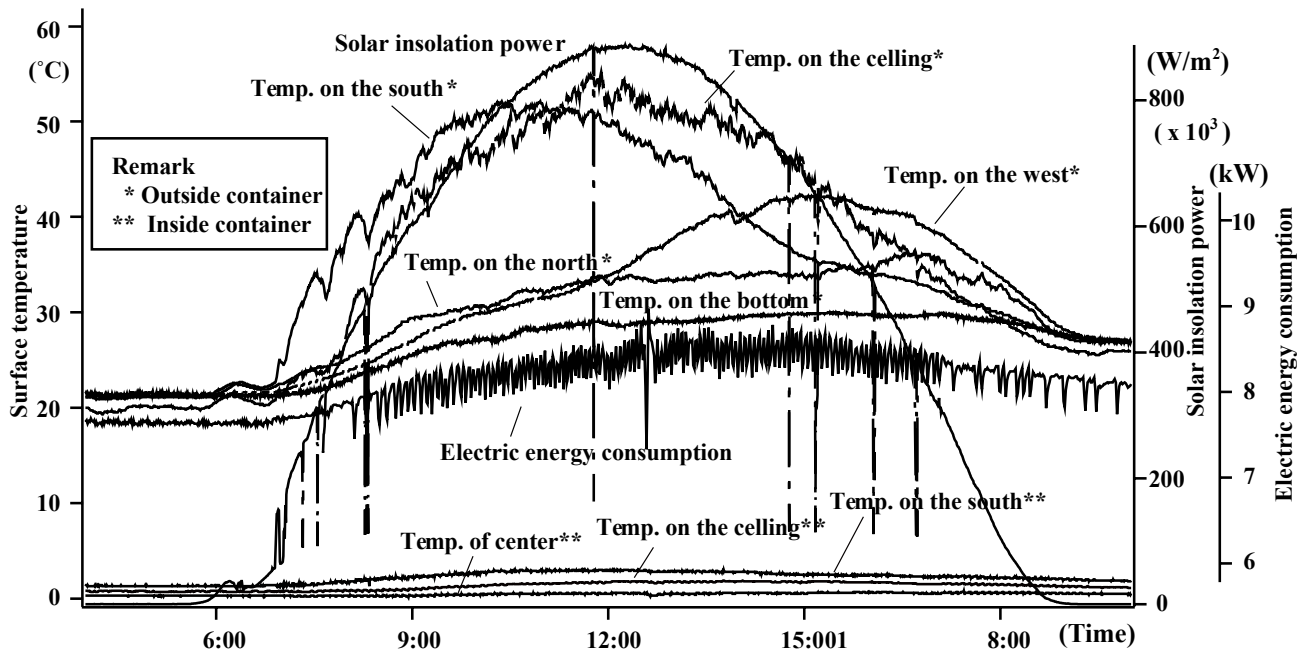


Fig 5. Results of measuring experimentation on the top of reefer container in the condition without roof shade during the day (on August 27th, 2013)

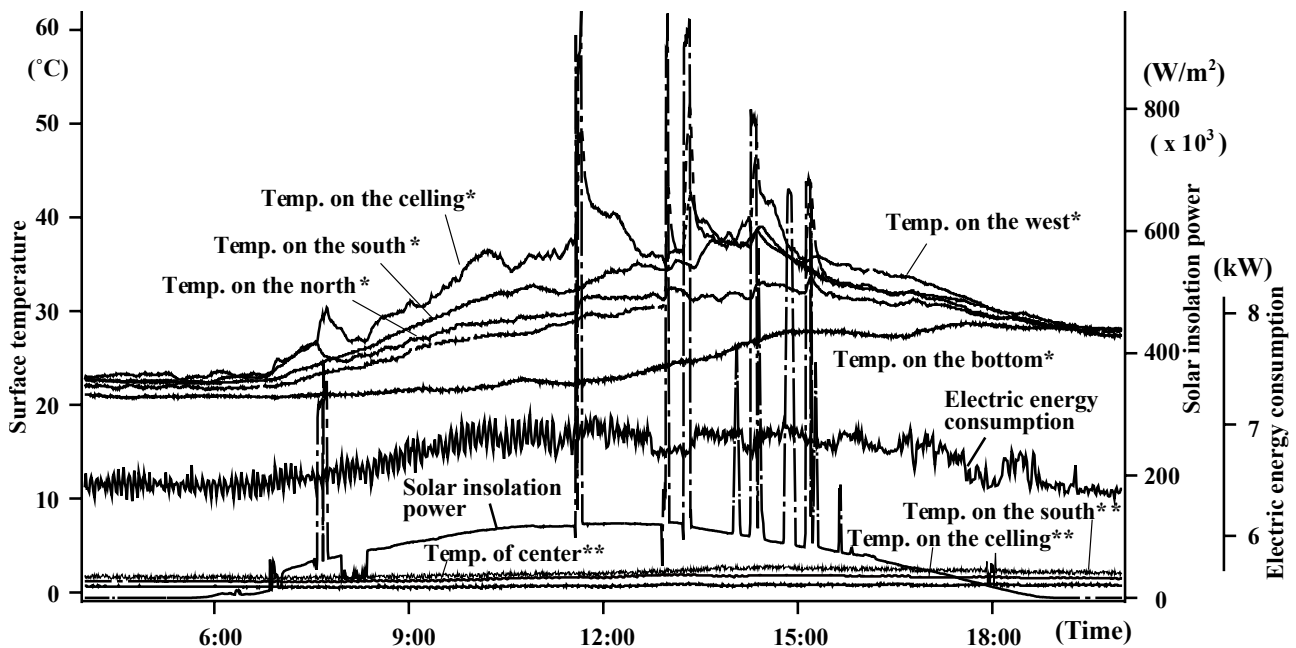


Fig 6. Results of measuring experimentation on the top of reefer container in the condition with roof shade during the day (on August 27th, 2013)

On the other hand, Figure 6 shows results of measuring experimentation on the top of reefer container when the experimental set of containers is stored in the same slot R4 with roof shade. Surface temperatures on each side increase not as much as temperature in the condition without roof shade, also the electric energy consumption remains in low range between 6.4 kW and 6.8 kW. Each temperature inside container remains equal to the preset temperature 0 degrees C. The electric energy consumption seems to keep the low level due to installation of roof shade.

Furthermore we investigate an influence of roof shade that acts to the vertical direction of reefer storage yard. Figure 7 shows change of surface temperatures outside container in the slot of R4 in the vertical direction and the measuring position is shown as table in the top of Figure 7(b). Even in the case without roof shade, temperatures indicate lower in located lower tier. Moreover in the case with roof shade, temperatures also indicate lower in located lower tier more, and the case with roof shade shows low more significantly than in the case without roof shade.

Thus, the roof shade over reefer container storage yard has resulted in the advantageous effect on electric energy-saving under strong solar insolation in summer.

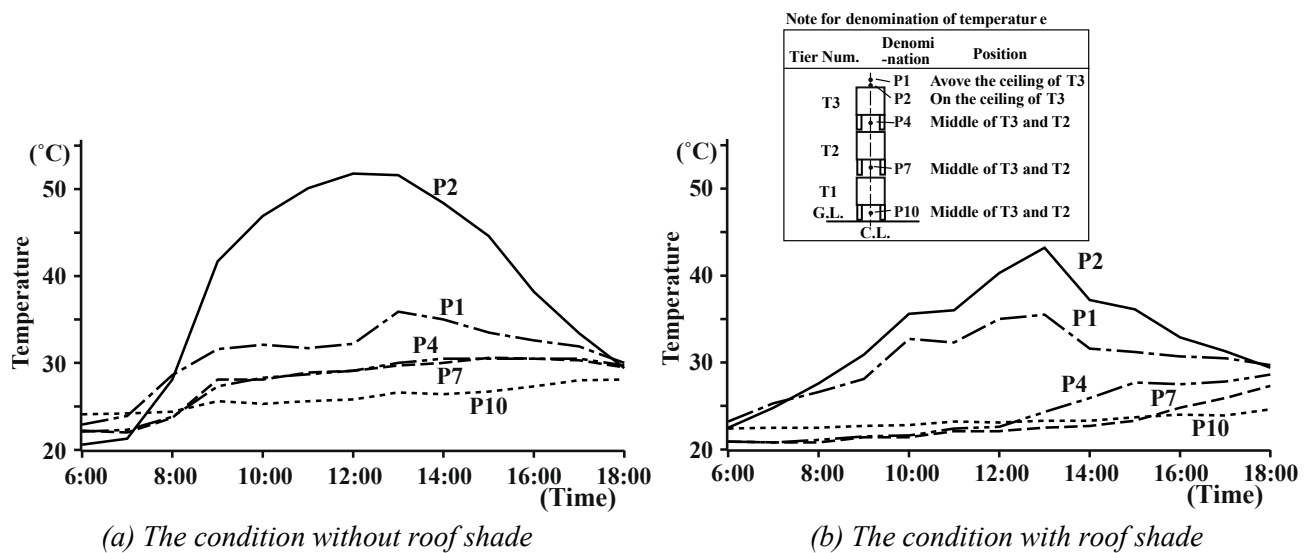


Fig 7. Change of temperature of vertical section on reefer container during the day (on August 27th, 2013)

Table 1: Evaluation for the effect of energy-saving on reefer shade

Date Slot	0818 R1	082 R4	0905 R8	Average of tier	Average of bay	Total difference of bay -12.76
H17T3	5.62	0.00	-5.05	0.07		
H17T2	-15.52	0.43	-4.74	-2.21		
H17T1	-11.38	-15.15	-19.27	-15.19	-5.78	
Average of slot	-7.09	-4.91	-9.69			
P39T3	2.29	-18.13	-23.45	-16.24		
P39T2	-17.13	-20.48	-23.83	-20.48		
P39T1	-17.89	-18.23	-23.85	-18.89	-18.54	
Average of slot	-10.91	-18.95	-23.71			

4. Evaluation for an Effect of the Roof Shade

In this chapter, we attempt to establish a quantitative evaluation method concerning an effect of the roof shade over reefer container storage yard. The benchmark for energy saving is defined as the following equation;

$$REC = (OEC - SEC) / SEC \times 100 \quad (1)$$

Here, value of *REC* represents the ratio of electric energy consumption and *OEC* represents the objective electric consumption. The value of *SEC* represents the base of electric consumption, and in this paper, this value is taken the electric consumption of reefer container located at the top and in the slot of R4 without reefer shade because R4 is middle of bay of container storage yard can be thought as representative position.

Table 1 shows the effect of roof shade comparing both electric energy consumptions in the case with roof shade and without roof shade. In the case without roof shade, the containers located at the top of this bay are exposed to solar insolation, and consume higher electric energy. Especially, the container located at the top of R1 consumes the highest energy of all containers because the containers in R1 have the south side and are also exposed to strong solar insolation in the morning. On the other hand, in the case with roof shade, a good effect on energy-saving are observed in all containers in this bay. Especially, good effect on energy-saving is observed in containers stored in the slot of R8 because all faces of container in R8 are hidden by a shade area. In comparison with difference of both averages of energy consumption in the case with roof shade and without roof shade, the expected electric energy-saving due to installing roof shade is 12%.

This result lead us to an expectation of a cost benefit for roof shade in operation using following equations.

$$CB = (Cb \cdot Ib + Cu \cdot Iu) \cdot Sr \quad (2)$$

$$Cb + Cu = 1.0 \quad (3)$$

Here, *CB* represents the ratio of cost benefit to electric power rate and *Sr* is the share of electric consumption on reefer container, *Cb* is the ratio of basic charge of electric power rate, and *Cu* is the ratio of usage charge. These *Cb* and *Cu* have the relations each other as shown in Eq.(3). Furthermore, *Ib* represents the impact of installation of roof shade for basic charge and *Iu* is the impact for usage charge.

The share of electric consumption on reefer container *Sr* is about 50 % of all electric consumption in this container terminal, and 12% of effect due to installing roof shade can reduce in day time of summer mainly. The impact of *Iu* is around 6% in summer. Furthermore, the basic charge of electric power rate in Japan is paid for the basis of the maximum of electric usage and *Cb* shares around 50% of total amount of electric power rate. Therefore, it can be roughly expected that the ratio of cost benefit to electric power rate *CB* is around 4.5%.

5. Conclusion

The measuring experimentation are created to clarify the effect of reducing electric energy consumption of reefer container due to installing the roof shade that covers the reefer container storage yard. In the container terminal where the measuring experimentation was carried out, 12% of the electric energy-saving due to installing the roof shade and 4.5% of the cost benefit can be expected quantitatively.

Acknowledgements

The authors would like to express our gratitude to crews of Hakata Port Terminal for collaborative experimentation and providing required data during this research and suggestion for future related research.

References

Hakata Port Terminal Co. Ltd., Introduction for HICCT, <http://www.hakatako-futo.co.jp/islandcity.html> (Retrieved March 10, 2014).

Development of Equipment for Ballast Water Treatment by Filtration Technology

Takeshi Shinoda

Department of Marine Systems Engineering, Kyushu University, Japan

Abstract

International Maritime Organization (IMO) adopted the International Convention for the Control and Management of Ships' Ballast Water and Sediments in 2004. This convention requires the strict standard for discharge of ballast water performance described as D-2 regulation, but many technical problems in developing ballast water management systems remain to be solved to keep the D-2 regulation. Most developed equipment for ballast water treatment are based on chemical treatment, but it could be feared that the chemical substances cause some marine environment risks due to residual chemical ones in the discharged ballast water. Our developed equipment for the ballast water treatment is based on filtration technology by the combination of spring filter and diatomite as physical treatment. We expect that this technology would become one of practical measures for environmental-friendly ballast water treatment without use of chemical ones.

Keywords: Ballast Water Treatment, Filtration Technology, International Convention on IMO, D2 regulation

1. Introduction

The ocean environmental problems about the contamination of marine life through ballast water exchanges has been reported from all over the world today since the 1980s. These problems were introduced into an important discussion at international conference on ballast water management for ship in IMO. After a long continuous discussion in the conference, IMO adopted the International Convention for the Control and Management of Ships' Ballast Water and Sediments in 2004.

This convention requires the strict standard as D-2 regulation for discharge of ballast water including the organism kind of aquatic phytoplankton and zooplankton which disturb the marine ecosystem in the site where ballast water is discharged. In addition, D-2 regulation restricts the discharge of harmful microbes such as pathogenic bacteria to keep human health safety.

Most developed equipment for ballast water treatment systems are based on chemical treatment, but it could be feared that the chemical substances cause harm to marine environment and marine ecological systems due to residual chemical ones in the discharged ballast water. Especially, there is a cause of concern over a large amount of discharge due to the current trend of large size vessel and this discharge into closed sea area such as a port.

Our developed equipment for the ballast water treatment is based on filtration technology by the combination of spring filter and diatomite as physical treatment. Diatomite has the capacity to remove bacteria because its shape is porosity glass and it can catch bacteria. Our developed equipment make use of the merits of diatomite. Developed equipment for experimental demonstration has been designed as treatment capability of amount of ballast water between 150 and 200 tons per hour. The experimental results show the reduction rate between 98% and 99% of all microbes in raw sea water and could have the possibility to satisfy the requirement of D-2 regulation. We expect that this technology would become one of practical measures for environmental and ecological friendly ballast water treatment without chemical ones.

2. Regulation concerning Ballast Water Management System and System examples

The restriction of discharge of ballast water in IMO convention is called as D-2 regulation, which is show summarily in Table 1 (International Maritime Organization 2004). The regulation about size of organism on D-2 is divided into three major categories. Here, the unit of “cfu” is abbreviation of the Colony Forming Unit on bacteriological examination by the culture method, and this unit is defined as the number of colony which microbes grow as forming on the laboratory dishes under the prescribed cultivate condition.

The values of this D-2 regulation are almost equal to the water quality of sea bathing in Japan, but actual raw sea water unexpectedly includes rich organism. According to our water survey on sea water, the number of organism per one milliliter in actual raw sea water contains about one million microbes, one thousand phytoplankton and one zooplankton (Shinoda T., et al. 2010a).

The largeness of organism in raw sea water comes variety in scale size from several tens micrometers of plankton to one micrometer of microbe, and also raw sea water contains large quantities of organisms. Furthermore, the different biological feature of organisms are remarkable variations with season and weather. So, many technical problems remain in developing ballast water management systems to keep the D-2 regulation. Furthermore, the severe regulation for discharged ballast water, which is called phase-two discharge regulation, is proposed by United States Coast Guard (USCG). This proposed regulation is thousandth part of D-2 regulation in IMO convention 2004.

There are additional two main guidelines for the approval of equipment for ballast water treatment system in IMO convention. These are shortly called as G8 and G9. G8 is guideline for procedure for type approval certificate of ballast water management systems in order to assess whether ballast water management systems comply with the standard in D-2 regulation of the ballast water convention. And to achieve general requirements of instrument concerning design and construction, this guideline includes the plan approval, the shipboard testing, the land-based testing and the environmental testing, and also includes the technical procedures for evaluation and issuance of the approval certificate for ballast water management systems (International Maritime Organization 2008a, 2008b).

On the other hand, G9 is guideline for approval procedure of ballast water management systems that make use of active substances such as chemical treatment, to comply with the ballast water convention concerning ship safety, human health and the aquatic environment. The equipment systems whether comply with the regulations are finally approved through the IMO Technical Group review.

Table 1. D-2 ballast water performance standard in IMO convention

Hazardous aquatic organism	Standard of discharge
Greater than 50 μm viable organisms (Zooplankton mainly)	Less than 10 ind. / m^3
10 μm ~ 50 μm viable organisms (Phytoplankton mainly)	Less than 10 ind. /mil.
Toxicogenic <i>Bibrio Cholerae</i> (O1 and O139)	Less than 1 cfu/100mil.
<i>Escherichia coli</i>	Less than 250 cfu/100mil.
Intestinal <i>Enterococci</i>	Less than 100 cfu/100mil.

(cfu: colony forming unit)

Table 2. Examples of developed equipment for ballast water management system

Equipment No.	Country	Method of treatment
#1	Sweden	Filter+Ultraviolet rays(UV) /oxidized titanium
#2	Norway	Filter+Deoxidation+Cavitation +Seawater electrolysis(SE)
#3	Germany	Filter+Hydroxy radical
#4	US	Chlorine dioxide
#5	US	Deoxidation
#6	Korea	Ozone
#7	Japan	Cavitation+Ozone
#8	Japan	Filter+Polymer coagulant
#9	Japan	Heat treatment

Table 2 shows examples of developed equipment for ballast water management systems (Fukuyo Y., Hisano K., et al. 2008). Many ballast water treatment systems are mainly taken some measures using active substances, such as chlorination, ozonizing, deoxidizing and so on. The way to supply these active substances is delivered from outboard where ship calls at a port, and the other way is production onboard by the ballast

water treatment systems itself. On the other hand, some systems to combine an active substance treatment system and a filtration treatment system as physical treatment have been developed. But, ballast water management system by pure filtration treatment remains to be developed. The filtration treatment has an advantage to remove a cyst in sediment which plankton change their formation to protect themselves against environment deterioration where they are in. Additionally, when filtration treatment can take only physical treatment for the ballast water management systems, it would be expected as an advantage that the official procedure for approval of equipment could be simplified thorough only G8 guideline. Therefore we challenge to develop the equipment for ballast water treatment using pure filtration treatment as physical treatment.

3. Development of Equipment of Filtration Treatment for Ballast Water Management System

3.1 Engineering Development of Equipment for Ballast Water Treatment

For reducing some marine environment risks, ballast water treatment system using filtration technology as physical treatment has been developed in our research laboratory. In order to practically prove the filtration treatment technology, the experimental equipment by filtration treatment is designed. Figure 1 shows the outline of experimental equipment by filtration treatment. The spring filter is made from stainless-steel (SUS316), 15 mm in diameter and 450 mm in length. This filter has coiled shape and has many gaps which keep the proper height of micrometers level using some bridges with wart-like projection. The 7 units of spring filter is installed to produce 1.4 ton/hour of treating capacity.

Figure 2 shows the pathway diagram for experimental equipment for ballast water treatment. This treatment system is composed of three main processes, the process of pre-coating, the process of ballast sea water treatment and the process of reverse cleaning of filter. Here, the arrows in this figure shows the direction of flow of water. The detail of process is described as follows. In the process of pre-coating, diatomite is pre-coated properly on the surface of spring filter by circulating water flow. Then the process of ballast sea water treatment are started and driven by the water flow from the bottom of water treatment vessel, this process continues until a predetermined high limitation of water pressure of the vessel or a predetermined low limitation of flow rate of treated water. This decrease in flow rate is caused by obstacle clogging in the surface of filters. At last, to prevent the filter from clogging and to keep the proper flow rate, reverse cleaning of filter is taken by water flow from the top of vessel in the process of reverse cleaning of filter.

The works of spring filter are featured as illustrated in Figure 3. In the process of water treatment, the direction of water flow to the surface of spring filter is from outside of filter, and the compression force works to the filter, so the spring filter keeps the constant gaps. When the clogging is taken place in the filter, the water flow into filter switches the flow from inside of filter and the expansion force works to the filter, so the gaps of spring expands and the clogging by plankton and sediment are removed from the surface and the gap spacing of filter.

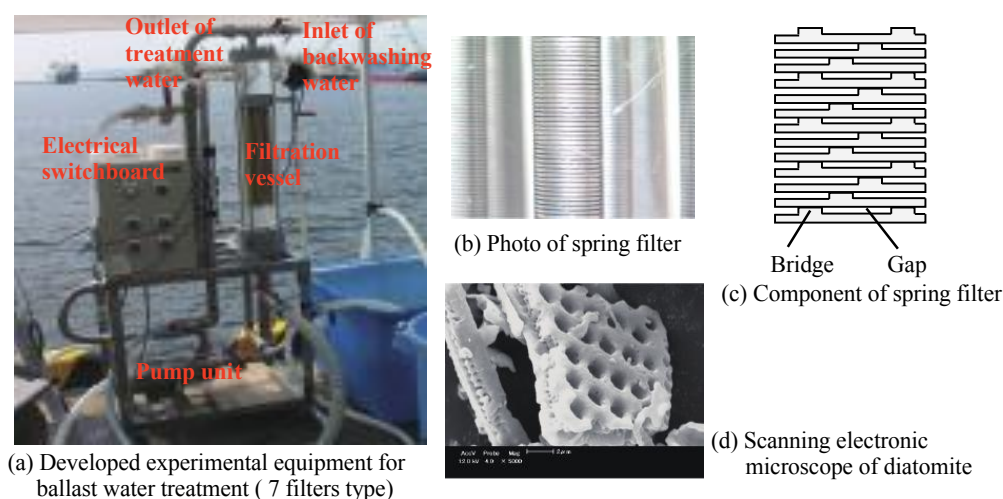


Fig 1. Outline of introduce experimental equipment by filtration treatment

We have been trying to check the effectiveness of experimental equipment with considering many experimentations for many kinds of sea water condition, depend on differences of saline concentration, contained amount of plankton, contained amount of suspended solid (SS) and so on. These conditions of sea water for experimentation are planed on the assumption of land-base test that is described in approval guideline of G8 ANNEX 4 (International Maritime Organization 2008a). Especially amount of SS is the most important factor to keep the proper flow rate on filtration equipment. We make an improvement of flow control to avoid the clogging problem by SS.

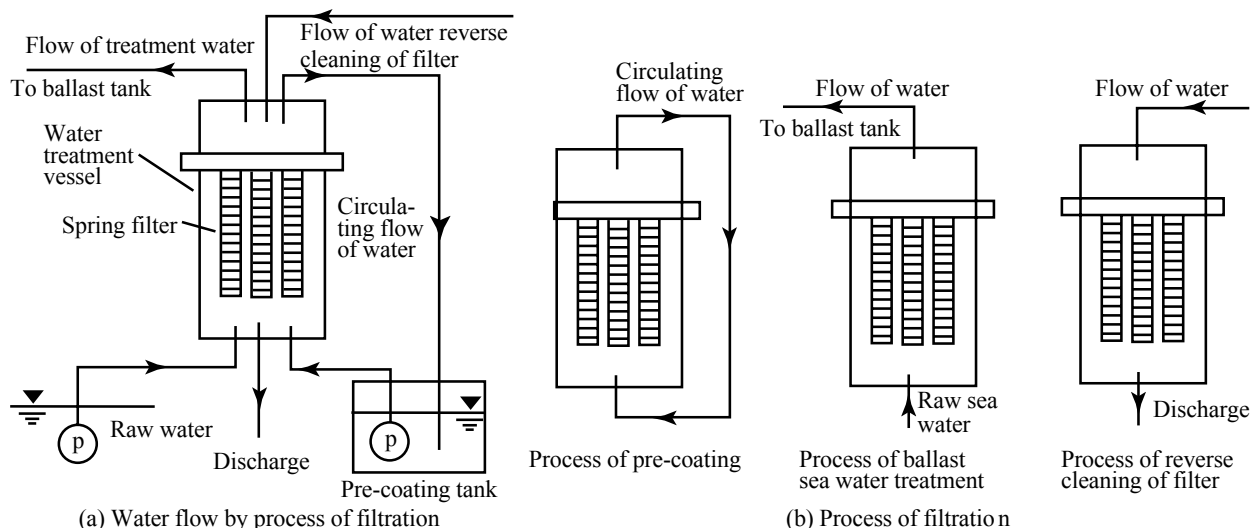


Fig 2. Pathway diagram for experimental equipment

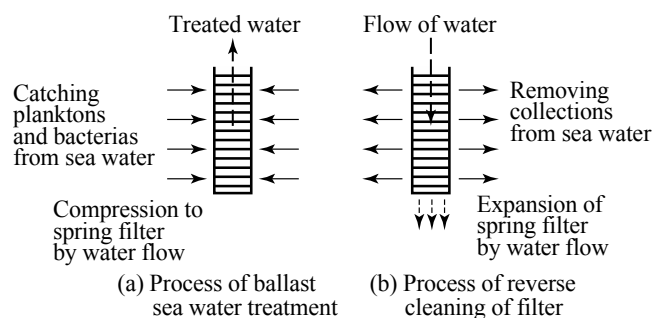


Fig 3. Feature of spring filter works

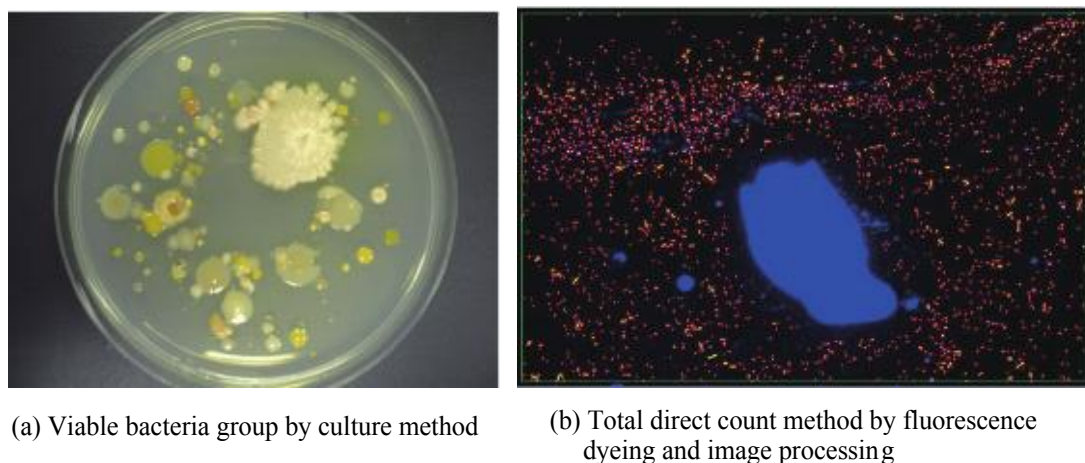


Fig 4. Comparison of methodology of microbial enumeration technique

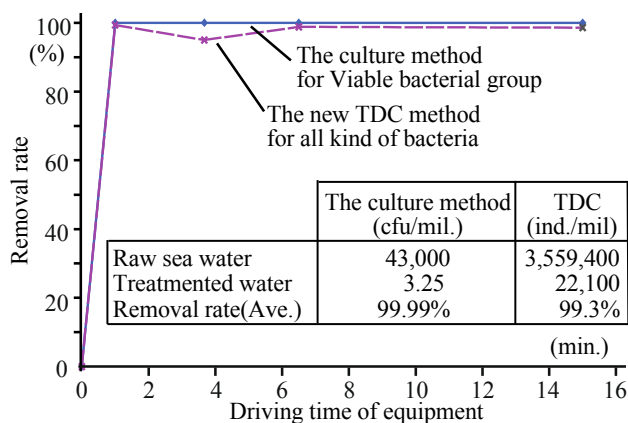


Fig 5. Removal rate compared the culture method with the new TDC method

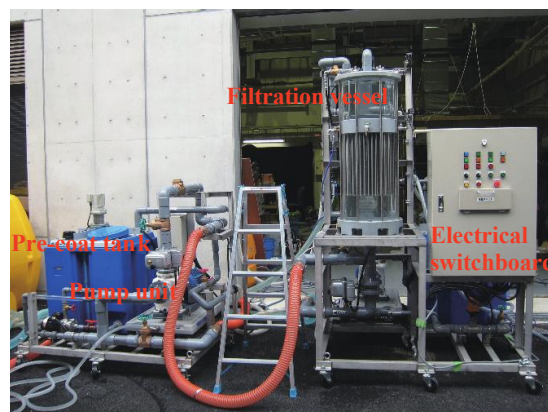
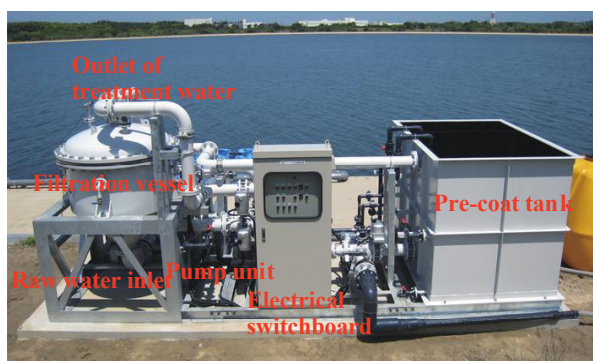


Fig 6. Developed ballast treatment equipment (100 filters type)



(a) Outline of developed equipment



(b) Flange with its suspended spring filter

Fig 7. Developed ballast treatment equipment (700 filters type)

3.2 Improvement for Indication of evaluation for filtration treatment ability

It takes a good amount of time and much cost to confirm the effectiveness of experimentation by an ordinary cultural method that evaluate the filtration treatment counting total bacteria and is shown in Figure 4(a). This method has interfering problems for promoting the development by experimentation, so we consider to take an alternative method such as the method of total direct counts (TDC). The TDC is a methodology of count of total bacteria in the sample sea water including viable bacteria, viable but non-culturable (VNC) bacteria and killed bacteria. This TDC is based on technologies of the fluorescence dyeing of bacterial cell nucleus and counting them by the image processing as shown in Figure 4(b). Total bacteria content by TDC is around one million individuals per milliliter, also it is almost nearly constant in raw sea water. In addition, this methodology dramatically reduces the time to count bacteria within 15 minutes and provides cost saving for bacteriological testing. Our research laboratory has introduced the TDC apparatus to measure the ability of filtration treatment for the developed experimental equipment instead of the cultural method after comparative check the TDC method with the cultural method.

Figure 5 shows the comparison between the cultural method for Viable bacterial group and the new methodology of TDC for all kinds of bacteria as the removal rate in the time of before and after treatment to raw sea water. In case of the culture method, raw sea water including 43,000 cfu/mil. of Viable bacteria changes to 3.25 cfu/mil. in the treated water average, and this method shows 99.99% of the removal rate by filtration. On the other hand, in case of the new methodology of TDC by “bioplorer” which is manufactured by Panasonic Corporation, raw sea water including 3,559,400 individuals/mil. of Viable bacteria changes to 22,100 ind./mil. in the treated water average, and this TDC method shows 99.3% of the removal rate by

filtration. Through these experimental results, the ability of filtration equipment would be evaluated by the removal rate of bacteria with TDC in our research.

Our developed equipment by filtration could remove between 98% and 99% of total bacteria from raw sea water. This removal rate between 98% and 99% shows that when some kinds of sea water richly contain about 12,500-25,000 cfu/100 mil. of *Escherichia coli* bacterium, which could be a rare case, the successful treated water by the developed equipment would be expected to satisfy D-2 regulation 250 cfu/mil. And we also expect that the developed equipment would have a possibility for ballast water treatment.

3.3 *Scale up experimental equipment and further improvement*

More large scale of experimental equipment for ballast water treatment has been developed for the aim at actual equipment. First, the experimental equipment, which 100 units of spring filters are installed in treatment vessel shown in Figure 6, was designed on treatment capacity around 30 ton/hour (Shinoda T., et al. 2010b). Then, on the basis of experimental result on 100 units equipment, more large experimental equipment was designed on treatment capacity around 200 ton/hour as shown in Figure 7(a). This experimental equipment has 700 units of spring filters that are installed in suspended flange shown in Figure 7(b). Experimentation for both experimental equipment are carried out using actual sea water. The experimental results are that both equipment can meet the designed treatment capacity, also can achieve the removal rate between 98% and 99% of total bacteria in raw sea water.

Furthermore, our developed filter treatment system is arranged vertically, but it is sometimes difficult to be arranged vertically because of the restriction of height at the installation site such as ship's onboard. It is needed to be free to arrange the filtration unit such as horizontal arrangement. Therefore we are challenging new horizontal arrangement on filtration unit.

4. **Conclusion**

There are still many technical challenges on ballast water treatment system in order to treat properly ballast water with keeping strict D-2 regulation in IMO convention and environmental and ecological friendly, and even more challenges to treat enormous ballast water in short time. On the other hand, shipping companies and ship yards desire more cost effective treatment equipment, also it is needed to develop new innovative equipment continuously. In this stringent circumstances, our developed equipment for ballast water treatment by filtration is introduced. We expect that developed filtration technology would have an advantage to environmental and ecology friendly technology due to applying only physical treatment.

References

- Fukuyo Y. and Hisano K., et al. (2008), Trends of Ballast Water Regulations and Development of Ballast Water Treatment System, NTS 23-26.
- International Maritime Organization (2004), International Convention for the Control and Management of Ship's Ballast water and Sediment, International conference on BWM for ship Agenda item 8.
- International Maritime Organization (2008a), Annex 4 Guideline for approval of ballast water management systems (G8), Resolution MEPC 174 (58).
- International Maritime Organization (2008b), Procedure for approval of ballast water management systems that make use of active substances (G9), Resolution MEPC 169(57).
- Shinoda T., Uozumi J. and Mononobe S. (2010a), Development of Filtration Treatment Equipment for Ballast Water Management on IMO, Proceeding of the Japan Society of Naval Architects and Ocean Engineers 30-31.
- Shinoda T., Uozumi J. and Mononobe S. (2010b), Development of Equipment of Filtration Treatment using Spring Filter for Ballast Water Management, Proceeding of the Japan Society of Naval Architects and Ocean Engineers 343-344.

Container Seaports Connectivity: A “Concept” Analysis

P. Paflioti¹, T.K. Vitsounis², I. Tsamourgelis¹ and M.G.H. Bell³

¹Department of Shipping, Trade and Transport, University of the Aegean, Chios, Greece

²¹Department of Infrastructure, Transport and Logistics, National ICT Australia, Sydney, NSW, Australia

³Institute of Transport and Logistic studies (ITLS), Business school, University of Sydney, Sydney, NSW, Australia

Abstract

Ports stand as connection nodes of the global shipping transportation network and have become increasingly important in economic, social and demographic reasons. Seaports networks constitute the operational backbone of maritime trade and in extent of the contemporary globalized economy. Measuring their attractiveness as nodes in terms of connectivity has become a matter of crucial importance for managers and policy makers. The concept of connectivity is well-documented in the social network literature and to some extent, transportation engineering literature. The measurement of a port's connectivity is challenging especially, as it cannot be observed directly through published statistics. Previous attempts to define port connectivity are based on different techniques; from ad hoc metrics to concentration methods and more recently to more complex network models.

Whereas all these methods give some measures of connectivity, identifying a ports' relative position, they are subject to specific limitations, omitting important characteristics of the liner shipping network (e.g. hub and spoke system) and thus concluding to misspecified results. Furthermore, due to the complexity of the network theory metrics and high data requirements, previous attempts also generally provide connectivity scores for a single year, without sufficient information to examine how a port's location is changing over time. The present paper aims to accentuate the importance to measure a port's relative position in the maritime network through an extensive analysis of what has been done until now. Underscoring and analyzing the limitations of previous studies, it redefines a port's connectivity through a gravity-based approach.

Keywords: container seaports, connectivity, liner shipping, gravity model

1. Introduction

The growing interconnectness of production processes has been one of the most important changes in the nature of international trade over the last decades. This argument affirms the concept of vertical specialization in production chains, with each country or economy specializing in particular stages of goods' production processes (Feenstra 1998; Hummels et al., 2001; Miroudot et al., 2012). The economy and trade progress of a country depends upon the nature and pattern of its transport connectivity. A good transportation network with greater accessibility and connectivity promotes the smooth flow of commodities from production/supply areas to consumption/demand areas. The contemporary globalized economic environment goes hand in hand with the extensive use and the exploitation of liner shipping advantages (Levinson, 2006; Krugman, 2009b). Intermediate goods move faster to manufacturers and final goods reach customers safely and securely creating links between regional and global economies.

Liner shipping remains the most dynamic sector of maritime transportation. From 1985-2010 total international maritime trade volumes grew with an average rate of 3.3% per annum, while containerized trade grew at an impressive 8.8% (UNESCAP, 2011a)ⁱ. Containerized trade has been the fastest-growing market segment accounting for over 16% of global seaborne trade by volume in 2012 and at about half by value (UNCTAD, 2013). Containerization is closely associated with globalization and the fragmentation of global production, thus its contribution in the development of the global supply chains remains extremely significant. Empirical evidence show that containerization is the driver of the twentieth century's economic globalization

explaining an average increase of between 75% and 100% in bilateral trade flows (Bernhofen et al., 2013).

In this context, ports –the gateway through which maritime trade exists- should act as an integral part of a chain of transport linkages designed to move cargoes from origin to destination. Ports are regarded as economic units providing a service as nodes between various transportation modes, or as facilities enabling the flow of cargoes, or as a part of logistics and supply chains (Cullinane and Talley, 2006). However, and despite their role in the worldwide distribution of goods, seaports have not received much attention as central nodes of the supply chains. “Being an interface linking sea and land transport, a port is an integral platform serving as a base for production, trading, logistics and information transfer [...] the performance of a port will have a direct impact on the competitive advantage of its user and affect the economic development of both the origin and destination hinterlands” (Lam and Yap, 2011:1).

In the present study, our focus is on ports’ role as nodes in the liner-shipping network. We examine their characteristics as connecting links between transport modes of the global logistics chain making them vital for the efficiency of the whole maritime transportation system. We undertake a detailed literature review on maritime and ports connectivity and turn our focus specifically on the relative position of container ports within the liner-shipping network. The review is conducted to identify the characteristics of the existing ports connectivity measures, to identify potential research gaps and further research needs. Finally, we put forward an alternative framework for assessing container ports connectivity taking into consideration the foreland connections, the structural and qualitative characteristics of ports and the relative intermodal network.

The remainder of the paper is organized as follows: In section 2 the importance of container ports connectivity is presented. In Section 3, an assessment of the current state of connectivity measures of ports is analyzed, identifying probable gaps and limitations of previous research. Section 4 defines the alternative concept of container port connectivity and the probable limitations of such a study. Finally, concluding remarks will be presented and suggestions for further research are proposed.

2. Setting the Scene: The Importance of Connectivity

The *new economic geography* is a discipline developed since the late 70s-early 80s and allows *-inter-alia-* to interpret patterns of intra-industry trade while suggests that “the location of production factors and economic activity can be stringently analyzed within the framework of a general equilibrium model” (RSAS, 2008:5). It also gave rise to fundamental theories such as the home-market effect, the core-periphery model, the agglomeration theory (Krugman, 1979; 1991) and ultimately the new trade theory. The latter is described by Krugman (2009a) as follows: “Increasing returns provide an incentive to concentrate production of any one product in a single location; given this incentive to concentrate, transport costs are minimized by choosing a location close to the largest market, and this location then exports to other markets.”

The new economic geography theory is “to date the only theory within mainstream economics that takes the economics of location seriously” (Brakman and Garretsen, 2003: 638). But what is exactly this “location”? The dramatic decrease of transport costs -since the early 90s- allowed the displacement of “locations” at points easily accessible by producers, offering advantages in reaching the largest-target markets. In this setting, stakeholders of a transport operation are not only interested about the total transportation cost, but place extra emphasis on the total transit time and in general the “ease” of reaching multiple destinations. Here the term “ease” refers to a combination of total cost and transit time affected by the frequency and number of alternative services, alternative means of transport available, direct calls to destinations etc. Connectivity focuses on outcomes related to interactions in a network and provides strong indications on the “ease” of reaching multiple destinations. Naturally, a node’s connectivity becomes a critical measure capable to complement transportation cost and derive more meaningful and valid conclusions in various respects: from the competitiveness of spatial nodes (countries, regions, municipalities but also ports, airports etc.) and local businesses, to the attractiveness of establishing a business and/or production unit and the attraction of foreign direct investments. In short, connectivity allows redefining and interpreting “locations” more accurately.

With the emergence of globalization, the economic integration became a priority for every sovereign country. Production processes are becoming gradually more interconnected and give rise to vertical specialization of

production chains with each country or economy specializing in particular stages of the production process (Feenstra, 1998; Hummels et al., 2001), stimulating intra-industry trade. Today, an economy has to be highly interdependent by and part of the globalized economic environment. Industries' should be well connected with international markets to compete successfully. On the output side, greater connectivity enhances access to international markets and intensifies the competitiveness of exports. On the input side, greater connectivity allows the local industrial sector to attract and develop skilled labor and capital investments. Within this framework, improved connectivity, especially through transport links, is an essential condition for economic growth and trade (Hoffmann and Kumar, 2002), enhances market access and promotes the smooth flow of commodities from the production areas to consumption areas.

Connectivity also affects investment decisions of foreign and domestic firms. Businesses are more likely to consolidate their activities (with the typical example here being their head offices and the production units) in places well connected both internationally and domestically. Agglomeration benefits (Krugman, 1991) generated by the co-location of firms and industries are more likely to rise in areas (countries and regions) with well-connected transportation systems. To rephrase, given that hub ports develop due to their self-reinforcing agglomeration economies, their very presence generates lock-in effects for individual agents, which find it difficult to relocate, while attracts new agents (Fujita and Mori, 1996). As a result, a port in a peripheral region is likely to attract second-order activities (e.g. manufacturing) while higher-order activities remain concentrated in the core region (ibid).

In this setting, container trade has been a catalyst towards globalization and thus deserves further attention. The movement of goods became more standardized and rapid, transportation costs decreased substantially while the formation of a global network of liner shipping services resulted in the systematic connectivity of container ports. Containerization contributed to the development of the global supply chain production system and the global liner-shipping network, whereby every port can be linked to every other one. Within such a framework, ports have a direct effect on a country's and businesses position within the globalized economic environment. Ports are essential elements of contemporary transportation systems and supply chains (Robinson, 2002), and stand as nodes linking the three dominant means of transport (shipping, road and rail), and maritime with land networks (Weigend, 1958; Vigarie, 1968).

On the port side, connectivity is also expected to stimulate investment, technological advances, skilled labour and in general improve labour market conditions. Notably, technological advances in shipping and ports allow a node to operate under increasing returns and thus to attract more trade that in its turn, generates greater scale of production and stimulates further investment.

In short, container ports are essential elements of competitiveness within the contemporary globalized economic environment and thus of extreme importance for policy makers. Their relative position and connectivity, is subject to the 'port triptych' where hinterland, port and foreland act as essential and interdependent components (Vigarie, 1979; Ducruet and Zaidi, 2012). National and supranational authorities should monitor the ability of ports to act satisfactory as the bidding point between the foreland and the hinterland. They should also act pro-actively to ensure that ports are not the bottlenecks of supply chains but equipped with sufficient tools (from superstructures and infrastructures to free trade agreements, customs procedures etc.) enhancing their connectivity with the main global transportation networks.

The fundamental objective of container seaports is to facilitate trade flows from the hinterland to the foreland -and *vice versa*- and as such they are parts of greater network constellations. In other words, ports should be equipped with sufficient network connections to both ends (foreland and hinterland) while their internal characteristics as nodes of the wider network are equally important. In this context, the assessment of container ports connectivity refers to a "before the border" analysis but highly affected by the 'push' and 'pull' effects exerted from "at" and "beyond the border" (figure 1). In any case, efforts to measure and quantify container ports connectivity are largely absent.

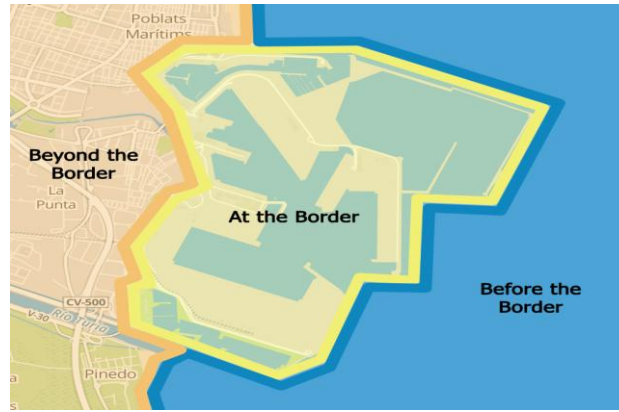


Fig 1. “Before” “At” and “Beyond” the border Analysis

3. Maritime Connectivity: A literature Review

Seaports can be categorized broadly into (a) gateway and/or (b) transshipment ports. Focusing on the gateway ports, their primary role is to connect the seaside with the foreland and the landside with the hinterland. When it comes to transshipment ports, the emphasis is on their role as hubs connecting the various maritime routes and spokes. For transshipment ports the importance of hinterland connections is declining and emphasis is on their location and efficiency.

In both cases, the fundamental objective of a seaport is to facilitate trade flows and its importance within the shipping network depends on the extent and efficiency of its hinterland connectionsⁱⁱ, the potential to attract freight flows (Wegend, 1958; Yeo et al., 2008) and its distance from main navigational routes relative to the efficiency and effectiveness of services offered.

The special position of ports at the intersection of foreland and hinterland gives rise to the concept of “inter-connectivity”ⁱⁱⁱ (Rietveld, 1995), defined as an element of spatial systems. In extent, “the development of a port depends on the connectivity between the existing transport networks of the regions, which leads to good infrastructure facilities” (Rietveld, 1997: 177-178). The relative position of a port and thus its connectivity is subject to the port triptych where hinterland, port and foreland act as essential and interdependent components (Vigarie, 1979; Ducruet and Zaidi, 2012).

A literature review reveals that efforts to define ports’ characteristics from a network perspective gather steam especially during the last five years. However, a proper definition and quantification of ports connectivity is still largely missing. A container ports connectivity indicator should capture its (cap)ability to “push” and “pull” flows from the foreland to the hinterland and vice versa, while ports characteristics are also crucial (and complement the foreland-port-hinterland triptych). Notwithstanding, there are numerous studies examining and quantifying either the foreland, or the hinterland or the ports characteristics but to the best of our knowledge there are no efforts to combine all of them in a single indicator.

3.1 Foreland Connectivity

Foreland connectivity has been extensively studied in the maritime literature with the majority of efforts concentrating on the use of connectivity measures as determinants of trade costs^{iv} (table 1). However, none of these efforts develops a stand-alone connectivity indicator.

Table 1. Connectivity Components and Transport Costs

Author	Connectivity Measure	Effects
Wilmsmeier at al. (2006)	Port connectivity: the monthly frequency of direct liner services between the ports of country i and country j <i>Sample:</i> trade costs in 16 Latin American Countries	Increasing the frequency of liner services between a pair of ports by 1 per cent leads to a reduction of freight by 0.113%

Wilmsmeier and Hoffmann (2008)	Principal Component Analysis: composed of the number of carriers, level of deployed TEU, number of vessels, vessel sizes, number of shipping possibilities and the number of services <i>Sample:</i> freight rates in the Caribbean Basin	An increase of connectivity by 1 standard deviation, decreases freight rates by 287USD.
Wilmsmeier and Sanchez (2009)	Transshipment Connectivity Index: measures the centrality of a country within the global shipping network taking transshipment requirements into account. <i>Sample:</i> food prices for South American imports	If a country can ‘double’ its centrality in the network, meaning a significant increase in direct liner services to a wider range of countries, transport costs can decrease up to 15.4%.
Wilmsmeier and Martinez-Zarzoso (2010)	Liner shipping network structure (LSNS) between origin and destination <i>Sample:</i> transport costs for intra-Latin America trade	The results indicate a significant effect of the liner service network structure (LSNS) on transport costs. The more centrally a trade route is located in the maritime liner service network the lower the average transport costs.
Marquez-Ramos et al. (2011)	Principal Component Analysis: maritime route structure, characteristics of ships deployed, structure of liner services. <i>Sample:</i> all Spanish exports to 17 countries	The explanatory power of the transport cost model increases when connectivity and service quality measures are included in the model with the expected negative sign.

The Liner Shipping Connectivity Index (LSCI)^v (UNCTAD, 2006) quantifies the connectivity of the liner shipping sector and is generated from five components, namely: (a) the number of ships; (b) the container-carrying capacity of those ships; (c) the maximum vessel size; (d) the number of services; and (e) the number of companies that deploy containerships on services from and to a country’s ports. The LSCI “adopts an intuitive but ad hoc approach to developing a connectivity indicator for liner shipping” (Arvis and Shepherd, 2011: 2) and does not take into account the hub and spoke nature of the liner shipping industry. Thus it is hard to identify the role of attractiveness - repulsiveness and the structural characteristics of the ports. Another significant limitation of the indicator is that larger nodes appear to be better connected (size-bias) and thus it is not considered as “a global metric rooted in network modeling” (ibid: 55).

The LSCI has been constructed on a country level and is benefited by the fact that the majority of economic indicators are also on a country level, thus making any comparisons and interpretation of results easier. Notwithstanding, liner services in reality are connected with ports and not countries and a further disaggregation at a port level would be more adequate and more reliable. This stands true especially for developed (with extended hinterland links) or big in size countries whose trade is facilitated by more than one major ports. For most developing countries however (where UNCTAD is mainly interested in) freight is usually transported through a single port and thus the LSCI fulfills its objectives. In any case, the LSCI is found to be important determinant of freight rates, port competitiveness or attractiveness (UN ESCAP, 2011b).

Another stream of research that gained attention only recently aims to interpret maritime foreland through network modeling. Transportation networks in general describe the form of connecting terminals by links operated with transport vehicles. In the case of maritime industry, networks refer to the services conducted between the nodes; that is ports.

Transportation networks may be studied by identifying the “centralities”, which represent the more critical nodes having a major impact to the network operations as a whole (for a review see: Ducruet and Lugo, 2013). Network centrality is a concept introduced in social science to analyze important nodes in social networks (Landherr et al., 2010). The typical network centrality measures include the following: degree centrality, closeness centrality, betweenness centrality (Freeman, 1979) and eigenvector centrality. Notably, most of the centrality measures are based on the assumption that information spreads only through shortest paths, which is

regarded unrealistic (Newman, 2005). At the same time, many networks are intrinsically weighted and edge weights contain many useful information. Therefore, researchers redirected their focus towards weighted networks (Opsal et al, 2010).

In the maritime literature, efforts to study the relative location of ports through network analysis is limited due to the lack of detailed data on inter-port activity and the difficulty to define and detect the spatial structure of such networks (Ducruet et al., 2010b). Angeloudis et al. (2006) and Bichou (2004) examine connectivity in the context of maritime security. Network modeling approach is also used to study container shipping operations (Gelareh et al., 2011; Meng and Wang, 2011), the geographic coverage of carriers' networks (Bergantino and Veenstra, 2002; Fremont, 2007) and inter-firm competition (Caschili and Medda, 2011).

A number of studies identifies the 'centrality' of ports within the network modeling and focuses on worldwide container movements (Wei et al., 2008; Deng et al., 2009; Hu and Zhu, 2009; Ducruet and Notteboom, 2010), while others proceed to a comparative analysis between air and sea transport (Meza et al., 2011) or between different types of sea cargo (Kaluza et al., 2010; Montes et al., 2012) identifying probable similarities and differences. The channel of network analysis examines the sub-networks of the container shipping industry and practical applications are usually on a regional level such as the Caribbean basin (McCalla et al. 2005) the Mediterranean (Cisic et al., 2007) and the Atlantic (Helmich et al., 1994; Ducruet et al., 2010a). An increased number of researchers focus on the examination of the relative position of Asian ports (Low et al., 2009; Ducruet et al., 2009; Ducruet et al., 2010b; Cullinane and Wang, 2012; Lam and Yap, 2011; Wang and Wang, 2011). This comes natural due to their ability to attract the majority of liner shipping services on a global scale. While the most of the aforementioned studies focus on the topological characteristics of the maritime system, others proceed to a more integrated approach comparing the properties of maritime structure with the small-world^{vi} and scale-free networks^{vii} (Kaluza et al., 2010; Deng et al., 2009; Wei et al., 2008).

3.1.1 Limitations

The aforementioned studies accentuate the importance of the topological structure of the maritime network and examine their "proximity" from different aspects. Nevertheless, they present some limitations and drawbacks that need to be considered for future research analysis.

The first point of interest in identifying the accessibility of a maritime node (port) and thus its connectivity is the selection of adequate measures. Network modeling concentrates on centrality measures, but their importance in identifying the relative position of a node in a network is characterized by some weaknesses, presented in brief as follows.

The *degree centrality* determines the number of direct connections but does not take into account indirect connections. It argues that nodes with an increased number of connections are more likely to be powerful because they affect directly more actors. On the other hand, Bonacich (1972) argued that a node's power is determined not only by the number of its direct connections but also by the connections of its neighbors. The degree centrality is a local measure, because it depends only on the number of the neighbors in a vertex (Koschutzki et al. 2005) and does not incorporate information for the structure of the network as a whole.

Closeness centrality is used to overcome the limitations of the degree centrality. It is based on the idea that nodes with a short distance to other nodes can spread information more efficiently through the network (Beauchamp, 1965). A main limitation however, is the lack of its applicability to networks with disconnected components (Opsal et al., 2010). Moreover, "the concept of separation distance is topological; it imperfectly emulates real distance, time, or some other bilateral cost that is an important determinant of activity in real-life economic networks" (Arvis and Shepherd, 2011: 60). In the maritime network modeling, geographical proximity and regional integration still plays a crucial role as most traffic occurs between relatively short distances (Ducruet and Notteboom, 2010), but the number of long-distance links (i.e. trans-Pacific, trans-Atlantic and Europe to Asia trading relations) is gradually increasing as a result of globalization and technological progress^{viii}.

Betweenness centrality measures the number of shortest paths from all vertices to all others that pass through

the focal node^{ix}. It can be applied to networks with disconnected components and takes into account the global network structure. The limitations of the betweenness centrality are associated with its instable performance in dynamic networks (like the maritime network), because the removal of a node induces significant perturbations (Koschutski et al. 2005). At the same time, a great proportion of nodes in a network generally does not lie on the shortest path between any two other nodes, and therefore receives the same score of 0 (Opsal et al., 2010).

Eigenvector centrality measures the extent that a node influences the whole network. It accepts that a more interconnected node contributes to the centrality of another node more than a less interconnected one. Eigenvector centrality is a very attractive measure for maritime connectivity (Cullinane and Wang, 2006), but “there is no easy way to adapt the model to produce non-trivial results for an approximately symmetric flow matrix” (Arvis and Shepherd, 2011: 60), which is exactly the case for maritime slot capacity or the number of ships between two points.

A fundamental measure that has long received attention in both theoretical and empirical research is the *clustering*. It assesses the degree to which nodes tend to cluster together. Clustering remains a measure of local connectivity and the degree of belonging to a local cluster. A hub will tend to exhibit local clustering, but so does an isolated node bridging between clusters (Arvis and Shepherd, 2011). Clustering may also be used to model cases where ports enter to privileged trade relations as a consequence of agreements between their holding companies that are also active ship owners (typical examples are the shipping lines Cosco Pacific, Maersk, MSC, CMA-CGM etc. owning parts of or operating directly container terminals).

The second point of interest generating significant limitations, relates with the analysis of the maritime transportation network as a theoretical mathematics problem. The competitive forces within the maritime industry -which in much shape the overall structure of the network and the connectivity of the nodes- are often neglected and researchers focus mainly on the relation of port throughput with the centrality indicators (Deng et al., 2009; Ducruet et al., 2009; Ducruet et al., 2010a; 2010b; Montes et al., 2012). The argument in this case is that the growth of a container’s port traffic is driven mainly by its ability to be a catchment area for cargoes and provide adequate services to the shipping lines. Ports fulfilling these criteria will attract shipping lines and ultimately increase their freight volumes (Ding and Teo, 2009). However, this relation actually suggests that centrality is proportionally correlated with port throughput, which may not be the case in real life (Ducruet et al., 2010b). Therefore, the development of indicators -to complement or even increase the validity of the centrality measures- able to capture the competitive forces of the maritime network is highly suggested. In the same vein, an effective method or tool to evaluate the maritime hub-and-spoke system and/or to measure the extent that shipping lines affect the structure of the global maritime network (Wang and Wang, 2011) is also greatly missing from the literature.

The complexity of the network theory metrics in combination with substantial data requirements, limit most research efforts to the provision of connectivity scores for a limited period of time (one or two years or even months) (Montes et al., 2012). Examining the evolvement of connectivity over time through systematic and regular measurements, is highly recommended especially as “the structure of liner shipping networks evolves over time. As a consequence, the position of ports as nodes in the network also changes over time. Understanding these changes is crucial for analyzing the competitive position and growth prospects of container ports” (de Langen et al., 2002: 1).

Moreover, the network structure of liner shipping is usually examined with the assessment of a sample limited to a single month under the assumption that “liner services are relatively constant throughout the year despite seasonal effects” (Ducruet et al., 2009: 4). Indeed, routes do not change much over a year but are subject of “slack” and “peak” periods season services with consortia trying to contract or expand their capacity relative to the cargo volumes. In general the liner shipping market is relatively dynamic and throughout a year both vessel partners and consortia are subject to changes given the market conditions. Temporary capacity adjustments during a single year are further confirmed by Drewry as “the frequency of cancellations usually spiking in months when the supply-demand equation was expected to tip against carriers” (Drewry, 2014: 10). Therefore, taking into account the frequency of liner shipping services provided on a yearly basis, contributes to the generation of more accurate results in regards to the relative position of ports within the maritime

networks (Cullinane and Wang, 2009; Lam and Yap, 2011).

Finally, the relative position of a port may vary according to the scope of the geographical scale analysis. Transportation networks exhibit important and dynamic structures on a regional scale. Therefore understanding deeply the structural properties of each network before defining and analyzing it is of vital importance. For instance, a given port may be very central among neighboring ports but becoming peripheral when the study area enlarges. In any case, the regional level in which ports are studied is usually defined arbitrarily (Joly, 1999; Ducruet et al., 2009) and the characteristics of the regional areas are regularly overlooked.

3.2 *Hinterland Connectivity*

As it is obvious from the preceded analysis, efforts to assess maritime and ports connectivity with the adoption of a “before the border” analysis are flourishing. On the other hand, efforts to quantify and monitor ports connectivity with their hinterland (“after the border”), remain relatively scarce and a limited number of outputs have been produced only recently (Aronietis et al., 2011; Ferrari et al., 2011; De Langen and Sharypova, 2012). These efforts are considered a good starting point but the connectivity measures applied do not focus on a theoretical model, but remain rather case specific. A notable exception here is the study of Ferrari et al. (2011), which assesses the quality of port hinterland accessibility of the Ligurian ports. It is based on the gravity theory derived from the spatial interaction modeling and adopts distance as a proxy for trade costs. Interestingly, the relatively low number of research outputs on ports hinterland connectivity is mainly due to limited data availability and the complexity of contestable/overlapping hinterlands with respect to commodities, transport modes, technological changes, economic cycles and infrastructural changes (Blawens and Van De Voorde, 1988; Haralambides, 2002; Notteboom, 2008)^x.

In general, hinterland accessibility has been discussed in the literature from a theoretical perspective for defining port strategies (Van De Berg and De Langen, 2011) and for assessing the performance of ports within the intermodal network (Thill and Lim, 2010). The hinterland access of seaports is also extensively analysed in an effort to better understand the position of seaports within the supply chains^{xi} (for a detailed analysis see: Pallis et al., 2011). Improving hinterland access to seaports is, at least partially, an *inte-rorganisational* issue (De Langen and Chouly, 2004) that depends on the behavior of a large variety of actors, such as the terminal operators, the freight forwarders, the transport operators and the port authorities.

The main challenge for assessing ports’ hinterland connectivity is to define their potential to attract flows to and from the hinterland especially as the traditional captive hinterland evolves dynamically over time. The competitiveness among the top players, the development of inland transport infrastructures and efficient hinterland links are eliminating, to a certain extent, the importance of physical distance (Notteboom, 1997; Olivier and Slack, 2005). Therefore, the distance would seem to have become only one of the different parameters that contribute to determine the share of the inland market of a port. Today, a port’s potential hinterland can be defined as the area that can be reached at a cheaper cost or in a shorter time in comparison to other ports (Wilmsmeier et al., 2011).

3.3 *Port Infrastructural characteristics and connectivity*

A portion of ports competitiveness literature focuses on the location of ports (Song and Yeo, 2004; Teng et al., 2004; Castillo-Manzano et al., 2009), with connectivity being treated implicitly as part of the competitiveness concept. In this case, connectivity depends not only on hinterland or foreland conditions and locational characteristics but also on the port’s structural characteristics such as the provision of logistics services (Yeo et al., 2008), the use of technology or pricing (Song and Panayides, 2008).

The quality of port infrastructure services (draught, berths, storage facilities, etc.) is increasingly seen as a determinant of the trade performance for developing and developed economies. Shipping companies aim to further exploit economies of scale in order to effectively confront the fluctuations (and especially the latest significant increases realized) of bunker costs with the development and use of bigger vessels. The average capacity of container vessels is constantly increasing during the last decade^{xii} (Clarksons, 2013) and so does

the number of Post-Panamax vessels. In turn, a quite limited number of ports are able to serve big in size vessels due to draught and technological restrictions. Thus, the world's shipping developments do not affect ports' relative position in the same manner, since infrastructures do not adjust symmetrically to meet the requirements of newly built sizeable vessels of advanced technology (Arduino and Carillo, 2010). At the same time, port capacity constraints also play a role here. Ports are being confronted with capacity constraints as the supply of container trade is intensified (Clarksons, 2013). In this respect, the more efficient^{xiii} ports are the ones confronted with capacity issues more frequently, as their use is favorable by shipping companies. As relative efficiency declines at a port, cargo is headed to other ports, leading a port into a downturn, affecting agglomeration of cargo, and, in turn, connectivity or regularity of ocean services (World Bank, 2009). In other words, if a port's physical infrastructure is inadequate and/or if it is operationally inefficient, the costs incurred by shipping lines will be higher than necessary, and this will influence the ports' connectivity and in turn trade and regional economic growth.

To sum up, the literature does not provide an effective method to evaluate the hub-and-spoke system and to what extent carriers have modified the structure of the global maritime network (Wang and Wang, 2011). Against this background, responsible decision makers should always be aware of the information a centrality measure provides and the relative limitations. Thus, a connectivity measure should be selected carefully and not arbitrarily, taking into account important aspects of the network (e.g. frequency, transit time) over time and scale (regional vs global). Instead, a cautiously analysis regarding the requirements resulting from the particular application case is necessary.

What should be highlighted is the evidence that port connectivity contributes to economic development. A first step is to examine the correlations between a connectivity index and basic economic indicators. This will provide a first indication of some level of relations, positive or negative. But correlation does not necessarily imply causation. Thus appropriate regression analysis is needed. For example a basic regression analysis permits a rough calibration of how a country's growth or trade could accelerate if that country improved its ports' connectivity score. A distinct but more powerful way of examining whether global port connectedness can increase prosperity, is by analyzing the channels through which those gains might be generated (e.g global financial crisis, trade facilitation indicators, logistics, intermodal transport systems, etc.).

As suggested in recent research (Notteboom and Rodrigue, 2009), further research is highly recommended in relation with the evolution of port hinterlands, "[...] A port must have interfaces between major oceanic maritime trade and economic activities of ports and inland terminals that provide intermodal structures and connections between the forelands and hinterlands [...] The quality and capacity of hinterland modalities, roads and relays are essential to any expansion of trade" (Merk, 2013: 68). In addition, the application and comparability of more measures on all connections such as concentration, and entropy are highly suggested in recent research (Ducruet et al., 2009; 2010). Last but not least, the structural/qualitative characteristics of a port directly affecting its attractiveness and ability to perform efficiently as a connecting point serving the needs and strategies of export and import trading agents, deserves further attention. The interconnection between structural characteristics and connectivity produces serious endogeneity, resulting in misspecified theoretical and empirical estimations, unless properly treated.

4. Redefining Connectivity: A "Gravity-based" Approach

4.1 Conceptual Framework

Accessibility, a concept used in different ways in a number of scientific fields such as spatial planning, transport geography and urban analysis, plays an important role in policy making. However, accessibility is often misunderstood, poorly defined and poorly measured (Cullinane and Wang, 2009). Indeed, finding an operational and theoretically sound concept of accessibility is quite difficult and complex (Geurs and Wee, 2004). It is related to distance (Litman, 2003) but it can also be defined in terms of consumption possibilities (Fortuna et al., 2001).

A direct description of accessibility is related to connectivity (Baradaran and Ramjerdi, 2001). A location is assumed to be accessible if it is sufficiently and regularly connected to other locations via a link (e.g. road, rail,

airports, seaport) (Bruinsma and Rietvelt, 1998). A clear definition of connectivity however, is essential and without it no meaningful analysis of its impact in transport and the economy can be estimated with measurement becoming rather arbitrary (Lekakou and Vitsounis, 2011).

Port Connectivity as undertaken to date, falls under specific limitations (see section 3) relative to a) the specific approach (network analysis, intuitive or ad hoc metrics), b) the time frame (limited to a specific year or month), c) the geographical coverage (regional vs global), d) the frequency of services, e) the use of distance as the only impedance factor, f) the absence of correlation and causation with basic macroeconomic and port determinants, and g) the approach of connectivity either from the foreland or the hinterland e) the non modelling of the endogeneity between some of the aforementioned factors with connectivity itself.

In any case, focusing only on the number of available destinations may lead to a partial analysis of connectivity, as usually the potential destinations are not of equal importance. Taking into account also the frequency^{xiv} of services, generates more valid indications about the strength of the relationship between the various nodes. Finally, the cost of separation between two nodes is always of extreme importance and usually takes the form of time, distance and other costs.

Container Ports Connectivity is a multifaceted phenomenon incorporating different types of connections from the foreland to the hinterland. Its theoretical analysis and measurement requires first the definition of the phenomenon and then the selection of the underlying variables to be included in the estimation.

Connectivity relates to the ability of reaching destinations j from multiple points of origin i and *vice versa*. It also captures the patterns that the various nodes ij are linked, both spatially and temporally. The number of destinations j served by a node i affect positively the potential to supply transport services between ij , result in more frequent services to the destinations j and eventually increase the level of connectivity between ij . Notably, connectivity is also affected by other characteristics, such as the relative (economic) importance and the size of destinations served, and the cost of accessing them (generalized costs). Yet, incorporating these factors in a single definition is rather complex and in any case not straightforward (Oxera, 2010).

The construction of a Global Container Ports Connectivity Index (hereafter GCPCI) should be a stepwise analysis.

First of all, it should focus on “before the border” connections within the maritime network, taking into consideration the frequency of services offered and different aspects of costs (distance, time, combination of the two, etc.) that affect a ports’ potential to “push” and “pull” container flows. Moreover, it should be a global index calculated on a time series base enabling a better understanding of how port networks and the relative position of ports within maritime networks evolve over time. Moreover the extended timeframe of the indicator will unveil whether the preferences of different actors (shippers, carriers, terminal operator, etc.) change and to what extent over a given period of time.

The GCPCI should be a tool for policy makers. Connectivity should not be seen as a pure mathematical approach that gives some values about the topography of a port. It is an important policy tool and must be related with local (port throughput, port infrastructure) and regional indicators (GDP, trade, logistics) that verify its validity. More integrated regression analysis will reveal a port’s or a country’s specialization patterns with respect to connectivity.

At a second stage, GCPCI should incorporate a more integrated analysis, taking into consideration the ports’ characteristics and the relative hinterland connections (see section 3.2 and 3.3). GCPCI depends strongly on ports and inland characteristics affecting the services provided to the shipping lines, as well as on trade volumes and inter-modal connections. Scholars have explicitly analyzed that relations between port efficiency, maritime costs and trade flows do exist (Lima and Venables, 2001; Wilson et al., 2004) and that hard and soft infrastructures affect a country’s export performance (Portugal-Perez and Wilson, 2010). Indeed, port costs have an impact upon international trade patterns (Sanchez et al., 2003) and volumes (Clark et. al., 2004). Similarly, port infrastructures affect both freight rates and trade costs (see Table 2) but at a lower extent than distance.

Concluding GCPCI should be seen from two aspects: in a “narrow” and a “broad sense” (Márquez-Ramos et al., 2011). The “*narrow sense*” refers to the physical properties of the transport network. Thus it should be treated as a pure network outcome, separated from port performance and hinterland connection (figure 1). On the other hand, connectivity in a “*broad sense*” includes those factors related to the features of the services and cooperation of transport operators, which are essential for the efficiency and effectiveness of the transport network (figure 1).

Table 2. Literature of port infrastructure and maritime transport costs

Author	Sample	Dependent Variable	Explanatory Variables	Infrastructure Efficiency Variables	Results relative to distance	Results relative to Infrastructure Efficiency
Limao and Venables (2001)	1990 and 1998, cost of transporting a standard container from Baltimore to selected destinations	Transport cost factors (CIF/FOB)	Distance, per capita incomes, geographical factors (common island barriers, dummies)	Infrastructure index (length of road, length of paved road, length of rail, telephone main lines per person)	Distance alone explains only 10% of the variation of transport costs	If a country with a relatively poor infrastructure, say at the 75th percentile in an international ranking, is able to upgrade to the 25th percentile, it will be able to reduce transport costs by between 30% and 50%.
Micco and Perez (2001)	US, 1995-1999	Import charges	Distance, unit weight, price fixing/ cooperative agreement, containerization, total liner volume, foreign gdp per capita	Port efficiency (quality index (GCR), port efficiency according to LV	An increase in distance raises maritime transport costs by around 0.2%	Improving port efficiency from the 25th to the 75th percentile reduces shipping costs by 12 percent
Fink et al., (2002)	US, 1998	Import charges	Distance, total containerization, liner imports, price-fixing-cooperative agreements, cargo reservation	Cargo-handling services, mandatory port services ⁴	Transport cost increases with distance but less than proportionately	Cargo handling services reduce the cost. Competitive provision of shipping services are to be found at the ports rather than in the ocean leg (indirect measure)
Sanchez et al., (2003)	Latin America, 1999	Per ton cost of waterborne transport	Distance, unit value, frequency, transport insurance, pricing failures, containerization ratio	Port efficiency (multiple qualitative characteristics: hourly container load rate, general turn around, bureaucratic turn around, container waiting time, ship waiting time, yearly congestion, average container per vessel, container handling capacity)	A 10% increase in distance, increases transport costs in 0.9%	Port efficiency indicates that a 25% increase in the efficiency of a port, provokes a reduction near to 2% in total waterborne transport costs.

Clark et al., (2004)	1998 US	Import charges to (port)	Distance, bilateral port volume, total import volume of the exporter, trade imbalances, containerization ratio from the exporter	Efficiency indicators of the ports of the exporter (port efficiency index of the country, GDP per capita of the exporting country, the same infrastructure index as that used by LV(2001), cargo handling restrictions, mandatory port services	A doubling in distance, for instance, roughly generates an 18% increase in transport costs. This distance elasticity close to 0.2 is consistent with the existent literature on transport costs.	Improving port efficiency from the 25th to 75th percentiles reduces shipping costs by more than 10%
Wilmsm et al., (2006)*	16 Latin American countries (2002)	Freight charges	Cargo value, volume per transaction, geographical distance, bilateral trade volume, trade imbalances	Port infrastructure, port efficiency, overall transport infrastructure, private sector participation, average customs delay	An increase by 1 per cent leads to an increase of the freight by 0.37 per cent. Doubling the distance does not double the freight rates.	1% increase of the combined port infrastructure index leads to a reduction of the freight by 0.24%. Increasing the indicator for port efficiency by 1 per cent reduces freight charges by 0.38 per cent. Customs delay, connectivity and port privatization have the expected signs.
Blonigen and Wilson (2006)	US 1991-2003	Port to port import charges	Distance, weight, value per unit, containerization ratio, trade imbalances,	Exporter port specific dummy examining the cost efficiency. Inefficiency for each port	A 10% increase in distance will increase import charges from 1.3 to 2.1%	Port efficiency appears to strongly reflect not merely the technical efficiency, but the costs in total, including both pecuniary port tariffs and charges and the implicit time costs from the congestion and inefficiency in all the process in the ports.
Wilmsm et al., Hoffman 2008*	Caribbean region, 2006	Freight rate (company level)	Distance, trade balance, gdp per capita export and import, dummy variables, transit time, speed	Infrastructure (port area, storage area, length of quays, maximum draft)	Transit times in spite of distance gives better results. Each additional day of transit will lead to an increase of the freight rate of around 56 USD.	The port infrastructure in the importing country seems to have a strong bearing on the freight rate. An increase of infrastructure of one standard deviation reduces the freight rate of Company A by 225 USD

Abe and Wilson (2009)	US 2001-2006	Port to port import charges (country level)	Distance, import containerization ratio	Port congestion index, port infrastructure index, water transportation index, port and time dummy variables (fuel prices, technology, etc)	A 10% increase in distance increase import charges less than proportionally.	A one point increase in the port infrastructure quality index of the GCR, WTI would reduce transport cost by 7.4 and 5.1 respectively percent. Port congestion will increase transport cost by 7.3%.
Wilmsm ier and Sanchez (2009)*	Latin america	all food products costs of imports of containerizable cargo	Distance, dummy for reefer container, competence of the logistics industry of the importing country, size of the market	Infrastructure endowment (draught, berth and storage capacity)	An increase in distance increase import charges less than proportionally.	An increase in port infrastructure decreases transport cost under different scenarios
Marquez-Ramos et al., (2011)*	Spanish ports, 2003	Freight rates ports	Distance, trade imbalances, volume, common island dummy, GDP, population	port infrastructure, quality of services	Average real distance from port to port is significant and has the expected sign. Longer distances increase maritime transport rates. The estimated distance elasticity ranges from 0.06 to 0.23	The coefficient and sign estimated for the port variable show that the larger the size of the port, the lower the freight rates.

Notes: Studies with * include connectivity measures as an explanatory variable from transport costs. More details are found in Table 1.

4.2 A Gravity-Based Connectivity Definition

The connectivity measure should be realistic “and linked with mainstream models in transportation economics, such as the gravity-type model” (Arvis and Shepherd, 2011:11) that take into consideration the size of the nodes and the costs of moving on a given string or route. Gravity modeling represents the most widely used framework for spatial analysis.

GCPCI is defined as the (cap)ability of a container seaport i to push and pull flows within the whole maritime network. The definition takes into consideration not only the direct activity between the seaport i and its direct trading partners j , but also the interactions with “the rest of the world”, thus accounting for the whole interactions of a node within the maritime transportation network.

Based on the gravitational form, the interaction between any two ports, called origin and destination, is proportional to the product of the mass of the origin (O_i) and destination (D_j) and inversely proportional to some measure of separation (usually distance) (K_{ij}) (cost function).

$$X_{ij} = O_i D_j K_{ij} \quad (1)$$

$$X_{ij} = O_i D_j / d_{ij} \quad (2)$$

However, equation (1) has at least one obvious deficiency: if a particular O_i and a particular D_j are each doubled, then the number of trips between these zones would quadruple according to the equation (2), while it would be expected that they would double also. To overcome this criticism, the following constraint equations on X_{ij} (3) and (4) (Wilson, 1967) should always be satisfied:

$$O_i = \sum_j X_{ij} \quad (3)$$

$$D_j = \sum_i X_{ij} \quad (4)$$

That is, the row and column sums of the trip matrix should be the numbers of trips generated in each zone, and the number of trips attracted, respectively. These constraint equations can be satisfied if sets of constants A_i and B_j associated with production zones and attraction zones respectively are introduced (usually referred as balancing factors).

Therefore, generalizing Eq. (1) and introducing the balancing factors, the gravitational model changes as follows:

$$X_{ij} = A_i O_i B_j D_j f(d_{ij}) \quad (5)$$

where

$$A_i = [\sum_j B_j D_j f(d_{ij})]^{-1} \quad (6)$$

$$B_j = [\sum_i A_i O_i f(d_{ij})]^{-1} \quad (7)$$

Equations (6) and (7) are solved iteratively and ensure that the X_{ij} given in equation (5) satisfies the constraint equations (3) and (4). Note also that d_{ij} in this model should be interpreted as a general measure of impedance between i and j , which may be measured as actual distance, as travel time, as cost, or as some weighted combination of these factors (also referred as “generalized cost”).

Following the above specification, connectivity is defined according to Arvis and Shepherd (2011):

$$\bar{C}_i = \sqrt{\frac{X_i / A_i + B_i}{\sum_j B_j}} \times \sqrt{\frac{X_i / B_i + A_i}{\sum_j A_j}} \quad (8)$$

The above construction produces a consistent definition of connectivity. It is rooted not only on the topology of the network, but also in a fundamental understanding of spatial interactions among the nodes. It is also closely related to the idea of multilateral resistance underlying the recent gravity literature in international

trade. Under this definition, connectivity is a non-dimensional number between zero and one.

Potential is the total interaction calculated between an origin and all destinations and vice versa and is closely related with the gravity model. The potentials^{xv} ($A_{i,j}$ and $B_{j,i}$) (balancing factors) of the gravitational model, were first defined as measures of “accessibility” or “nearness” by Stewart and Wamtz (1958). The interpretation of the balancing factors was facilitated by the measure of accessibility (Hansen, 1959; Warntz, 1956, 1957 Alonso 1978; Hua 1980), since there is an inverse relation between balancing factors and accessibility. The measure of accessibility is dependent upon three terms, namely attractiveness, repulsiveness and the travel deterrence (Wilson, 1971; Pooler, 1995). This may be the reason why the balancing factors are interpreted as accessibility and competition.

The main advantage of using the balancing factors of the doubly constrained spatial interaction model is that the measure accounts for competition effects. The balancing factors will provide a more realistic accessibility estimate compared to simple network measures in the case of competition for both the demand and supply opportunities. For example, the doubly constrained model, estimates fixed/symmetric numbers of flows between origin and destination. As the balancing factors (potentials) are dependent and estimated in this way, the model can incorporate the competition of demand on supply opportunities and vice versa (Geurs et al., 2004). Furthermore, the balancing factors can be also interpreted as an indicator of economic benefit (Neuburger, 1971).

The main issue within this context is the measurement of the cost function (K_{ij}) both in what concerns the type of measure of transport cost as well as the specification and parameterization of the deterrence factor (Thill and Kim, 2005). Studies have proven that geographical distance is an important determinant of transport costs (Deardoff, 1998; Anderson and van Wincoop, 2004). However, distance “is a time-invariant variable, so the instrument to gauge the contribution of changes in trade flows is decidedly blunt” (Jacks and Pendakur, 2008:7). Moreover, geographical distance may be affected by a series of factors such as cultural proximity, a shared history, a perception of closeness and information costs rather than being a proxy of maritime freight rates (Limao and Venables, 2001; Marquez-Ramos et al. 2011). Recent studies proved that distance is not proportional to transport costs, creating implications for the proper application of the gravity model (see Table 2). Despite that the geographical location of countries cannot be modified, the effect of distance can be limited by improving the quality and efficiency of related infrastructures (hard and soft), and the intensity of connections between the origin and destination through the development of efficient hinterland connections and thus the intensification of intermodalism. As such, transportation costs are not only linked to distance (Brun et al., 2003; Disdier and Head, 2008) but also to the quality of transport services. In addition, technical changes and fuel costs influence both trade and transport costs (Behar and Venables, 2010) over time.

For instance, containerization, technological improvements of vessels (speed, reliability), open registry shipping and other transport deregulations (Hummels, 2007) are factors that distance alone cannot capture. On the other hand, due to these technological improvements, transportation time has fallen decisively with a direct affect on trade volume and costs (Behar and Venables, 2010). Hummels (2001) accentuates the importance of time as a trade barrier and indicates that a reduction in travel time can play a significant role in the size and composition of trade growth. Wilmsmeier and Hoffman (2008) examining the freight rates in the Caribbean region, found that transit time exercises a greater impact on freight rates than distance. This development has a direct effect and implications on the connectivity of ports since the majority of trade takes place through these gateways. With the development of globalized supply chains, the importance of transit time increases decisively due to just-in-time production patterns and fragmentation of production sites (Notteboom, 2006; Djankov et al., 2006; Korinek, and Sourdin, 2009).

A possible proxy for transportation cost can be the transit time^{xvi} or a combination of distance, time and fuel cost and infrastructural efficiency including intermodalism alternatives and structural/qualitative characteristics. Notably, different measures or compound indicators of transport costs have not been tested in the literature to a great extent until recently. According to the preceded discussion the proposed cost function^{xvii} (K_{ij}) may be of the following form:

Cost= c (distance and/or transit time, intermodalism, infrastructure characteristics, qualitative characteristics]

Where infrastructure characteristics include among others load/unload capacity, draught, berthing, storage, and qualitative characteristics pertain structural changes in the port sector ownership schemes and the extent of privatization in port operations.

Notably, the functional form of the cost function is a very critical issue, which in turn affects the end value of the estimated cost function (coefficient) and thus the estimated results. Several forms of cost functions are used in accessibility studies such as: a) the negative power function (Hansen, 1959), b) the negative exponential function (Wilson, 1971), c) a modified logistic function (Arvis and Shepherd, 2011), and d) a modified version of the normal function (Guy, 1983). Geurs et al., (2001) suggests that the choice of the cost function used in a connectivity/accessibility measure depends on: a) the specific characteristics of the function, b) the study area and, c) the “fit” on empirical data. In general, the literature offers no strong theoretical arguments in favor of one particular specification and underlines that the choice of a deterrence function is essentially a pragmatic one (Nijkamp and Reggiani, 1992). In any case, care must be taken when the empirically derived deterrence functions are used in the estimation of the connectivity.

4.3 Hyperpath Costs

The connectivity of maritime networks depends on the cost of shipping a container between pairs of ports, which in turn depends on a number of factors, like the routes operated by individual services, their frequencies, the sizes of the ships deployed and the capacities of ports for handling transshipment. All of these factors, plus empty container repositioning costs, are included in the container assignment model (Bell et al, 2011; 2013).

Between the origin and destination ports there may be a number of paths and services that are potentially optimal, depending on the timing of the shipment and the afore-mentioned factors included in the container assignment model. For example, an indirect service involving transshipment at an intermediate port offers cost and/or time advantages over a direct service, or perhaps the direct service offers insufficient capacity for the flow of full containers forcing some on to one or more indirect routes. Where flows of full containers are particularly unbalanced, as in the case of Australia, the need to reposition substantial numbers of empty containers adds to the cost of shipping full containers and therefore reduces connectivity.

The hyperpath includes the set of all paths, direct and indirect, that are potentially optimal. Given the routes operated by services, their frequencies, ship sizes and the transshipment capacities of ports (imports and exports take priority over transshipment), the hyperpath between any pair of ports and its expected cost may be found by solving a linear programming problem (ibid). Where ship size or port capacity constraints are inactive, it is possible to identify hyperpaths and their costs without knowledge of a full container origin-destination matrix. It is proposed to use hyperpath costs in future connectivity work.

5. Conclusions and Further Considerations

Ports' connectivity is a vital enabler in delivering economic growth. Connectivity is important in facilitating the efficient movement of economic resources to and from the points of supply to the points of demand. Since the majority of international trade is carried by sea, ports are considered the points connecting various sectors and countries. As economic linkages between countries develop and demand grows, so does the importance of port links.

The paper analyses and summarizes the main issues related to seaports location with respect to their connectivity. The primary focus has been a review of the existing literature in this area with a view to: a) providing a clear overview of the attempts of defining and measuring maritime connectivity, b) identifying the gaps of past research, c) providing an overview over the importance of port connectivity, d) considering the factors that may affect or alter a ports' connectivity, and e) suggesting an integrated methodology on assessing and constructing a port's connectivity index.

What emerges from reviewing the theoretical and empirical literature of connectivity is the fundamental ambiguity in the concept and definition of maritime connectivity. In fact most papers pay special attention to the foreland connectivity through network analysis. As such, important determinants like the

structural/qualitative characteristics as well as hinterland links able to influence a port's connectivity are often neglected. However, attaining such an integrated connectivity index is not a simple task. As a matter of fact, a proper definition constitutes a crucial barrier, since connectivity is a complex issue to define and measure.

Therefore port connectivity should be a stepwise process. A container ports' connectivity index should at first be a "before the border" analysis, and then be integrated to a more complicated concept including "at the border" and "beyond the border" characteristics. In this respect, infrastructural characteristics of ports and their connections to the hinterland constitute an important and direct determinant of transport costs, impinging indirectly on their connectivity. While distance is usually assumed to be among the main determinants of transport costs and thus affecting the trade competitiveness of countries, research outputs suggest that distance explains only one fifth of the variance of the published freight rate and its explanatory value has to be questioned, especially in transshipment markets. In other words, it is crucial to understand all the factors and dynamics that can play a role in the process of connectivity.

The present paper proposes an integrated method grounded on network analysis but derived from gravity modeling. It is rooted not only in the topology of the network, but also in a fundamental understanding of spatial interactions among the nodes. It allows the modeling of different determinants that may affect ports' connectivity through transport costs (e.g distance, time, infrastructural/qualitative characteristics, intermodalism) and allows for a comparative analysis of different measures or compound indicators of transport costs, and thus connectivity, that have not been tested in the literature until recently. In this respect a port connectivity index should be a flexible and easy adaptable tool, able to measure any changes through time and space.

While methods for measuring connectivity, as well as their economic impacts, are in their infancy, it is undeniable that connectivity constitutes an important determinant not only for the port itself but also for the general regional economic environment in the following areas (in accordance with Oxera, 2010):

a) Business Agglomeration

Through better connectivity, the region around a seaport can take advantage of the fact that it will be more attractive as a place to locate businesses. The wider economic benefits include agglomeration benefits (clustering), labour market effects, and imperfect competition effects. For example the increased size of an international product market available to a firm may help to increase its output and results in a greater demand for labour, with a consequent effect on the job market. Another potential wider economic benefit of increased connectivity is an increase of competition in both product and labour markets. The increase in competition could arise from widening the geographic size of the market. A good port transport network facilitates economic growth by improving efficiency, boosting investments and leading to more innovation.

b) Investments Motives

The level of international connectivity is a key factor in the investment decisions of many foreign and domestic firms. Naturally, people and businesses favor their location in places offering a better and more frequent access to international and domestic destinations. As such, connectivity affects directly foreign direct investments and thus a country's or a region's competitiveness.

c) Productivity and Trade Incentives

Port connectivity can help the economy to achieve higher productivity. These productivity gains are not limited to the maritime sector, but, crucially, also accrue to the sectors that make use of port services. Different studies point out that better connectivity leads to a larger market, which allows companies to make use of economies of scale and decrease unit costs. Moreover ports connectivity promotes bidirectional international trade, which facilitates economic growth through enabling countries to develop comparative advantage. Exporters will be able to widen the market for their goods and services, enabling them to benefit from economies of scale and increase productivity.

Port connectivity now and in the future is primarily influenced by the continued availability of sufficient capacity and the willingness of carriers to provide links. A port's connectivity is not only important for the services it provides to its focal country. Access to international connections is important in order to make a

full and effective contribution of the productivity of its country. But the level of international connections depends on the nature of demand, the geographical position of port, the infrastructural technology and hinterland connections, able to affect carriers' decisions. Moreover, while direct links are important, indirect routes offer important competing alternatives. Similarly the importance of frequency varies according to specific situations. The extent to which connectivity contributes to economic growth in the future depends on the nature of connectivity, the strength of the connections to particular destinations to which a port is, and will be, linked. Good port connectivity is a precondition for successful economic growth, even if it cannot directly cause growth or improve a country's ranking in the global transport network.

Fundamentally connectivity is formed of two components: the range of available destinations and generalized cost, which is itself a function of frequency, freight, transit time, and the need to transship, etc. A "one-size-fits-all" approach for both assessing and enhancing connectivity is, therefore, not appropriate; a more multi-faceted approach, tailored to different needs, should be obtained if the prospects which offer the most promising potential both economically and commercially, are to be effectively targeted, realized and successfully implemented. The overall conclusion is that there is an increasing interest and practical use of connectivity indicators, however substantial attempt and opportunity for further refinement of analytical methods and their conclusions need to be obtained.

Note: The authors are currently testing the suggested methodology with the use of real data. Their intention is to develop the first version of the Global Container Ports Connectivity Indicator before the conference and present the results for the first time during the conference.

Acknowledgements

The conducted research has been financially supported by the "SSF grants", co-financed by the State Scholarships Foundation (SSF) from the sources of the EP "Education and Lifelong Learning" of the European Social Fund of ESPA, 2007-2013.

References

- Abe, K. and Wilson, J. S. (2009), Weathering the storm: Investing in Port Infrastructure to lower trade costs in East Asia, Policy Research Working Paper 4911, World Bank, Washington DC.
- Alonso, W. (1978), A theory of movement, In N.M. Hansen (ed.) Human Settlement Systems. Cambridge, MA: Ballinger 197-211.
- Anderson, J. E. and Van Wincoop, E. (2003), Gravity with gravitas: A solution to the border puzzle, American Economic Review 93: 170-192.
- Angeloudis, P., Bichou, K. and Bell, M. G. H. (2007), Security and reliability of the liner container-shipping network: analysis of robustness using a complex network framework, In: Risk Management in Port Operations, Logistics and Supply Chain Security, edited by K. Bichou, M. G. H. Bell, and A. Evans (London: Informa) 95-106.
- Arduino, G., and Carrillo, M.D.G. (2010), Dynamic role of actors in freight transport and logistics, SIET Società Italiana di Economia dei Trasporti e della Logistica Working Paper 1005.
- Arvis, J.F., and Shepherd, B. (2011), The air connectivity index: measuring integration in the global air transport network, Policy Research Working paper 5722, World Bank, Washington DC.
- Arvis, J-F, Raballiland, G. and Marteau, J-F. (2007), The Cost of Being Landlocked: Logistics Costs and Supply Chain Reliability, Policy Research Working Paper 55837, World Bank Washington DC.
- Aronietis, R., Pawels, T., Vanelslander, T., Gazinski, J., Goleczynska, A. and Wasil, R., (2011), Port hinterland connections: a comparative study of Polish and Belgian cases, Procedia Social and Behavioural Sciences 20: 59-68.
- Barabási, A. and Bonabeau E. (2003), Scale-free networks, Scientific American 288 (5): 60-69.
- Baradaran, S., and Ramjerdi, F. (2001), Performance of accessibility measures in Europe, Journal of Transportation and Statistics 4(2/3) 31-48.
- Beauchamp, M.A. (1965), An improved index of centrality, Behavioural Science 10(2):161-163.
- Behar, A. and Venables, A.J. (2013), Trade Costs and International Trade, In: Handbook of Transport

- Economics, edited by De Palma. A., Lindsey, R., Quinet, E. and Vickerman. R. (Edward Elgar Publishing) 97-115.
- Beuran, M., Mahihemni, M.H., Raballand, G. and Refas, S. (2012), The Impact of Demand on Cargo Dwell Time in Ports in SSA, Policy Research Working Paper 6014, World Bank, Washington DC.
- Bernhofen, D.M., El-Sahli, Z. and Kneller, R. (2013), Estimating the effects of the container revolution on world trade, CESifo Working Paper Series 4136, Munich.
- Bergantino, A.S. and Veenstra, A.W. (2002), Interconnection and co-ordination: An application of network theory to liner shipping, *International Journal of Maritime Economics* 4(3): 231–248.
- Bichou, K. (2004), The ISPS code and the cost of port compliance: An initial logistics and supply chain framework for port security assessment and management, *Maritime Economics and Logistics* 6: 322–348.
- Blauwens, G. and Van de Voorde, E. (1988), The evaluation of time savings in commodity transport, *International Journal of Transport Economics* 15(1): 77–87.
- Bloningen, B. and Wilson, W. (2008), Port Efficiency and Trade Flows, *Review of International Economics* 16(1): 21–36.
- Bonacich, P. (1972), Factoring and weighting approaches to status scores and clique detection, *Journal of Mathematical Sociology* 2: 113–120
- Brakman, S. and Garretsen, H. (2003), Rethinking the 'new' geographical economics, *Regional Studies* 37: 637–648.
- Bruinsma, F. R. and Rietveld, P. (1998), The accessibility of European cities: theoretical framework and comparison approaches, *Environmental Planning* 30(3): 449–521.
- Brun, J.F., Carrere, C., Guilaumont, P. and De Melo, J. (2003), Has Distance Died? Evidence from a panel Gravity Model, *World Bank Economic Review*.
- Caschili, S., Ferrari, C., Medda, F. and Parola, F. (2011), Co-operation in Liner Shipping: Managing a Small World Network of Agreements, *International Conference Econship 2011, Chios*.
- Castillo-Manzano, J. I., Castro-Nuño, M., Laxe, F. G., López-Valpuesta, L. and Teresa Arévalo-Quijada, M. (2009), Low-cost port competitiveness index: Implementation in the Spanish port system, *Marine Policy*, 33(4): 591-598.
- Cisic, D., Komadina, P. and Hlaca, B. (2007), Network analysis applied to Mediterranean liner transport system, Paper presented at the International Association of Maritime Economists Conference, Athens, Greece, July 4-6.
- Clark, X., D. Dollar and A. Micco (2004), Port efficiency, maritime transport costs, and bilateral trade, *Journal of Development Economics* 75: 417–450.
- Clarkson Research Services Limited, (2013), *Container Intelligence Quarterly*, (London, Clarkson Research Services).
- Cullinane, K. and Talley, W. K. (2006), Introduction. In; Cullinane, K. and Talley, W. K. (Eds) *Port Economics* (London: Elsevier).
- Cullinane, K. and Wang, Y. (2012), The hierarchical configuration of the container port industry: an application of multiple linkage analysis, *Maritime Policy and Management* 39(2): 169-187.
- Cullinane, K. and Wang, Y. (2009), A capacity-based measure of container port accessibility, *International Journal of Logistics Research and Applications: A Leading Journal of Supply Chain Management* 12(2): 103-117.
- Cullinane, K.P.B, Cullinane, S.L. and Kwan, R. (2000), Logistics decisions in Southern China: mode choice, *Hong Kong Logistics* 2: 4–7.
- Deardoff, A. (1998), Determinants of bilateral trade: does gravity work in a neoclassical world? In: *The Regionalization of the World Economy* edited by Frankel, L., (The University of Chicago Press: Chicago) 7-32.
- Deng, W.B., Long, G., Wei, L. and Xu, C. (2009), Worldwide marine transportation network: Efficiency and container throughput, *Chinese Physics Letters* 26 (11): 118901.
- De Langen, P.W., van der Lugt, L.M. and Eenhuizen, J.H.A. (2002), A stylised container port hierarchy: a theoretical and empirical exploration, Paper Presented at the International Association of Maritime Economists Conference, Panama.
- De Langen, P.W. and Chouly, A. (2004), Hinterland access regimes in seaports, *European Journal of Transport and Infrastructure Research* 4(4): 361–380.
- De Langen, P.W. and Sharypova, K. (2013), Intermodal connectivity as a port performance indicator, *Research in Transportation Business and management* 8: 97–102.

- Ding, D. and Teo, C.P. (2010), World container port throughput follows lognormal distribution, *Maritime Policy and Management* 37(4): 401–426.
- Disdier, A. and Head, K. (2008), The Puzzling Persistence of the Distance Effect on Bilateral Trade, *The Review of Economics and Statistics* 90 (1):37–48.
- Djankov, S., Freund, C. and Pham, C.S. (2006), *Trading on Time*, Policy Research Working Paper 3909, World Bank, Washington DC.
- Drewry, (2014), *Quarterly Analysis of Container Service Key Performance Indicators*, issue 8.
- Ducruet, C., Rozenblat, C. and Zaidi, F. (2010a), Ports in multi-level maritime networks: Evidence from the Atlantic (1996-2006), *Journal of Transport Geography* 18(4): 508–518.
- Ducruet, C., Lee, S.W. and Roussin, S. (2009), Local strength and global weakness: A maritime network perspective on South Korea as Northeast Asia's logistics hub, *International Journal of Maritime Affairs and Fisheries* 1(1): 32–50.
- Ducruet, C. and Notteboom, M. (2010), The Worldwide Maritime Network of Container Shipping: Spatial Structure and Regional Dynamics, *GaWC Research Bulletin* 364.
- Ducruet, C., Lee, S.W. and Ng, A.K.Y. (2010b), Centrality and vulnerability in liner shipping networks: revisiting the Northeast Asian port hierarchy, *Maritime Policy and Management* 37(1): 17–36.
- Ducruet, C. and Zaidi, F. (2012), Maritime constellations: a complex network approach to shipping and ports, *Maritime Policy and Management* 39(2):151–168, Special issue on The Geography of Maritime Transport: Space as a Perspective in Maritime Transport Research.
- Ducruet, C. and Lugo, I. (2013), Structure and Dynamics of Transportation Networks: Models, Methods and Applications, In J. Rodrigue, T. Notteboom, & J. Shaw (Eds.), *The SAGE handbook of transport studies* 347–365.
- Feenstra, R.C.1 (1998), Integration of trade and disintegration of production in the global economy, *The Journal of Economic Perspectives* 12: 31–50.
- Ferrari, C., Parola, F. and Gattorna, E. (2011), Measuring the quality of port hinterland accessibility: The ligurian case, *Transport Policy* 18(2): 382–391.
- Fink, C., Mattoo, A. and Neagu, I. (2000), Trade in international maritime services: how much does policy matter, *World Bank Economic Review* 16 (1):81–108.
- Fortuna, M. A., Dentinho, T. P. and Vieira, A. C. (2001), *The costs of Peripherality*, Working Paper, Regional Policy Series, Brussels: European Commission.
- Freeman, L.C. (1979), Centrality in social net-works: conceptual clarification. *Social Networks* 1(3):215–239.
- Fremont, A. (2007), Global maritime networks: The case of Maersk, *Journal of Transport Geography*, 15(6):431–442.
- Fujita, M. and Mori, T. (1996), The role of ports in the making of major cities: self-agglomeration and hub-effect, *Journal of Development Economics* 49(1): 93-120.
- Gelareh, S., Nickel, S. and Pisinger, D. (2010), Liner Shipping hub network design in a competitive environment, *Transportation Research Part E* 46: 991–1004.
- Geurs, K.T. and Van Wee, B. (2004), Accessibility evaluation of land-use and transport strategies: review and research direction, *Journal of transport Geography* 12:127–140.
- Gouernal, E. and Daydou, J. (2005), Container Rail freight Services in North-west Europe: Diversity of Organizational Forms in a Liberalizing Environment, *Transport Reviews* 25(5):557–571.
- Guy, C.M. (1983), The assessment of access to local shopping opportunities: a comparison of accessibility measures, *Environment and Planning B* 10: 219–238.
- Hansen, W. G. (1959), How accessibility shapes land use, *Journal of the American Institute of Planners*, 25(2): 72–76.
- Haralambides, H.E. (2002), Competition, excess capacity, and the pricing of port infrastructure, *Journal of Maritime Economics and Logistics* 4(4): 323–347.
- Helmick, J. S. (1994), *Concentration and connectivity in the North Atlantic liner port network, 1970–1990*, PhD Dissertation, Miami, University of Miami.
- Hoffmann, J. and Kumar, S. (2002), Globalisation: The Maritime Nexus, in *Handbook of Maritime Economics*, Chapter 3:35–62.
- Hu, Y. and Zhu, D. (2009), Empirical analysis of the worldwide maritime transportation network, *Physica A* 388(10): 2061–2071.
- Hua, C. (1980), An exploration of the nature and rational of a systemic model, *Environment and Planning A* 12:713–726.

- Hummels, D. and Schaur, G. (2012), Time as a Trade Barrier, NBER Working Paper 17758, National Bureau of Economic Research, Cambridge, MA, <http://www.nber.org/papers/w17758>.
- Hummels, D. (2001), 'Time as a trade barrier', GTAP Working Paper.
- Hummels, D. (2007), Transportation Costs and International Trade in the second era of Globalization, *Journal of Economic Perspectives* 21 (3): 131–154.
- Jacks, D.S., and Pendakur, K. (2008), Global trade and the maritime transport revolution, NBER Working papers series 141.
- Joly, O. (1999), *La Structuration des Réseaux de Circulation Maritime*, PhD Dissertation in Territorial Planning, Le Havre University, Le Havre.
- Kaluza, P., Kölzsch, A., Gastner, M.T. and Blasius, B. (2010), The complex network of global cargo ship movements, *Journal of the Royal Society Interface* 7(48): 1093–1103.
- Kgare, T., Raballand, G. and Ittmann, H.W. (2011), Cargo dwell time in Durban: Lessons for Sub-Saharan African Ports, Policy Research Working Paper, 5794, World Bank, Washington DC.
- Konings, R. (2007), Opportunities to improve container barge handling in the port of Rotterdam from a transport network perspective, *Journal of Transport Geography* 15(5): 443–454.
- Korinek, J. and Sourdin, P. (2009), Clarifying trade costs: maritime transport and its effect on agricultural trade, OECD Trade Policy Working Paper 92.
- Koschützki D, Lehmann K.A, Peeters L., Richter S., Tenfelde-Podehl, D. and Zlotowski O. (2005), Centrality indices, In *Network Analysis: Methodological Foundations*, eds Brandes U, Erlebach T (Springer, Heidelberg), LNCS Tutorial 3418: 16–61.
- Krugman, P.R. (1979), Increasing returns, monopolistic competition, and international trade, *Journal of International Economics* 9(4): 469–479.
- Krugman, P. (1991), Increasing returns and economic geography, *Journal of Political Geography* 99(31): 483–499.
- Krugman, P. (2009a), The increasing returns revolution in trade and geography, *The American Economic Review* 561–571.
- Krugman, P. (2009b), Citigroup Foundation Special Lecture, Festschrift paper in Honor of Alan V. Deardorff, University of Michigan IPC working paper 91.
- Lam, J.S.L., Yap, W.Y., (2011), Dynamics of liner shipping network and port connectivity in supply chain systems: analysis on East Asia, *Journal of Transport Geography* 19:1272–1281.
- Landherr, A., Friedl, B and Heidemann, J. (2010), A critical review of centrality measures in Social networks, *Business and Information Systems Engineering*, 2(6): 371–385.
- Lekakou, M., and Vitsounis, T.K., (2011), Market concentration in coastal shipping and limitations to island's accessibility, *Research in Transportation Business and Management* 2: 74–82.
- Levinson, M. (2006), *The Box: How the Shipping Container Made the World Smaller and the World Economy Bigger*, (New Jersey, Princeton University Press).
- Lima, N. and Venables, A.J. (2001), Infrastructure, geographical disadvantage, transport costs and trade, *The World Bank Economic Review* 15(3): 451–479.
- Litman, T. (2003), Measuring transportation traffic, mobility and accessibility, *Journal of Transportation of the Institute of Transportation Engineers* 73(10): 28–32.
- Low, J. M. W., Lam, S. W. and Tang, L. C. (2009), Assessment of hub status among Asian ports from a network perspective, *Transportation Research Part A: Policy and Practice* 43:593–606.
- Márquez-Ramos, L., Martínez-Zarzoso, I., Pérez-García, E. and Wilmsmeier, G. (2011), Special Issue on Latin-American Research Maritime Networks, Services Structure and Maritime Trade, *Networks and Spatial Economics* 11: 555–76.
- McCalla, R., Slack, B., and Comtois, C. (2005), The Caribbean basin: adjusting to global trends in containerization, *Maritime Policy and Management* 32: 245–261.
- Meng, Q. and Wang, S. (2011), Liner shipping service network design with empty container repositioning, *Transportation Research Part E* 47:695–708.
- Merk, O. (2013), *The Competitiveness of Global Port-Cities: Synthesis Report*, OECD Regional Development Working Papers, 2013/13, OECD Publishing.
- Meza, O.W., Thiemann, C., Grady, D., Lee, J.J., Seebens, H., Blasius, B. and Brockmann, D. (2011) Complexity in human transportation networks: a comparative analysis of worldwide air transportation and global cargo-ship movements, *The European Physical Journal B* 84: 589–600.

- Micco, A. and Perez, N. (2001), Maritime Transport Costs and Port Efficiency, Inter-American Development Bank, IADB Annual Meeting, Santiago.
- Milgram, S. (1967), The small world problem, *Psychology Today* 2(1):60–67.
- Miroudot, S., Lanz, R. and Ragoussis, A. (2012), Trade in Intermediate Goods and Services, Trade Policy Working Paper 93, OECD.
- Montes, C.P., Seoane, M.J.F. and Laxe, F.G. (2012), General cargo and containership emergent routes: a complex networks description, *Transport Policy* 24: 126–140.
- Neuburger, H. (1971), User benefits in the evaluation of transport and land-use plans, *Journal of Transport Economics and Policy* 5(1):52–75.
- Newman, M.E.J. (2005), A measure of betweenness centrality based on random walks, *Social Networks* 27(1): 39–54.
- Ng, A.K.Y. and Gujar, G.C. (2009), The spatial characteristics of inland transport hubs: evidences from Southern India, *Journal of Transport Geography*, 17(5): 346–356.
- Nijkamp, P. and Reggiani, A. (1992), *Interaction, evolution and chaos in space*, Springer-Verlag.
- Notteboom, T.E. (1997), Concentration and load centre development in the European container port system, *Journal of Transport Geography* 5(2): 99–115.
- Notteboom, T. (2006), The time factor in liner shipping services, *Maritime Economics and Logistics* 8: 19–39.
- Notteboom, T. (2008), Bundling of freight flows and hinterland network developments, In R. Konings, H. Priemus, & P. Nijkamp (Eds.), *The future of intermodal freight transport*, Cheltenham: Edward Elgar 66–88.
- Notteboom, T. E. and Rodrigue, J. P. (2009), Foreland-based regionalization: integrating offshore hubs with port hinterlands, *Proceedings of the International Forum on Shipping, Ports and Airports (IFSPA) 2009*, The Hong Kong Polytechnic University, Hong Kong 400–417.
- Olivier, D. and Slack, B. (2005), Rethinking the port, *Environment and Planning A* 38(8): 1409–1427.
- Opsal., T., Agneessens, F., and Skvoretz, J. (2010), Node centrality in weighted networks: Generalizing degree and shortest paths, *Social Networks* 32: 245–251.
- Oxera (2010), Understanding the theory of international connectivity, provided for DfT.
- Pallis, A.A., Vitsounis, T.K., De Langen, P.W. and Notteboom, T.E. (2011), Port economics, policy and management. Content classification and survey. *Transport Reviews* 31(4): 445–471.
- Pooler, J. (1995), The use of spatial separation in the measurement of transportation accessibility, *Transportation Research A* 29(6): 421–427.
- Portugal-Perez, A., and Wilson, J.S. (2010), Export Performance and Trade Facilitation Reform: Hard and Soft Infrastructure, Policy Research Working 5261, World Bank, Washington DC.
- Rahimi, M., Asef-Vasiri, A. and Harrison, R. (2008), An inland port location-allocation model for a regional intermodal goods movement system, *Maritime Economics and Logistics* 10(4): 362–379.
- Rietveld, P. (1995), Some notes on interconnectivity in transport networks, In H. Coccossis, & P. Nijkamp (Eds.), *Overcoming isolation*, Berlin: Springer 18–28.
- Rietveld, P. (1997), Policy aspects of Interconnectivity in networks, in Cristina Capineri and Piet Rietveld (Eds), *Networks in Transport and Communications – A Policy Approach* (Ashgate Publishing Company: Vermont, USA).
- Robinson, R. (2002), Ports as elements in value-driven chain systems: the new paradigm, *Maritime Policy and Management* 29(3): 241–255.
- Roso, V. (2008), Factors influencing implementation of a dry port, *International Journal of Physical Distribution and Logistics Management* 38(10): 782–798.
- RSAS- Royal Swedish Academy of Sciences (2008) Trade and geography – Economies of scale, differentiated products and transport costs, Scientific background on the Sveriges Riksbank Prize in Economic Science in Memory of Alfred Nobel, Compiled by the prize committee of the Royal Swedish Academy of Sciences.
- Sanchez, R. J., Hoffmann, J., Micco, A., Pizzolitto, G., Sgut, M. and Wilmsmeier, G. (2003), Port efficiency and international trade, *Maritime Economics and Logistics* 5:199–218.
- Song, D. W., and Panayides, P.M. (2008), Global supply chain and port/terminal: integration and competitiveness, *Maritime Policy & Management* 35(1):73–87.
- Song, D. W. and Yeo, K. T. (2004), A competitive analysis of Chinese container ports using the analytic hierarchy process, *Maritime Economics and Logistics*, 6(1): 34–52.
- Stewart, J. Q. and Wametz, W. (1958), Physics of population distribution, *Journal of Regional Science* 1: 99–

- Teng, J. Y., Huang, W. C. and Huang, M. J. (2004), Multicriteria evaluation for port competitiveness of eight East Asian container ports, *Journal of Marine Science and Technology* 12(4): 256–264.
- Thill, J.C. and Lim, H. (2010), Intermodal containerized shipping in foreign trade and regional accessibility advantages, *Journal of Transport Geography* 18: 530–547.
- Thill, J.-C. and Kim, M. (2005), Trip making, induced travel demand, and accessibility, *Journal of Geographical Systems* 7: 229–248.
- Van den Berg, R., and de Langen, P. W. (2011), Hinterland strategies of port authorities: A case study of the Port of Barcelona, *Research in Transportation Economics* 33(1): 6–14.
- Van Klink, H.A. and Van Den Berg, G.C. (1998), Getaways and Intermodalism, *Journal of Transport Geography* 6(1): 1–9.
- Vigarié, A. (1968), *Geographie de la Circulation*, Genin, Paris.
- Vigarié, A. (1979), *Ports de Commerce et Vie Littorale* (Paris: Hachette).
- UNCTAD, (2006), *Transport Newsletter*, various issues: <http://extranet.unctad.org/transportnews>.
- UNCTAD, (2013), *Trade and Development Report, Review of maritime transport*. New-York-Geneva: UNCTAD Secretariat.
- UNESCAP (2011b), *Trade Facilitation in Asia and the Pacific: Which Policies and Measures affect Trade Costs the Most?* Bangkok 2011, <http://www.unescap.org/tid/publication/swp111.pdf>.
- UNESCAP (2011a), *Review of developments in transport in Asia and the Pacific*, United Nations Economic and Social Commission for Asia and the Pacific, New York, 2011.
- Walter C.K. and Poist, R.F. (2004), North American inland port development: international vs domestic shipper preferences, *International Journal of Physical Distribution and Logistics Management* 34(7): 579–597.
- Wang, C. and Wang, J. (2011), Spatial pattern of the global shipping network and its hub-and-spoke system, *Research in Transportation Economics* 3: 54–63.
- Warntz, W. (1956), Measuring spatial association with special consideration of the case of market orientation of production, *Journal of the American Statistical Association* 51: 597–604.
- Warntz, W. (1957), Geography of price and spatial interaction, *Papers and Proceedings of the Regional Science Association*, 3: 118–129.
- Weigend, G.G. (1958), Some elements in the study of port geography, *Geographical Review* 48: 185–200.
- Wei, T., Deng, G., and Wu, P. (2008), Analysis of network effect in port and shipping system characterized by scale-free network, *Chinese Journal of Management* 5(3): 381–389.
- Wilmsmeier, G., Hoffmann, J. and Sancez R.J (2006), The impact of port characteristics on international Maritime transport costs, *Research in Transportation Economics*, 16:117–140.
- Wilmsmeier, G. and Hoffmann, J. (2008), Liner Shipping Connectivity and Port Infrastructure as Determinants of Freight Rates in the Caribbean, *Maritime Economics and Logistics* 10:130–151.
- Wilmsmeier, G. and Sánchez, R. (2009), The relevance of international transport costs on food prices: Endogenous and exogenous effects, *Research in Transportation Economics* 25(1): 56–66.
- Wilmsmeier, G., and Martínez-Zarzoso, I. (2010), Determinants of maritime transport costs – a panel data analysis for Latin American trade, *Transportation Planning and Technology* 33(1): 105–121.
- Wilmsmeier, G., Bergqvist, R. and Cullinane, K.P.B. (2011), Special issue: Ports and Hinterland-Evaluating and managing location splitting, *Research in Transportation Economics* 33: 1–5.
- Wilson, J.S., Mann, C.L. and Otsuki, T. (2004), *Assessing the Potential Benefit of Trade Facilitation: A Global Perspective*, Policy Research Working Paper 3224, World Bank, Washington DC.
- Wilson, A.G. (1967), A statistical theory of spatial distribution models, *Transportation Research*, 1(3): 253–269.
- Wilson, A.G. (1971), A family of spatial interaction models, and associated developments, *Environment and Planning A* 3: 1–32.
- Woodburn, A. (2007), The role for rail in port-based container freight flows in Britain, *Maritime Policy and Management* 34(4): 311–330.
- World Bank, (2009), *Logistics, Transport and Food Prices in LAC: Policy Guidance for Improving Efficiency and Reducing Costs*, World Bank, Washington DC.
- Yeo, G.T., Roe, M. and Dinwoodoe, J. (2008), Evaluating the competitiveness of container ports in Korea and China, *Transportation Research Part A* (42): 910–921.

ⁱ Since 1990, container traffic has steadily increased with an average annual growth rate of 9.8%

ⁱⁱ The hinterland potential of a seaport *i* may be defined “as the demand for transshipment in terms of import and export to/from a set of places *j* weighted with generalized transport costs between *i* and *j*” (Van Klink and Van De Berg, 1998).

ⁱⁱⁱ Connectivity can be defined as the existence of a connection or link between two points of network, which relates to the existence of direct or indirect links. The concept of inter-connectivity, however, varies from connectivity. Connectivity is a property of two nodes, while inter-connectivity is a property of at least three nodes of a link.

^{iv} And thus regarded as very useful policy tools

^v Data are derived from Containerization International Online. The index is generated as follows: For each of the five components, a country's value is divided by the maximum value of that component in 2004, and for each country, the average of the five components is calculated. This average is then divided by the maximum average for 2004 and multiplied by 100. This way, the index generates the value 100 for the country with the highest average index of the five components in 2004.

^{vi} The small world concept in simple terms describes the fact that in most networks despite the large number of nodes they are made of, the typical distance between two nodes is very short. The distance between two nodes in a network is defined as the number of edges in the shortest path connecting them. The most popular manifestation of "small worlds" is the "six degrees of separation" concept, uncovered by the social psychologist Stanley Milgram (1967).

^{vii} Scale-free networks are the ones that the number of contacts is not distributed homogeneously across all nodes. Instead, such networks are made up of many scarcely interconnected and only some highly integrated members – so-called hubs (Barabasi and Bonabeau, 2003). These hubs act as a link between individual groups of strongly interconnected members.

^{viii} In addition the increase of long-distance links, reflects other types of proximities based on former colonial ties, shared language and culture (Ducruet and Zaidi, 2012).

^{ix} As defined in Wikipedia.

^x It should be noted that emphasis here is on maritime and port transportation networks. Therefore, “after the border” measures focusing on inland transportation such as the “Logistics Performance Index” are not analysed.

^{xi} Evidence emphasize the increasing importance of freight corridors, such as rail (Gouvernal and Daydou, 2005; Woodburn, 2007) and barge (Konings, 2007), and of inland ports (Walter and Poist, 2004; Roso, 2008; Rahimi et. al., 2008; Ng and Gujar, 2009) for ports' position within the supply chains.

^{xii} Post-Panamax containerships increased from 134 to 469 during the 2007-2013 period, while the average carrying capacity of containerships was also increased over the same period (Clarksons, 2013).

^{xiii} The term “efficient” here is used for ports whose offering in various respects (technology, draught, performance indicators, hinterland penetration etc.) outperforms other offerings.

^{xiv} The frequency of ship services is a major determinant for port choice by shippers (Cullinane et al., 2000).

^{xv} The potentials are determined endogenously in the gravity model through fixed effects of the importer and exporter port. Thus, it accounts for “multilateral resistance terms”, a term defined by Anderson and Van Wincoop (2004)

^{xvi} In respect to transit time, cargo dwell time at port is considered a critical issue (Kgare et al., 2011; Beuran et al., 2012). Longer transport time which leads to slow import processes, dramatically reduces trade (Hummels and Schaur, 2012). In addition more than half of the time needed to transport cargo from port to hinterland cities in landlocked countries in SSA is spent in ports for land transport to landlocked countries (Arvis et al., 2010).

^{xvii} It should be noted that the proposed approach allows also the modelling of the effect of qualitative characteristics such as the clustering among ports and shipping companies or/and the effect of private or public ownership of ports on their cost and therefore on their connectivity through the use of dummy variables that distinguish among cases.

The New Mode of Container Trailer Transportation Management in Chinese Ports Area with the Development Trend of New Energy Consuming and E-commerce Technology

Kai Luo¹, Pin Xu¹, Bo Ma¹, Apollo Zhou² and Julian Guna²

¹Department of Transportation Development Studies, China Academy of Transportation Sciences, China.

²TruckingChina (Yantai) Ltd., China.

Abstract

With the rapid development of Chinese port industry in recent years, the constraint problem of collecting and distributing system's capacity become more prominent which caused by the poor transportation infrastructure and lower level development of container trailer transportation market. Otherwise, under the strict policies and regulations on the environment protection, the container trailer transportation market in China is also facing more challenges of emission-reduction and energy-saving in the supply chain management. So the purpose of this paper is to build a new mode, such as the public platform to solve the serious problem issued in container trailer transportation market of Chinese port industry via e-commerce technology, also give the possible profit pattern to support its works with the new energy consuming, and to improve the current condition, make innovation of modern logistics.

Keywords: New mode, Container trailer, Public platform, New-energy consuming, E-commerce, Profit pattern.

1. Introduction

In recent years, the collection and distribution system is more dependent on the container trailer transportation, but lower efficiency of domestic road transportation is becoming the constraint of container ports' development, especially on the land-side, the development level of collection and distribution system are not good as sea-side. Under the fully standardization of container ports' operation, it is limited to get more improvement for cargoes loading\discharging, time-reduction of anchoring for sea-side operation. so the focus are moved onto the inland transportation. With the high pressure of environment protection and rising cost, the container trailer transportation market is turning worse and needed to introduce a new mode for making innovation of container trailer transportation management, also give its framework and profit pattern. Which can possibly promoting IT ability and pushes the market to build the efficiency public platform according to the concept of mechanism of network structure.

2. Current Condition and Problems of Container Trailer Transportation Market in China

2.1. Current condition of container trailer transportation market in China

Nowadays, the industry of container trailer has become the important part of collection and distribution system in ports, and it grows rapidly with the development of ports' scales in China. For example, the growth rate of Chinese container transportation market are more than average level of all the world, the CAGE is nearly 6%~8% from the 1980s. Obviously, container trailer transportation plays an important part in the inland logistics. It estimated that number of container trailers in the coastal of China is more than 300 thousands and carrying about 150 million TEUs according to throughputs in Chinese container ports, which excluding the transportation mode of water-water/water-rail transfer. Also, the market value of all the container trailer transportation breaks through 170 billion RMB assuming the unit price of TEU is 1200 RMB. The container trailer is studied in this paper is the trailer out of port yard (See figure 1: demonstration of container trailer studied in this paper). Comparing to the container trailer in the port yard, the features of container trailer operators studied in this paper are as below:

- **Ownership:** disperse and owned by logistics companies or personal.
- **Operation scale:** no special limits on the business and its operation is very flexible. Operators' and trailer's licence are registered and administrated by transportation department of government according to the normal policies.
- **Cost control:** due to daily business decision are making by companies itself or personal, operators should face rising of fuel/labour cost greatly caused by the market fluctuation.
- **Business management:** the container trailer's operation are market-oriented, not like the trailer in the port yard which is operated by the port operator and its work are arranged by plan can be forecasting.

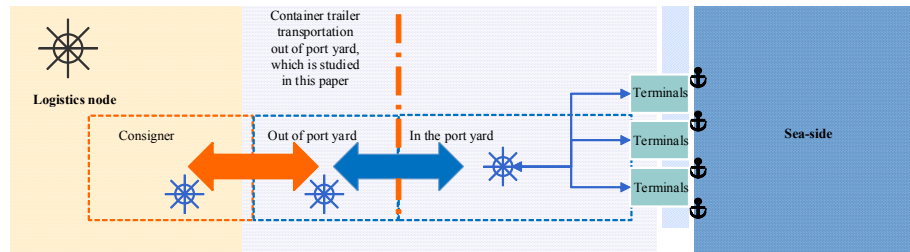


Fig 1. Demonstration of container trailer studied in this paper

Source: Kai Luo of the Management Solution of Container Truck Transportation Based on 4PL (4th Party Logistics) Model, the 15th China Science Association Annual Meeting (2013)

2.2. Problems of container trailer transportation market in China

Overall, the development of road logistics in China is 20 years or more behind developed countries. according to statistics (GuanJu Xu, 2014, Chinese road logistics fall behind developed countries 20 years or more, China Net News), though the freight volume of container trailer transportation makes up more than 60% of internal road logistics market of China, deadhead ratio (means deadhead kilometres/total kilometres of trailers) is close to 40%, and have great negative effect to the environment. According to the survey (Apollo Zhou, 2012-2013), container trailers of coastal in China, we can see four typical problems:

- **Small scale of market:** especially many small scale of trailer operators in the market. the average number is only 1.5 trailer per operator and the total number of Chinese road Logistics Company is more than 7.5 million (GuanJu Xu, 2014).
- **Fragmented organization:** the current status of container trailer market is very fragmented and level of industry development is much lower. 90% of the capacity of the market are controlled by individual person or one family and the concentration ratio is only 1.2% (GuanJu Xu, 2014).
- **Disordered competition:** due to lack of requirements on the standard procedure and regime of credit of in Chinese container trailer market, the competition and behaviour of operation is disordered. According to statistics of Shenzhen container trailer association, it estimated that 30% of container trailers in Shenzhen market have cheating or unfair competition behaviour in the business, such as using fake license plate or super-lower price against competitors, and number is still growing years and years.
- **Lower service level:** operators of container trailer out of the port yard are harder to be controlled and managed, and it reflects on the different quality of service, level of management and efficiency.

Above all, these are more challenges faced by container trailers transportation industry in China and directly affect the efficiency and cost of supply chain in the port logistics, which need to give a solution for changing the condition.

3. The Solution of Public Platform of Container Trailer Transportation Management with E-commerce

3.1. Core idea of public platform with e-commerce

For solving the problems above, and need to define key subjects and method first. Figure 2 shows that tradition operation channel of supply chain in port logistics makes container trailer operators face pressures coming from forwarder/consignor/cargo owner and warehouse/yard/terminal operator. According the 2.2 part

of this paper, the main problem we can easily to change and solve is improving the information flow and its goal is to reduce deadhead ratio and help container trailer operators save money and get more profit. So, changing structure of information flow via e-commerce public platform is the core idea of the method. From the figure 2, a public platform is established and including four important functions what are schedule/interactive, finance/insurance, risk control, negotiate/cooperate, and terminal operator, consignee, consignor, forwarder and the other participants (including container trailer operators) in the supply chain of port logistics are customers to the platform. On the basis of concept from 4PL (four-party logistics), the public platform with technology of e-commerce is like virtual integrated operator to achieve the more convenient and much cheaper business between container trailer operators and other participants (Apollo Zhou, 2012), which plays a role of center and backbone node to the network in the multiple channel.

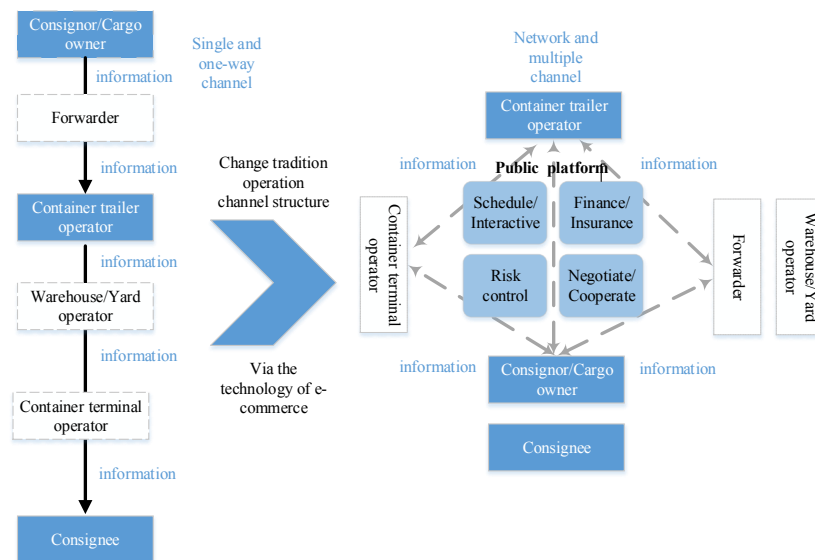


Fig 2. Change tradition operation channel structure

Source: Kai Luo, Apollo Zhou, Julian Guan

3.2. Implementation of public platform with e-commerce

According the core idea showing in the figure 2, TruckingChina (Yantai) Ltd has proposed the implementation programs of container trailer transportation public platform and put them into practices (Apollo Zhou, Julian Guan, 2012). On the base of TruckingChina platform established in 2011, and proposes the program of “Three in One” (operation/management/business sub-platform and its technology basis/working features/main function/value achieved/product form are showing in table 1) structure, which including port logistics supply chain as backbone, trailer/container/driver as key elements. Due to the complexity of implementing the whole program, the real and easy way is to build it one by one in each module and function, and then integrate them to a full-system. Now TruckingChina (Yantai) Ltd has completed part of schedule function which has finished products including i-genzong search engine (www.igenzong.com), system of container trailer driver security, system of transportation enterprise information management.

Table 1. “Three in One” structure of the pubic platform

	Technology basis	Working features	Main function	Value achieved	Product form
Operation platform	Internet and mobile technology based on the SAAS	- passive management for a single trailers - information sharing for trailers and cargos	- sales order - drivers performance - trailers maintenance - invoice/charge	- improve ability service of trailers - increase drivers' motivation and	- trailer online management system (download /installment/use for free)

			- operation report	performance - regulate asset management - control finance risk	
Management platform	process optimization based on the mathematical method	- active management for multiple trailers - entrusted management/project management	- routine optimization - stowage optimization - container tracing - emergency report - charge record	- increase efficiency, market recovery - reduce deadhead ratio and cost - improve price advantage - improve the brand's effect for operator	- entrusted management system for multiple trailers - system of container trailer driver security - system of transportation enterprise information management.
Business platform	e-commerce based on dynamic plan method	- interactive/open platform - convenient business for demand/supply	- search engine - order reservation and appraisal - on-line payment	- transparency process - guaranteed quality service and efficiency - value-added service to choose - low cost for finance and insurance service	- i-genzong tracing search engine - trailer booking system - finance and insurance on-line service

Source: Apollo Zhou, Julian Guan of the TruckingChina (Yantai) Ltd (2013)

3.3. Appraisal for the practices of the public platform

With different transportation form showing in the table 2, the public platform of TruckingChina program can help container trailer operators to increase profit and reduce cost significantly. Take form of semi-trailer swap transportation, which using one trailer carry the container to destination via the public platform can save 30% cost and directly increase 30% profit comparing to the tradition business way. Otherwise, the public platform can make a considerable income assuming that it charge a little from user, for example, if the average price per TEU is 1200 RMB, and choose the double-container carpool can make income of 480 RMB per TEU for container trailer operators, and to the platform can also get 3.75 billion RMB if service charge of the public platform is 100 RMB per TEU.

Table 2. Appraisal for the public platform of TruckingChina program

Transportation form	With one trailer	With one container/cargo	At same time	Change of profit	Change of cost	Degree of difficulty
Heavy truckload transportation	Yes	No	No	+25%	-25%	9.0
Semi-trailer swap transportation	No	Yes	No	+30%	-30%	9.5
Double-container carpool	Yes	Yes	Yes	+20%	-20%	8.5
less than container load transportation	Yes	Only for picking-up cargo	No	+15%	-15%	8.0

Source: Apollo Zhou, Julian Guan of the TruckingChina (Yantai) Ltd (2013)

4. The Profit Pattern of Container Trailer Transportation Public Platform with New Energy Consuming

4.1. Channel possible for the profit pattern based on the public platform with new energy consuming

Actually, a sustainable and viable public platform need to have multiple profit pattern. Though normal service has a great potential showing in the part of 3.3, the channel is signal and be effected easily by the market fluctuation and operator credit's uncertainty. More importantly, the trend of new energy consuming has great hit the trailer industry, which is a challenge, also an opportunity. So, many possible channels for the profit pattern based on the public platform can be tried and it is showed in figure 3. Excluding the normal service channel of schedule/interactive/risk control part, so many value-added service can be innovated from the function of finance/insurance/negotiate/cooperate. Take the foreign trade export business as an example, service for advance payment of duty taxes can be achieved between bank and forwarder/consignor, and consuming of new energy can be applied in the service of LNG trailer buying load/insurance between bank/insurance company and container trailer operator, also, the public platform can be the integrator of business negotiation for forwarders/consignors and container trailer operators.

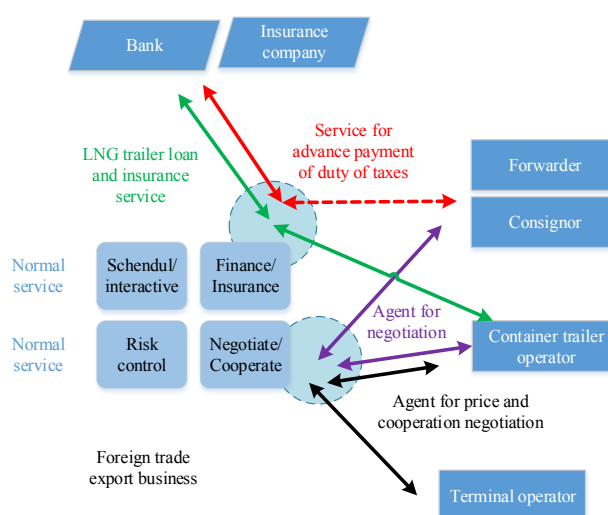


Fig 3. Possible service channel for the profit pattern based on the public platform
Source: Kai Luo of Management Solution of Container Truck Transportation Based on 4PL (4th Party Logistics) Model, the 15th China Science Association Annual Meeting (2013)

4.2. Practices possible for the profit pattern based on the public platform

According to the framework proposed in the 4.1, the service from different channel can be implemented as below.

4.2.1. Loan and insurance service to LNG trailers

The public platform can integrate container trailer operators who have demand of buying LNG trailers or replacing engine equipment into LNG, which take advantage of collective bargaining against retainers/banks/insurance companies for much more discount. The platform can get service fee from the bargaining service and profit come from 1%~3% of loan or insurance contract amount, meanwhile, it also can share the profit from the deal of selling trailer by retainers.

4.2.2. Collective bargaining for fee charged

As we know, container trailer operators have less bargaining power comparing to the cargo owners/forwarders/terminal operators due to problems described in 2.2, so the public platform can help to enhance the bargaining power by integrating fragment container trailer operators, and its profit can be get

from the a certain ratio of contract fee. More importantly, the public platform can be the agent for container trailer operators and bargain against terminal operator for fee charged and transportation plan, what can reduce deadhead ratio and its cost, improve the condition of congestion in the port.in addition, container trailer operators and their customers can use the platform as 3rd-party to do payments, such us paying fuel fee to oil retainer monthly, or drivers get salary from the platform account and etc. this means that public platform can attract a great amount of cash flow from small cash business and cooperate with banks.

4.2.3. Advanced payment of export taxes

The bank business innovation to foreign trade call “export refund tax pool”, which can be applied on the public platform to the consignor/forwarder and etc. Firstly, consignor/forwarder submits VAT tax refund papers to the platform and get 75%~ 85% of cargo value back, secondly, the platform collect certain amount of VAT tax refund papers and mortgage to banks get 85%~ 90% of the papers’ value, thirdly, banks own the VAT tax refund papers and get cash from tax department of government, what finish all the process of advanced payment of export taxes.

5. Conclusions

Facing the problems of inland transportation of ports in China, it needs to establish a public platform to integrate fragment resources of container trailer market and make it changing into a network structure for three chief goals, first is to reduce social logistics cost by lower the deadhead ratio and improve the environment, second is regulate the business behaviour of container trailer operators and change their passive condition in the supply chain of port logistics, third is to promote the market condition by building credit regime and etc.

References

- Jctrans (2009), <http://info.jctrans.com/xueyuan/wlyt/dswl/20091214831292.shtml>.
TruckingChina (2012), Build the e-commerce platform of container road transportation.
Shenzhen container trailer association (2006), Nearly 60% of container trailer operators of Shenzhen only in balance, Magazine of Transportation Manager World, 2006(8):19.

Evaluating the Effect of Logistics Learning Capability for International Distribution Center Operators in Taiwan

Ching-Chiao Yang^{1*} and Hui-Huang Tai¹

¹Department of Shipping and Transportation Management, National Kaohsiung Marine University, No. 142 Haijhuang Road, Kaohsiung City 811, Taiwan, ROC. *E-mail: yangcc@mail.nkmu.edu.tw

**Corresponding author*

Abstract

This study aims to examine the impacts of logistics learning capability on logistics service capability and firm performance in the context of international distribution center operators in Taiwan. A multidimensional construct including open-mindedness (O), commitment to learning (C), system perspective (E), partner learning (A), and shared vision (N) was proposed in this study to measure the logistics learning capability. A two-steps structural equation modelling (SEM) approach was subsequently performed to test the research hypotheses. Results indicate that logistics learning capability is positively related to logistics service capability, whereas logistics service capability is also positively related to firm performance. However, the relationship between logistics learning capability and firm performance was not supported in this study.

Keywords: Logistics learning capability, Logistics service capability, International distribution center

1. Introduction

Knowledge, which has the features of tacitness, inimitability, and immobility, is viewed as a strategic resource in today's turbulent marketplace (Grant, 1991; Hult et al., 2006). The source of a sustainable competitive advantage is reliant upon a firm's ability to learn faster than its competitors (De Geus, 1988; Stata, 1989; Kapp, 1999). Thus, all businesses seeking to compete in this dynamic and competitive marketplace must pursue the processes of learning (Slater and Narver, 1995; Organization for Economic Co-operation and Development-OECD, 1996). Specifically, international logistics is a knowledge and labor intensive service sector that links buyers and sellers, creating economic value by effectively providing and delivering logistics services to customers. It plays an important role in quality customer service and its performance has been shown to have a direct correlation with manufacturers'/suppliers' performance (Sharma et al., 2004).

Taiwan is an island-based economic entity in the center of the Asia-Pacific region, and its prosperity is highly dependent on export trade. Therefore, international trade plays an important role in the development of Taiwan's economy. According to the statistical report published by the Ministry of Economic Affairs (2013), the service industry contributed 69.2% of the GDP in 2012 in Taiwan, and the logistics industry's annual revenue reached US\$ⁱ 14.4 billion, contributing 3.1% of the GDP in the same year. To further enhance the competitiveness of Taiwan's international logistics environment for attracting foreign direct investment, the government issued the Global Logistics Industry Development Plan in 2010. However, a firm's competitive advantage is determined not only by the external environment but also by its capabilities to add value to clients (Barney, 1991; Russo and Fouts, 1997).

Logistics service capability is viewed as a core competence in leading superior performance and creating customer value (Yang et al., 2009). After Taiwan entered into the World Trade Organization (WTO) and signed an economic cooperation framework agreement (ECFA) with Mainland China, the logistics industry in Taiwan became highly competitive, and the percentage of foreign logistics service providers entering this market has remained consistently high. In addition, logistics service offerings and quality provided by international distribution centers are relatively easily imitated and duplicated by competitors (Slater, 1996). As a result, the increasing competition is likely to continue into the foreseeable future and will consequently force

international logistics center operators to build core capabilities that are inimitable and durable in order to reduce cost and increase service satisfaction in the global market (Lai, 2004; Tseng et al., 2005). Thus, in today's dynamic marketplace, it is imperative for an international distribution center operator to build its logistics learning capability to sustain a competitive advantage over logistics leverage (Esper et al., 2007).

Organizational learning has been seen as an important motivator for achieving logistics goals and superior firm performance (Hult et al., 2003; Garcia-Morales et al., 2007; Panayides, 2007; Jiang and Li, 2008; Jiménez-Jiménez and Sanze-Valle, 2010). However, to our knowledge few studies have empirically explored the effects of logistics learning capabilities on logistics service capability and performance in the context of international distribution centers. Moreover, the acquirement of instant information and knowledge about customers' requirements is a key factor for achieving speed, frequency, and reliability in modern logistics (Yang et al., 2009). This study differs from previous research in two ways. First, while prior studies have examined the effect of organizational learning on performance, few studies specifically focused on the logistics learning capability and examined its effect on service capability. Finally, this study proposes a new five-dimension to measure logistics learning capability which can be called OCEAN capability. Therefore, it is worth the effort to examine the effects of logistics learning capability on logistics service capability and firm performance from an international distribution center operator's (IDCOs) perspective. The term IDCOs will be used in the analysis of findings derived from the survey presented in the fourth section.

There are five sections in this study. Section 1 introduces the motivation and purpose of the research. Section 2 reviews the literature on logistics learning capability, logistics service capability, and firm performance. A conceptual framework and research hypotheses are also provided in this section. Section 3 describes the research methodology, including questionnaire design, sampling technique, and methods of analysis. Section 4 presents the results of analysis. The conclusions and implications are discussed in the final section.

2. Literature Review and Hypotheses Development

2.1 Logistics learning capability

An increasingly dynamic environment has forced firms to place a greater emphasis on organizational learning (Huber, 1991). Particularly, logistics industry is highly competitive and has the features of knowledge and labor intensive. Logistics learning capability, therefore, has been regarded as a means for creating a competitive advantage and potential to be innovative, and has been widely adopted by such organizations as Wal-Mart, Nokia, and UPS (Esper et al., 2007; Alegre and Chiva, 2008). Esper et al. (2007) defined logistics learning capability as, *"the ability of a logistics organization to effectively maintain and manage learning organization characteristics and convert learning outcomes to new logistics management strategies, tactics, and operations in support of future development of other logistics capabilities (p. 63)"*.

Organizational learning was composed of a set of learning foundations including shared vision, learning axioms, cross-functional teamwork, open mindedness, and experience sharing (Sinkula, 1994). When firms had organizational learning culture, it could help them develop system think, information sharing, and collaborative teamwork skills to improve their logistics and firm performance (Drew and Smith, 1998). Jerez-Gómez et al. (2005) developed a measurement scale for organizational learning capability including managerial commitment, systems perspective, openness and experimentation, and knowledge transfer and integration. Panayides (2007) also used four dimensions, namely, commitment to learning, shared vision, open-mindedness, and intra-organizational knowledge sharing to measure logistics service providers' organizational capability.

Because there is no one consistent dimension of learning capability, it is treated as a complex multidimensional construct (Slater and Narver, 1995; Jerez-Gómez et al., 2005). Based on a literature review of learning capability, this study proposed a multidimensional construct including open-mindedness (O), commitment to learning (C), system perspective (E), partner learning (A), and shared vision (N) to measure the logistics learning capability (Baker and Sinkula, 1999; Jerez-Gómez et al., 2005; Santos-Vijande, 2005; Panayides, 2007; Liao et al., 2008; Liao and Wu, 2010). This five-dimension construct also could be named OCEAN capability.

2.2 *Logistics service capability*

Capabilities was defined as complex bundles of skills and accumulated knowledge, exercised through organizational processes, which enable firms to coordinate activities and make use of their assets (Day, 1994, p.38). They are strategically valuable to firms (Prahalad and Hamel, 1990; Hafeez et al., 2002) and have been regarded as a strategic asset to lead superior performance and create customer value. As regards logistics, logistics service's purpose is to add value directly by providing a number of services to shippers, such as storage, cargo tracking, inland transport service, custom clearance service, packing, and documentation service (Lu, 2003; Yang, 2012). Thus, logistics service capabilities generally encompass such business behaviors and processes as customer service, responsiveness to customers, flexibility, quality, and order cycle time (Daugherty, 1998; Zhao et al., 2001; Sinkovics and Roath, 2004; Kim, 2006). Drawing from Lu and Yang's (2010) and Yang's (2012) studies, this study defined logistics service capability as an IDCO's skills and accumulated knowledge that are used to coordinate activities and make use of its resources for managing and integrating processes within supply chains to provide one-stop logistics shopping services and, in turn, better customer service performance.

Globalization has led to dynamic and highly competitive marketplace for logistics industry. It's imperative for logistics service providers to improve their logistics service capabilities to meet customers' requirements for an expanding range of logistics services (Lai, 2004). The issue of logistics capability thus has attracted a lot of attentions over the last few years. Attributes of logistics service capability were typically related to logistics services and activities such as EDI linkage, cargo tracing, customer response, service reliability, flexible operation, quality, and value-added services (Murphy and Poist, 2000; Lai, 2004). Hayes et al. (1988) identified five logistics service capabilities, namely, cost, quality, flexibility, delivery, and innovation, as driving strategy to deliver superior value to customers. Fawcett et al. (1997) also noted that delivery speed, quality service, flexibility, cost, and innovation could achieve high level international operations performance. Lu and Yang (2007) identified four key logistics capabilities, namely, customer response, innovation, economic scale, and flexible operation and logistics knowledgeability for international distribution center operators. Panayides (2007) examined the impact of organizational learning on logistics service effectiveness, measuring logistics service effectiveness in terms of reliability, timely responsiveness, accuracy in documentation, accuracy in information, service fulfillment, problem solving ability, and empathy towards client. Yang et al. (2009) found logistics service capabilities for liner shipping service are logistics service reliability capability, logistics value-added capability, relationship building capability, and information integration and flexibility capability.

Logistics service capabilities as means to enhance competitive advantage and performance has been widely espoused. Jones and George (2009) pointed out that efficiency, quality, customer response, and innovation were the crucial ways to create a firm's competitive advantage. Based on literature review on logistics service capability, four commonly used indicators, namely, customer response (Morash et al., 1996; Lu and Yang, 2007), quality (Hayes et al., 1988; Fawcett et al., 1997; Murphy and Wood, 2008), flexibility (Hayes et al., 1988; Fawcett et al., 1997; Sinkovics and Roath, 2004; Lu and Yang, 2007; Murphy and Wood, 2008), and innovation (Hayes et al., 1988; Fawcett et al., 1997; Lu and Yang, 2010) were adapted to measure logistics service capabilities for IDCOs.

2.3 *Firm performance*

Performance analysis is employed to measure the efficiency of resource allocation and the outcome of corporate objectives. Firm performance typically could be measured by both financial and non-financial indicators (Venkatraman and Ramanujam, 1986). To comprehensively measure a firm's performance, a composite measure of performance has been recommended by Dess and Robinson (1984). This study, thus, used a combination of both financial and customer service measures to evaluate the performance of IDCOs.

A number of performance indicators have been identified from previous studies on logistics management to measure firms' performance. To summarize, the recommended and common use of firm performance measures in logistics research were profit rate, sales' growth rate, market share growth, reduced logistics cost, return on investment, corporate reputation, market position, service quality, customer satisfaction, customer

relationship, customer satisfaction, and customer loyalty (Fawcett et al., 1997; Lynch et al., 2000; Panayides, 2004; Autry et al., 2005; Kim, 2006; Yang et al., 2009; Yang, 2012). These measures typically could be divided into financial and non-financial or customer service performance. It should be noted that perceptual measures were adopted to assess firms' performance due to the fact that actual performance data is rarely published for individual business units.

2.4 Research framework and hypotheses

The research framework for this study, based on previous studies on organizational learning and logistics service capability, is shown in Figure 1. The network of relationships among the variables in the model and the rationale for the proposed linkages are elaborated on below.

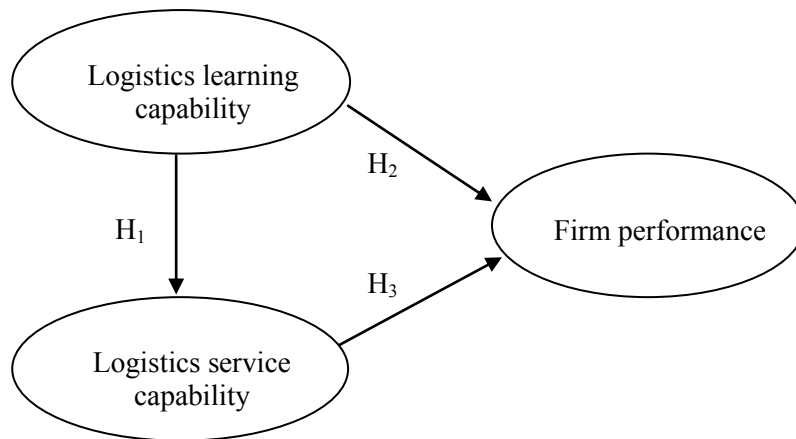


Fig 1. Research Framework

Capabilities that are inimitable and durable have been regarded as a key to attain sustainable competitive advantage. Thus, learning faster and to be more innovative in logistics service activities could help logistics companies to build a core capability which will be extremely difficult for competitors to buy and imitate in today's dynamic marketplace. Learning capability particularly has been seen as an important motivator for achieving logistics goals and improving logistics performance (Ellinger et al. 2002; Hult et al. 2003). Panayides (2007) also concluded that organizational learning had a positive influence on logistics service effectiveness and firm performance. Apparently, international distribution center operators can sustain their competitive advantage through a logistics learning capability (Esper et al. 2007). Accordingly, this study hypothesizes that:

H1: Logistics learning capability has a positive effect on the IDCs' logistics service capability

H2: Logistics learning capability has a positive effect on the IDCs' firm performance

Logistics service capability is the ability of logistics service providers to create and deploy resources to satisfy the logistics needs of their customers in pursuit of better service performance (Lai, 2004). Lu and Yang (2010) and found that logistics service capabilities had a significant positive impact on IDCs' firm performance. Yang et al. (2009) also noted that liner shipping firms' logistics service capability can significantly lead to superior customer service performance and financial performance. Thus, based on the preceding review of the literature on logistics capabilities, a firm with the ability to create and deploy resources to satisfy customers' logistics service needs will achieve superior firm performance. Accordingly, this study hypothesizes that:

H3: Logistics service capability has a positive effect on the IDCs' firm performance

3. Methodology

3.1 Questionnaire design and measures

The data for this study were collected from a self-administered questionnaire survey, which was designed

based on the stages outlined by Churchill and Iacobucci (2002). The measurements items for logistics learning capability, logistics service capability, and firm performance in this study were mainly adapted from prior studies and then discussed with logistics executives and experts in order to ensure their validity. Accordingly, content validity was ensured through basing questionnaire items on previous studies and discussions with logistics experts. Drawing from Baker and Sinkula's (1999) and Panayides's (2007) studies, five dimensions with 23 logistics learning capability attributes were selected for use in the questionnaire survey. On the other hand, four dimensions with 16 attributes adapting from Lu and Yang's (2010) work was used to measure the logistics service capability of IDCOs. Attitudes toward the logistics learning capability attributes and logistics service attributes were assessed using a five-point Likert scale where 1 corresponded to "strongly disagree" and 5 represented "strongly agree".

With regard to firm performance, a composite measure with seven-item was adapted from Lu and Yang's (2010) and Yang's (2012) studies to measure IDCOs' firm performance in this study. These seven items included customer relationship, customer satisfaction, customer loyalty, profit rate, sales' growth rate, market share growth, and reduced logistics cost. Respondents were asked to rate how well they considered their company's performance relative to their major competitors, using a five-point Likert scale, where 1 corresponded to "very poor" and 5 represented "very good".

3.2 *Sampling techniques*

The sample for this study was selected from the Directory of Members of the Logistics Management Association of Taiwan, 2013. The questionnaire survey was sent to 125 managers of public distribution center operators in Taiwan in May 2012. The initial mailing elicited 46 usable responses. A follow-up mailing was sent two weeks after the initial mailing. An additional 37 usable responses were returned. Therefore, the total usable number of responses was 83. Although the sample size was small, the overall response rate for this study was high, 66.4%, as it represented over half of the total target population. Accordingly, survey findings could not be considered biased since the return rate was not lower than 40% (Akintoye et al., 2000; Moser and Kalton, 1971).

A comparison of early (those responding to the first mailing) and late (those responding to the second mailing) respondents was carried out to test for non-response bias (Armstrong and Overton, 1977). The 83 survey respondents were divided into two groups, early ($n = 46$, 55.4%) and late ($n = 37$, the remaining 44.5%) respondents based on their response wave (first and second). T-tests were performed on the two groups' responses. At the 5% significance level, there were no significant differences between the two groups' perceptions of the agreement of the various logistics learning attributes. Although results did not rule out the possibility of non-response bias, they suggested that non-response bias was not a problem because late respondents' responses appeared to reflect those of first wave respondents.

Since both the independent and dependent measures were obtained from the same source and as this study collected data via the same method, this can lead to the possibility of common method variance bias (Podsakoff et al., 2003). This study therefore employed both procedural remedies and statistics remedies based on Podsakoff et al.'s study to check for such a potential problem. With respect to procedural remedies, respondents were assured of anonymity and the confidentiality of their response to encourage them to answer as honestly as possible. Moreover, since nearly 70% of respondents were managers or above and were actively involved in and anchor operations in their businesses, they were knowledgeable to provide the information the study required. On the other hand, statistics remedies applying Harman's one factor test where all items, presumably measuring a variety of different construct, were subjected to a single factor analysis was conducted in this study. The factor analysis result indicated 10 significant factors with eigenvalues greater than 1 were extracted, explaining 75.6% of the variances. Since the first factor only accounted for 35.74% of total variance, the common method variance problem was therefore mitigated in this study.

3.3 *Research methods*

A two-step structural equation modeling (SEM) approach suggested by Anderson and Gerbing (1988) was employed to analyze the data in this study. In the first step, confirmatory factor analysis was performed to

assess the validity of the measurement model. The second step then requires estimating the structural model from the latent variables. All analyses were carried out using the *SPSS 18.0 for Windows* and *AMOS 18.0* statistical packages.

4. Analysis of Findings

4.1 Respondents' characteristics

The profiles of respondents' companies and their characteristics indicate that most respondents were managers/assistant managers (39.8%), vice presidents or above (27.7%), directors (16.9%), clerks (10.8%) or held other positions (4.8%). In general, managers are actively involved in and anchor operations in businesses. The high percentage (67.5%) of responses from managers and vice presidents or higher, thus endorsed the reliability of survey findings. With respect to ownership pattern, the majority of respondents' firms were local companies (78.3%), followed by foreign companies (13.3%), and joint-venture companies (8.4%). Moreover, nearly 27% of respondents' firms had been in operation for more than 20 years, and 30.5% had been operating between 11 and 20 years. Analysis of responses also reveals that about 58% of respondents' companies employed between 51 and 300 employees, and 19.3% employed below 50 and more than 500 personnel, respectively. Respondents were also asked to provide their companies' annual revenue. Result shows 34.9% of respondents reported their firm's annual revenue was between NT\$100 million and NT\$499 million, while 18.1% and 27.7% of companies' annual revenue were below NT\$50 million and greater than NT\$1,000 million, respectively. Results also reveal 38.3% of respondents had one distribution center and remains (61.7%) had 2 distribution centers or more.

4.2 CITCs and reliability test

Prior to purification of the measurement model, corrected item-total correlation coefficients and Cronbach alpha statistics were used to determine whether these constructs were consistent and reliable. Item-total correlation refers to a correlation of an item or indicator with the composite score of all the items forming the same set. CITC does not include the score of the particular item in question in calculating the composite score, and thus it is labeled 'corrected' (Koufteros, 1999). Recommendations typically suggest that items from a given scale exhibiting item-total correlations should exceed 0.4 (Churchill and Iacobucci, 2002; Lai et al., 2002). CITC analyses were performed for each construct. Table 1 shows that all CITC scores were well above 0.4, concluding that these 46 items measured the same underlying construct.

Table 1. CITC coefficients and results of reliability test

Dimensions	No. of items	Mean	S.D.	Alpha	Range of corrected item-total correlation
Open-mindedness	5	3.786	0.268	0.814	0.492-0.718
Commitment to learning	5	4.188	0.195	0.859	0.490-0.748
System perspective	4	3.813	0.158	0.854	0.575-0.767
Partner learning	4	3.900	0.122	0.883	0.691-0.799
Shared vision	5	4.048	0.110	0.870	0.539-0.824
Flexibility capability	4	4.174	0.152	0.810	0.476-0.776
Innovation capability	4	3.664	0.084	0.844	0.617-0.782
Quality capability	4	4.186	0.182	0.844	0.588-0.758
Customer response capability	4	4.223	0.110	0.863	0.561-0.834
Customer performance	3	4.240	0.105	0.868	0.633-0.801
Financial performance	4	3.655	0.063	0.754	0.453-0.652

A reliability test based on the Cronbach alpha statistic was also used to determine whether each of the twelve dimensions was consistent and reliable. As shown in Table 1 Cronbach alpha values for each measure were

well above the suggested threshold of 0.7, which is considered adequate for confirming a satisfactory level of reliability in research (Nunnally, 1978; Churchill and Iacobucci, 2002). However, these techniques do not allow for assessing unidimensionality, convergent validity, nor discriminant validity (Anderson and Gerbing, 1988). A CFA with a multiple-indicator measurement model was therefore used to ensure validity (Anderson and Gerbing, 1988; Segars, 1997).

4.3 Analysis of the measurement model

Before testing the hypotheses, a confirmatory factor analysis using AMOS was performed to ensure the validity of the measurement scale (Anderson and Gerbing, 1988). The initial model was found to be discredited. The χ^2 value ($\chi^2=69.008$, $df=41$, $p=0.004$) was statistically significant at the 0.05 level of significance, indicating that differences between model-implied covariance matrix Σ and data-observed S were significantly large. Accordingly, the results implied that the initial model needed to be modified by examining the statistical criteria such as standardized residuals and modification indices. An inspection of the standardized residuals was subsequently conducted and the item “quality capability” was found to have the highest residuals (values=-1.834 and -1.727) with commitment to learning and system perspective. In addition, a high modification index (values greater than 4) was found to exist between quality capability and system perspective. The item “quality capability” was therefore removed in the revised model and its removal strengthened overall model fit (Hair et al., 2009). The resulting model consequently provided an adequate model fit ($\chi^2=41.696$, $df=32$, $p=0.117>0.05$; GFI=0.910; AGFI=0.846; CFI=0.978; RMR=0.021; RMSEA=0.061), indicating that the proposed model was purified and provided sufficient support for the results to be deemed an acceptable representation of the hypothesized constructs (Bagozzi and Yi, 1988; Koufteros, 1999). The tests of validity and unidimensionality are subsequently described below.

Convergent validity was proven due to all the critical ratio (C.R.) values were significant at the 0.05 level, effectively suggesting that all the indicators measure the same construct and providing satisfactory evidence of their convergent validity and unidimensionality (Anderson and Gerbing, 1988). Moreover, item reliability (R^2 value) can be used to estimate the reliability of a particular observed variable or item (Koufterous, 1999). With the exception of commitment to learning being close to the recommended level of 0.3, all the other items easily met the 0.3 criterion, providing evidence of convergent validity (Hair et al., 2009).

Discriminant validity was assessed by comparing the average variance extracted (AVE) with the squared correlation between constructs. Discriminant validity exists if the items share more common variance with their respective construct than any variance that the construct shares with other constructs (Fornell and Larcker, 1981; Koufteros, 1999). Results, as shown in Table 2, indicate that the highest squared correlation was observed between logistics learning capability and logistics service capability at 0.453. This was significantly lower than their individual AVE values of 0.628 and 0.537, respectively. Accordingly, the results demonstrate evidence of discriminant validity for the study constructs.

Table 2. Average variance extracted and composite reliability for each measure

Measure	AVE	Construct reliability	ξ_1 Logistics learning capability	η_1 Logistics service capability	η_2 Firm performance
ξ_1 : Logistics learning capability	0.628	0.891	1.000		
η_1 : Logistics service capability	0.537	0.774	0.673 (0.453)	1.000	
η_2 : Firm performance	0.658	0.793	0.377 (0.142)	0.510 (0.260)	1.000

Construct reliability provides a measure of the internal consistency and homogeneity of the items comprising a scale (Churchill, 1979). The reliability is the degree to which a set of two or more indicators share the measurement of a construct. Highly reliable constructs are those in which the indicators are highly intercorrelated, indicating that are all measuring the same latent construct. The range of values for reliability is between 0 and 1. The results in Table 2 indicate that the reliability of the constructs of logistics learning capability, logistics service capability, and firm performance scales was 0.891, 0.774, and 0.793, respectively,

all of which exceeded the recommended level of 0.60 (Bagozzi and Yi, 1988; Sanchez-Rodriguez et al., 2005; Hair et al., 2009).

4.4 Structural equation modeling: hypotheses testing

After confirming the fitness of the proposed model, this study proceeds to examine the hypothesized relationships. Results, as shown in Table 3, indicated that the data adequately supported the estimated model. The Chi-Square statistic ($\chi^2=41.696$, $df=32$) at 0.117 is below the threshold level of 0.05 significance, suggesting the differences in predicted and actual matrices are insignificant and strongly demonstrates the model's fitness to the data collected. Standardized parameter estimates and t values for the model are also shown in the Table 3. Results showed that logistics learning capability ($\beta = 0.811$, C.R. > 1.96) was found to have significant influences on IDCO's logistics service capabilities, supporting H₁. Results also supported H₃ and indicated that there is a positive relationship between logistics service capability ($\beta = 0.929$, C.R. > 1.96) and firm performance. However, there is a lack of support for a significantly positive relationship between logistics learning capability ($\beta = -0.322$, C.R. < 1.96) and firm performance, suggesting the impact of logistics learning capability on IDCOs' firm performance was not supported in this study (H₂).

Results implied that IDCOs take their efforts to undertake logistics learning activities can better their logistics service capability, and in turn, enhance their firm performance. The above findings are consistent with those from the studies of Ellinger et al. (2002), Hult et al. (2003), and Panayides (2007).

Table 3. Results of the structural equation modeling

Relationships	Estimate	S. E.	C.R.	P	Sign	Supported
Logistics learning capability > Logistics service capability	<u>0.811</u>	0.120	<u>4.640</u>	0.000	+	Supported
Logistics learning capability > Firm performance	-0.322	0.255	-1.191	0.234	-	Not supported
Logistics service capability > Firm performance	<u>0.929</u>	0.443	<u>2.888</u>	0.004	+	Supported

Fit indices: $\chi^2=41.696$ ($p=0.117$), $\chi^2/df= 1.303$, $GFI=0.910$, $AGFI=0.846$, $RMR=0.021$, $RMSEA=0.061$.

5. Discussions and Conclusions

This study draws attention to the importance of the effect of logistics learning capability on logistics service capability and firm performance in the context of international distribution centers. The main findings of this study are summarized below.

Drawing from literature review on organizational learning and logistics researches, a five-dimension scale including open-mindedness (O), commitment to learning (C), system perspective (E), partner learning (A), and shared vision (N) was proposed in this study to measure IDCOs' logistics learning capability and could be named OCEAN capability. According to the mean values of each dimension, commitment to learning was perceived to be the most valuable learning capability to IDCOs, followed by shared vision, partner learning, system perspective, and open-mindedness. On the other hand, customer response capability was perceived to be the most valuable service capability, followed by quality capability, flexibility capability, and innovation capability.

A two-step structural equation modeling (SEM) was performed to test the research hypotheses and evaluate the relationships among logistics learning capability, logistics service capability, and firm performance. Results indicated that logistics learning capability was significantly positive related to IDCOs' logistics service capability (H₁), which implies that IDCOs can significantly better their logistics service capability by organizational learning activities. Therefore, IDCOs were suggested to build a learning organization with the features of commitment to learning, partner learning, shared vision, open-mindedness, and system perspective. Through learning-by-doing, IDCOs can build their core logistics service capability specifically on customer response capability, flexibility capability, and innovation capability which will be extremely difficult for competitors to imitate. The finding is consistent with previous studies (Ellinger et al., 2002; Hult et al., 2003;

Panayides, 2007; Esper et al. 2007).

Results also indicate a significantly positive relationship between logistics service capability and firm performance (H3). Findings imply that IDCs can develop their customer response capability, flexibility capability, and innovation capability to positively strength their customer service performance and financial performance. The finding is consistent with previous studies (Innis and La Londe, 1994; Lai, 2004; Song and Panayides, 2008; Lu and Yang, 2010; Yang, 2012).

However, the effect of logistics learning capability on firm performance (H₂) was not supported in this study, which implies that the organizational learning activities do not directly influence firm performance. It is not surprising because it could impose additional costs on firms to build a learning organization. Thus, the involvement of learning activities could not provide superior performance in the short term for IDCs.

One of the major contributions of this study is that it is the first attempt to examine the impacts of logistics learning capability on logistics service capability and firm performance in the context of international distribution center operators. Moreover, this study contributes to the literature by proposing a new five-dimension construct for measuring logistics learning capability and demonstrates that through learning-by-doing on logistics activities can significantly enhance IDCs' logistics service capability and which in turn improve customer service performance and financial performance. Finally, though finding indicates that the involvement of logistics learning activities can not lead to superior firm performance in the short term. However, IDCs can put more efforts on the aspects of commitment to learning, partner learning, shared vision, open-mindedness, and system perspective to build their customer service capability, flexibility capability, and innovation capability and which in turn lead to superior firm performance in the long term.

From a theoretical perspective, this study contributes to the field by proposing a new five-dimension construct for measuring logistics learning capability and examining their effects on logistics service capability and firm performance. However, it suffers from several limitations. First, future research might be using the strategic group concept to classify IDCs into different logistics learning oriented firms based on the aforementioned logistics learning capability dimensions. Finally, logistics learning capability was no found to have a directly positive impact on firm performance. Future research therefore can perform hierarchy regression analysis to assess the mediating effect of logistics learning capability on logistics service capability and firm performance.

Acknowledgements

This research was sponsored by the National Science Council in Taiwan (R.O.C) under grant number NSC 102-2410-H-022-007.

References

- Akintoye, A., McIntosh, G. and Fitzgerald, E. (2000), A survey of supply chain collaboration and management in the UK construction industry, *European Journal of Purchasing & Supply Management* 6(3-4): 159-168.
- Alegre, J. and Chiva, R. (2008), Assessing the impact of organizational learning capability on product innovation performance: an empirical test, *Technovation* 28: 315-326.
- Anderson, J. and Gerbing, D. W. (1988), Structural equation modeling in practice: a review and recommended two-step approach, *Psychological Bulletin* 103(2): 411-423.
- Armstrong, S. J. and Overton, T. S. (1977), Estimating nonresponse bias in mail surveys, *Journal of Marketing Research* 14(6): 396-402.
- Autry, C. W., Griffis, S. E., Goldsby, T. J. and Bobbitt, L. M. (2005), Warehouse management systems: resource commitment, capabilities, and organizational performance, *Journal of Business Logistics* 26(2): 165-182.
- Bagozzi, R. P. and Yi, Y. (1988), On the evaluation of structural equation models, *Academy of Marketing Science* 6(1): 74-93.
- Baker, W. E. and Sinkula, J. M. (1999), The synergistic effect of market orientation and learning orientation on organizational performance, *Journal of the Academy of Marketing Science* 27(4): 411-427.

- Barney, J. B. (1991), Firm resources and sustained competitive advantage, *Journal of Management* 17(1): 99-120.
- Churchill, G. A. (1979), A paradigm for developing better measures of marketing constructs, *Journal of Marketing Research* 16(1): 360-375.
- Churchill, G. A. and Iacobucci, D. (2002), *Marketing Research: Methodological Foundation*, 8th Edition, South-Western: USA.
- Daugherty, P. J., Stank, T. P. and Ellinger, A. E. (1998), Leveraging logistics/distribution capabilities: the effect of logistics service on market share, *Journal of Business Logistics* 19(2): 35-51.
- Day, G. S. (1994), The capabilities of market-driven organizations, *Journal of Marketing* 58(4): 37-52.
- De Geus, A. P. (1988), Planning as learning, *Harvard Business Review* 66(2): 70-74.
- Dess, G. G. and Robinson, J. (1984), Measuring organizational performance in the absence of objective measures: the case of the privately-held firm and conglomerate business unit, *Strategic Management Journal* 5(3): 265-273.
- Drew, A. W. and Smith, A. C. (1998), The new logistics management: transformation through organizational learning, *International Journal of Physical Distribution and Logistics Management* 28(9/10): 666-682.
- Ellinger, A. E., Ellinger, A. D. and Keller, S. B. (2002), Logistics managers' learning environments and firm performance, *Journal of Business Logistics* 23(1): 19-38.
- Esper, T. L., Fugate, B. S. and Davis-Sramek, B. (2007), Logistics learning capability: sustaining the competitive advantage gained through logistics leverage, *Journal of Business Logistics* 28(2): 57-81.
- Fawcett, S. E., Stanley, L. L. and Smith, S. R. (1997), Developing a logistics capability to improve the performance of international operations, *Journal of Business Logistics* 18(2): 101-127.
- Fornell, C. and Larcker, D. F. (1981), Evaluating structural equation models with unobservable and measurement error, *Journal of Marketing Research* 30(2): 65-73.
- Garcia-Morales, V. J., Llorens-Montes, F. J. and Verdu-Jover, A. J. (2007), Influence of personal mastery on organizational performance through organizational learning and innovation in large firms and SMEs, *Technovation* 27: 547-568.
- Grant, R. M. (1991), The resource-based theory of competitive advantage: implication for strategy formulation, *California Management Review* 33(3): 114-135.
- Hafeez, K., Zhang, Y. B. and Malak, N. (2002), Determining key capabilities of a firm using the analytic hierarchy process, *International Journal of Production Economics* 76: 39-51.
- Hair, J. F., Black, B., Babin, B., Anderson, R. E. and Tatham, R. L. (2009), *Multivariate Data Analysis*, 6th Edition, Pearson Education Taiwan Ltd: Taiwan.
- Hayes, R., Wheelwright, S. C. and Clark, K. B. (1988), *Dynamic Manufacturing: Creating the Learning Organization*, The Free Press: New York.
- Huber, G. (1991), Organizational learning: the contributing processes and the literatures, *Organization Science* 2(1): 88-116.
- Hult, G. T. M., Ketchen, D. J. and Nichols, E. L. (2003), Organizational learning as a strategic resource in supply management, *Journal of Operations Management* 21: 541-556.
- Hult, G. T. M., Ketchen, D. J., Cavusgil, S. T. and Calantone, R. J. (2006), Knowledge as a strategic resource in supply chains, *Journal of Operations Management* 24(5): 458-475.
- Innis, D. E. and La Londe, B. J. (1994), Customer service: the key to customer satisfaction, customer loyalty, and market share, *Journal of Business Logistics* 15(1): 1-28.
- Jerez-Gómez, P., Céspedes-Lorente, J. and Valle-Cabrera, R. (2005), Organizational learning capability: a proposal of measurement, *Journal of Business Research* 58(6): 715-725.
- Jiang, X. and Li, Y. (2008), The relationship between organizational learning and firms' financial performance in strategic alliance: a contingency approach, *Journal of World Business* 43: 365-379.
- Jiménez-Jiménez, D. and Sanze-Valle, R. (2010), Innovation, organizational learning, and performance, *Journal of Business Research* 64: 408-417.
- Jones, G. R. and George, J. M. (2009), *Contemporary Management*, Sixth Edition, McGraw-Hill: New York.
- Kapp, K. M. (1999), Transforming your manufacturing organization into a learning organization, *Hospital Material Management Quarterly* 20(4): 46-54.
- Kim, S. W. (2006), Effects of supply chain management practices, integration and competition capability on performance, *Supply Chain Management: An International Journal* 11(3): 241-248.
- Koufteros, X. A. (1999), Testing a model of pull production: a paradigm for manufacturing research using structural equation modeling, *Journal of Operations Management* 16: 21-41.

- Lai, K. H. (2004), Service capability and performance of logistics service providers, *Transportation Research – Part E Logistics and Transportation Review* 40: 385-399.
- Lai, K. H., Ngai, E. W. T. and Cheng, T. C. E. (2002), Measures for evaluating supply chain performance in transport logistics, *Transportation Research Part E* 38: 439-456.
- Liao, S. H. and Wu, C. C. (2010), System perspective of knowledge management, organizational learning, and organizational innovation, *Expert Systems with Applications* 37: 1096-1103.
- Liao, S. H., Fei, W. C. and Liu, C. T. (2008), Relationships between knowledge inertia, organizational learning and organization innovation, *Technovation* 28: 183-195.
- Lu, C. S. (2003), Market segment evaluation and international distribution centers, *Transportation Research – Part E Logistics and Transportation Review* 39(1): 49-60.
- Lu, C. S. and Yang, C. C. (2007), Logistics capabilities, competitive advantage and firm performance in international distribution center operators, *Transportation Planning Journal* 36(2): 253-277.
- Lu, C. S. and Yang, C. C. (2010), Logistics service capabilities and firm performance in international distribution center operators, *The Service Industries Journal* 30(2): 281-298.
- Lynch, D. F., Keller, S. B. and Ozment, J. (2000), The effects of logistics capabilities and strategy on firm performance, *Journal of Business Logistics* 21(2): 47-67.
- Ministry of Economic Affairs's (MOEA) website: www.moea.gov.tw (Accessed in March 2014).
- Moser, C. A. and Kalton, G. (1971), *Survey Methods in Social Investigation*, 2nd Edition, Dartmouth Publishing: Aldershot, UK.
- Murphy, Jr. P. R. and Wood, D. F. (2008), *Contemporary Logistics*, Ninth Edition, Pearson Education, Inc., Upper Saddle River: New Jersey.
- Murphy, P. R. and Poist, R. F. (2000), Third-party logistics: some user versus provider perspectives, *Journal of Business Logistics* 21(1): 121-133.
- Nunnally, J. C. (1978), *Psychometric Theory*, 2nd Edition, McGraw-Hill: New York.
- Organisation for Economic Co-operation and Development (OECD) (1996), *The Knowledge-Based Economic*: Paris.
- Panayides, P. M. (2004), Logistics service providers: an empirical study of marketing strategies and company performance, *International Journal of Logistics Research and Applications* 7(1): 1-15.
- Panayides, P. M. (2007), The impact of organizational learning on relationship orientation, logistics service effectiveness, and performance, *Industrial Marketing Management* 36: 68-80.
- Podsakoff, P. M., MacKenzie, S. B., Lee, J. Y. and Podsakoff, N. P. (2003), Common method biases in behavioral research: a critical review of the literature and recommended remedies, *Journal of Applied Psychology* 88(5): 879-903.
- Prahalad, C. K. and Hamel, G. (1990), The core competence of the corporation, *Harvard Business Review* 68(3): 79-91.
- Russo, M. V. and Fouts, G. G. (1997), A resource-based perspective on corporate environmental performance and profitability, *Academy of Management Journal* 40(3): 534-559.
- Sanchez-Rodriguez, C., Hemsworth, D. and Martinez-Lorente, A. R. (2005), The effect of supplier development initiatives on purchasing performance: a structural model, *Supply Chain Management: An International Journal* 10(4): 289-301.
- Santos-Vijande, M. L., Sanzo-Pérez, M. J., Álvarez-González, L. I. and Vázquez-Casielles, R. (2005), Organizational learning and market orientation: interface and effects on performance, *Industrial Marketing Management* 34: 187-202.
- Segars, A. (1997), Assessing the unidimensionality of measurement: a paradigm and illustration within the context of information systems research, *Omega-International Journal of Management Science* 25(1): 107-121.
- Sharma, D., Scholar, R. and Sahay, B. S. (2004), Modeling distributor performance index using the system dynamics approach, *Asia Pacific Journal of Marketing and Logistics* 16(3): 37-67.
- Sinkovics, R. R. and Roath, A. S. (2004), Strategy orientation, capabilities, and performance in manufacturer-3PL relationships, *Journal of Business Logistics* 25(2): 43-64.
- Sinkula, J. M. (1994), Market information processing and organizational learning, *Journal of Marketing* 58: 35-45.
- Slater, S. F. (1996), The challenge of sustaining competitive advantage, *Industrial Marketing Management* 25: 79-86.

- Slater, S. F. and Narver, J. C. (1995), Market orientation and the learning organization, *Journal of Marketing* 59(3): 63-74.
- Song, D. W. and Panayides, P. M. (2008), Global supply chain and port/terminal: integration and competitiveness, *Maritime Policy and Management* 35 (1): 73-87.
- Stata, R. (1989), Organizational learning – the key to management innovation, *Sloan Management Review* 30(2): 63-74.
- Tseng, Y. Y., Yue, W. L. and Taylor, M. A. P. (2005), The role of transportation in the logistics chain, *Proceedings of the Eastern Asia Society for Transportation Studies* 5: 1657-1672.
- Venkatraman, N. and Ramanujam, V. (1986), Measurement of business performance in strategy research: a comparison of approaches, *Academy of Management Review* 11(4): 801-814.
- Yang, C. C. (2012), Assessing the moderating effect of innovation capability on the relationship between logistics service capability and firm performance for ocean freight forwarders, *International Journal of Logistics Research and Applications* 15(1): 53-69.
- Yang, C. C., Marlow, P. B. and Lu, C.S. (2009), Assessing resources, logistics service capabilities, innovation capabilities and the performance of container shipping services in Taiwan, *International Journal of Production Economics* 122: 4-20.
- Zhao, M., Droge, C. and Stank, T.P. (2001), The effects of logistics capabilities on firm performance: customer-focused versus information-focus capabilities, *Journal of Business Logistics* 22(2): 91-107.

ⁱ One U.S. dollar equals approximately 30 New Taiwanese (NT) dollars.

Development of Ship's Safety Management Evaluation Tool for Maritime Safety Information System – A Case Study of Korean Flag Ship and Shipping Company

Hwa Young Kim¹, Gyei Kark Park², Sung Woo Lee³ and Gun Woo Lee³

¹Maritime Safety Research Center, Korea Ship Safety Technology Authority, Incheon, Republic of Korea.

²Department of Logistics and Maritime Studies, Mokpo Maritime University, Mokpo, Republic of Korea.

³Department of Maritime Industry & Logistics Division, Korea Maritime Institute, Seoul, Republic of Korea.

Abstract

Maritime transportation by ship is expanding in accordance with the growth of global economy and the increase of international trades between countries. Recently, as a result of FTA (free trade agreements) between countries, worldwide cargo volume by ship is expected to increase. Such an increase in maritime transportation is led to a maritime traffic, and this poses a greater risk of maritime accidents in a country's coastal water. What's more, the mounting traffic of yacht and pleasure boats in littoral sea from the increase in maritime leisure activities are enhancing possibilities of maritime accidents. In accordance with such changes in maritime environment, it requires higher safety management skills from shipping companies, the main subject in charge of the safety matters. However, shipping companies tend to acknowledge safety as just a cost without profitability.

Therefore, in this paper, we propose a ship's safety evaluation tool, which can measure ship & shipping company's safety management level. We have drawn conclusions with an actual proof analysis in the paper. First of all, we established a safety evaluation tool, which have database and index for calculation of safety conditions since previous research about concept of safety management evaluation system. Secondly, we applied this proposed safety evaluation tool to Korean shipping company as a case study. Lastly, we found out the insufficient shipping companies on the safety management in ocean-going and coastal shipping industry.

Keywords: safety management evaluation tool, maritime safety information system, maritime safety, Korean shipping company, marine accidents.

1. Introduction

Maritime transportation by ship is expanding in the international trades between countries, and this trend is continuously on the rise. Especially, worldwide trade volume by ship is expected to continue due to the growth of Chinese economy and its shift of the world economy to Northeast Asia regions. And the number of international passengers by cruise ship, passenger ships and cargoes among the three countries of Korea, China and Japan keeps increasing. Such an increase in maritime transportation is leading to a higher maritime traffic, and this poses a greater risk of marine accidents in Korea's coastal water.

Moreover, human errors from aging of seafarers and multinational seafarers are threatening marine accidents. Above this, there are other factors that are putting maritime safety in danger such as shipping hazards affecting safe navigation of ships due to mounting traffic of yacht and pleasure boats in littoral sea due to the increase in maritime leisure activities.

According to such Korea's economic growth, there is a huge demand on improvement of the safety level and the government is pushing ahead with tougher safety management level. Despite a change in maritime safety environment, shipping companies are just regarding safety as a cost with no profitability. This resulted in their inactivity in management of ship's safety and investment.

Therefore, in this paper, we build a safety management evaluation tool to measure safety management conditions on shipping companies. And it's applied this tool to Korea shipping companies as practical case

study.

In chapter 2, we analysed marine accidents, port state control and safety management system in Korea. In chapter 3, we suggested that safety evaluation tool, which is consist of database and index for safety management conditions. And we carried out case study to Korean shipping company for rectifying proposed evaluation tool. Lastly, we suggested the practical use of evaluation tool to maritime safety information system for e-Navigation environment.

2. State of marine accidents and safety management in Korea

2.1 Analysis of marine accidents of Korea

In 2013, 87,489 vessels, which are consist of 75,031 fishing vessels, 9,360 cargo ships, and 3,098 vehicles for marine leisure, are registered in republic of Korea. In the recent five years (2009~2013), marine accidents occurred 3,770 cases on Korean flag vessels and littoral sea in Table 1. Marine accidents showed a tendency to slowdown annually since 946 cases in 2011 year. But, there are two points that have to solve and prevent marine accidents from statistical data. First of all, fishing vessel scored 77 percent of all marine accidents happened in recent 5 year. Second, there is no change the total case of accident in the merchant vessel since 2010. Rather, some serious collision and oil spill accidents happened last year in Korea.

Table 1. Number of marine accidents of Korea in recent 5 years (Year 2009-2013)

(Unit: case)

Type of vessel	2009	2010	2011	2012	2013	Sub total
Merchant vessel	115	184	199	189	194	881
Fishing vessel	608	553	747	537	444	2,889
Total	723	737	946	726	638	3,770

Source: Modified by author from data of Ministry of Oceans and Fisheries, Korea

The marine accidents such as casualty, total loss, oil pollution occurred to 216 ships in 2013 as shown in Table 2. These type of accident happened to 80 merchant vessel and 173 fishing vessel. In recent 5 year, the casualties by marine accidents are 415 peoples who are consist of 181 dead or missing and 234 seafarers injured.

Table 2. Major accidents and casualties by merchant vessel's accident

(Unit: ship's no, person)

Year	Major accidents (casualty, total loss, oil pollution)			Casualty in merchant vessel	
	Merchant vessel	Fishing vessel	Sub total	Dead or missing	Injured
2009	47	144	191	36	65
2010	66	147	213	46	14
2011	65	235	300	41	36
2012	69	173	242	30	43
2013	80	136	216	28	76
Total	327 (28.1%)	835 (71.9%)	1,162 (100%)	181	234

Source: Modified by author from data of Ministry of Oceans and Fisheries, Korea

According to the analysis of marine accidents, most accidents happened by the human error of crew. In recent 5 years, after analyzing 662 cases of marine accidents occurred in merchant ships, accidents due to human error were mostly accounted for 587 cases in Table 3, and poor handling or flaw, poor navigation infra the most in order. In terms of human error, there are poor handling, violation of voyage regulation, impropriety of ship maneuvering, and negligence of ship position check, etc. And in terms of poor handling or flaw include

poor fire-producing material handling, worn out wires, and in case of navigation infra, mainly the lack of waterway investigation attributed to marine accidents.

Table 3. Analysis for marine accidents by merchant ship

(Unit: case)

Type of accident causation	2009	2010	2011	2012	2013	Sub total
Human error	102 (141)	142 (150)	133 (120)	119 (133)	91 (109)	587 (653)
Poor handling or flaw	6 (11)	4 (11)	2 (5)	7 (5)	4 (9)	23 (41)
Navigation infra	2 (-)	1 (-)	- (-)	- (-)	2 (-)	5 (-)
Environment	1 (1)	2 (3)	1 (-)	1 (-)	5 (1)	10 (5)
Etc	10 (7)	8 (7)	8 (12)	6 (1)	5 (16)	37 (43)
Total	121 (160)	157 (171)	144 (137)	133 (139)	107 (135)	662 (742)

Remark: The figure in parentheses means that the accidents occurred by fishing vessel.

Source: Modified by author from data of Ministry of Oceans and Fisheries, Korea

2.2 Status of safety management

International Maritime Organization (IMO) adopted International Safety Management Code (ISM Code) for ships and shipping companies. The safety manual based on ISM Code provided a guideline seafarer's duties and work processes for safety and prevent accidents.

Accordingly, shipping companies' operating ships should embed in an importance of safety management and implement safety management systematically in order to prevent marine accidents. With that, each company's safety management level should be evaluated and be referred to enhancement of safety by complementing lacking parts for the reduction of marine accidents.

Most administration are strengthen port state control (PSC) to prevent marine accidents and protect coastal environment. The number of detention on Korean flag ships have been decreased from 27 cases in 2009 to 14 cases in 2013. On the Korean coastal area, many accidents are related with coastal ship such as small-sized cargo ship or towing vessel. So, Korean government was focused on the coastal ship for safety inspection. The frequency of inspection on the coastal ship is recorded to 957 cases, and found out 6,197 cases as a deficiency in Table 4.

Table 4. The result of PSC of ocean-going ship and safety inspection of coastal ship

(Unit: case)

Classification		2009	2010	2011	2012	2013
Ocean-going ship	Detention	27	28	26	25	14
Coastal ship	Frequency of inspection	58	188	1,118	1,242	957
	Deficiency	398	1,404	5,648	8,334	6,197

Source: Modified by author from data of Ministry of Oceans and Fisheries, Korea

Korean government is trying to prevent marine accident and grow up the abilities of shipping company's maritime safety management. In recent year, SMC (Safety Management Certificate) audit for coastal ship increased from 42 cases in 2009 to 109 cases in 2012, and major & minor non-conformity are also increased from 176 cases in 2009 to 276 cases in 2012 year in Table 5.

In case of DOC (Document of Compliance) audit on the ocean-going ship, audit frequency recorded 275 cases in 2009 to 157 cases in 2012, and major & minor non-conformity are decreased a little from 933 cases in 2009 to 664 cases in 2012. Especially, DOC audit frequency of coastal ship is increased annually from 1 case in 2009 to 49 cases in 2011, and also increased major & minor non-conformity from 4 cases in 2009 to 128 cases in 2011. In this result, we can found out administration focused on coastal ship for safety management.

Table 5. The result of ISM audit for ocean-going ship & coastal ship*(Unit: case)*

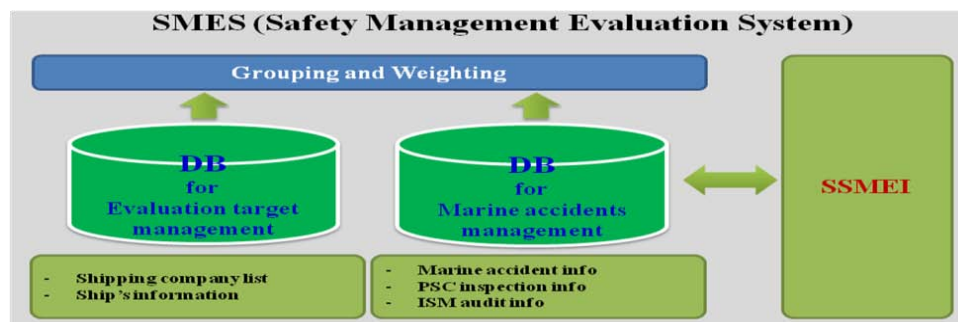
Classification		2009	2010	2011	2012
SMC audit for ocean-going ship	Frequency of audit	946	1,060	927	362
	Major non-conformity	164	134	89	9
	Minor non-conformity	1,063	1,367	1,041	563
SMC audit for coastal ship	Frequency of audit	42	112	158	109 ¹⁾
	Major non-conformity	7	23	81	28 ¹⁾
	Minor non-conformity	169	405	477	248 ¹⁾
DOC audit for ocean-going ship	Frequency of audit	275	281	230	157
	Major non-conformity	49	56	16	15
	Minor non-conformity	884	889	802	649
DOC audit for coastal ship	Frequency of audit	1	20	49	18 ¹⁾
	Major non-conformity	0	2	2	0 ¹⁾
	Minor non-conformity	4	76	126	33 ¹⁾

¹⁾ The data just accumulated from Jan to Aug in 2013.*Source: Modified by author from data of Ministry of Oceans and Fisheries, Korea*

3. A ship's safety management evaluation tool

3.1 Concept of safety management evaluation tool

A safety management evaluation sector should be simple, and have to accurate enough to secure reliability from the shipping companies when the results are presented. Therefore, the fundamental concept is based on the objectivity, reliability and simplicity for proposed the safety management evaluation tool. This constructed SMES (Safety Management Evaluation System), as a tool, is consist of two database that evaluation target management, marine accidents management, and one calculation formation for index, SSMEI(Ship Safety Management Evaluation Index), in the Figure 1(Kim, 2013).

**Fig 1. Diagram for constructed safety management evaluation system (SMES)**

3.2 Process for development of evaluation index

In Korea, the shipowner has to establish and conduct safety management system based on ISM Code on the Korean Maritime Safety Act. But, shipowner can consign to safety management agency company for improvement of safety management expertise.

The target vessels from the Act are ocean-going passenger ships, cargo ships more than 500 GT(gross tonnage), coastal tanker ship over 100 GT and towing vessel with barge for Korean flag ship and bareboat charter party hire purchase(BBCHP). In this study, we defined that the target ship was ocean-going vessels and coastal vessels with Korean flagged ships and BBCHP, which are only engaged in cargo transport except to passenger transportation.

In Korea, total number of ocean-going shipping companies are 187, and they are operating 1,635 vessels with 63.10 mil. GT. Especially, the 585 Korean flag vessels' gross tonnage is 9.5 mil. In case of BBCHP vessels,

occupied is 449 vessels accounting for 27.7 mil. GT. On the other hand, total coastal shipping companies are 718, and they have 2,034 vessels (1.88 mil. GT) as all Korean flag ship in the Table 6.

Table 6. The status of registered Korean ocean-going and coastal ships in 2012

(Unit: 1,000tons)

(Unit: 1,000tons)

Classification			Ship's no	GRT	DWT	TEU
Ocean-going vessel	Nat'l flag vessel	Korea flag	585	9,547	15,862	53,984
		BBCHP	449	27,744	44,049	409,539
		Sub total	1,034	37,292	59,912	463,523
	Foreign flag vessel	Bareboat Charter	62	2,015	3,637	20,052
		Time charter	539	23,706	33,407	577,793
		Sub total	601	25,812	37,044	597,845
Sub total			1,635	63,104	96,956	1,061,368
Coastal vessel	Coastal Nat'l flag vessel		2,034	1,880	-	-
Total			3,669	64,984	96,956 (-)	1,061,368 (-)

Source: Modified by author from data of Ministry of Oceans and Fisheries, Korea

In this research, we evaluated all vessels which are operating by ocean-going and coastal shipping companies, and then expressed safety management level by shipping company. So, we need to classify ocean-going and coastal shipping companies respectively depending on the size of their fleet such as the number of their owned vessels, and aggregation of gross tonnage. Because, most small-sized shipping companies, approximately 70%, are operating one or two ships, while big-sized companies are handling hundred of vessels in Korea shipping market. Therefore, we defined the group after due consideration from expert such as safety manager of shipping company, maritime researcher and public servant and so on.

3.3 Grouping of shipping companies for evaluation

For case study in this study, we defined the target companies that 119 ocean-going and 474 coastal shipping companies registered in the recent 3 years. It was grouped by ship's tonnage and number of operating ships.

In case of ocean-going shipping company, each group was set up based on 3 ships in number and 25,000 tons in gross tonnage. The group1 represents a company in possession of 1~3 ships and the average gross tonnage per ship less than 25,000 tons, group2 represents a company in possession of 4~7 ships or the average gross tonnage 25,001~77,000 tons, group3 represents a company in possession of over the 14 ships and the average gross tonnage more than 77,000 tons. As regards coastal shipping company, we set up the group by 950 gross tonnage as a standard. So, it was divided that group1 is under the 950 tons, group2 is 951~3,000 tons and group3 is over the 3,000 tons.

Table 7. The result of grouping for shipping company

(Unit: number)

Classification	Name of group	No. of shipping company	No. of ship
Ocean-going shipping company	Group 1	42	85
	Group 2	58	301
	Group 3	19	525
	Sub total	119	911
Coastal shipping company	Group 1	234	424
	Group 2	130	437
	Group 3	110	577
	Sub total	474	1,438
Total		593	2,349

As this result, we defined the three groups to ocean-going and coastal shipping companies respectively. As a result, group1 turns out to be 42 companies with 85 ships, group2 is 58 companies with 301 ships, and group3

is 19 companies with 525 ships in ocean-going shipping company. And also in case of coastal shipping company, group1 is 234 companies with 424 ships, 130 companies with 437 ships for group2, and group3 is 110 companies with 577 ships as Table 7.

3.4 Model for evaluation tool

It is established a safety management evaluation tool, SMEI (Safety Management Evaluation Index), as a function with MAR, MAPR, SAP shown as the Eq.1 based on its validity, objectiveness, reliability, clear-accurateness and availability. Evaluating subjects in safety management evaluation index are comprised of the number of marine accidents, and injuries, damages caused by marine accidents, and also the results of port state control, and ISM audit results of the safety management system based on ISM Code.

$$SMEI = f(MAR, MAPR, SAP) \quad (1)$$

MAR: marine accident ratio which is consist of number of accidents, type of accidents, injuries, ship's damage.

MAPR : Marine accident prevention ratio which is consist of number of detention & deficiency by port state control(PSC) inspection and major non-conformity & minor non-conformity by ISM audit.

SAP: safety advantage point which company's voluntary safety management activities and so on. (In this study, did not consider this element for case study)

$$MAR_i = \sum_{i=1}^n \frac{ar_i}{AR} \quad (2)$$

AR : accident ratio for all shipping companies

ar_i : i^{th} company's accident ratio

$$AR = \frac{A_{Total} \times w_1 + C_{Total} \times w_2 + D_{Total} \times w_3}{NoS} \times 100(\%) \quad (3)$$

NoS : total number of ships

A_{Total} : total number of accident

C_{Total} : total number of casualties by accident except to death

D_{Total} : total number of death by accident

w_1, w_2, w_3 : weight by type of accident

$$ar_i = \sum_{i=1}^n \frac{a_i \times w_1 + c_i \times w_2 + d_i \times w_3}{NoS_i} \times 100(\%) \quad (4)$$

NoS_i : total number of ships on i^{th} shipping company

a_i : number of accident number of i^{th} shipping company

c_i : number of casualties by accident on i^{th} shipping company

d_i : number of death by accident on i^{th} shipping company

$$MAPR_i = \sum_{i=1}^n \frac{pscr_i}{PSCR} + \frac{ismr_i}{ISMR} \quad (5)$$

$PSCR$: port state control result ratio

$ISMR$: ISM Code audit result ratio

$$PSCR = \frac{Det_{Total} \times w_4 + Def_{Total} \times w_5}{NoS} \times 100(\%) \quad (6)$$

Det_{Total} : total number of detention by PSC

Def_{Total} : total number of deficiency by PSC

w_4, w_5 : weight by type of PSC's result

$$pscr_i = \sum_{i=1}^n \frac{det_i \times w_4 + def_i \times w_5}{NoS_i} \times 100(\%) \quad (7)$$

Det_i : number of detention of i^{th} shipping company

Def_i : number of deficiency of i^{th} shipping company

$$ISMR = \frac{MAJOR_{Total} \times w_6 + MINOR_{Total} \times w_7}{NoS} \times 100(\%) \quad (8)$$

$MAJOR_{Total}$: number of major non-conformity

$MINOR_{Total}$: number of minor non-conformity

w_6, w_7 : weight by type of PSC's result

$$ismr_i = \sum_{i=1}^n \frac{major_i \times w_6 + minor_i \times w_7}{NoS_i} \times 100(\%) \quad (9)$$

$major_i$: number of detention of i^{th} shipping company

$minor_i$: number of deficiency of i^{th} shipping company

First of all, on the marine accidents, there are seventeen types of marine accidents such as collision, sinking, overturn, fire explosion and so on classified by the Korea Maritime Safety Tribunal (KMST). The KMST has been investigated marine accidents that the casualties include the number of dead or missing, seriously injured, slightly injured and the damage includes total loss, moderate damage and light damage etc. In this study, we used marine accident data and reports issued by KMST, and defined equation for calculation shown (2) to (4). Secondly, the result of port state control (PSC) are detention and deficiency. We collected this PSC result from Korean government, which ministry of oceans and fisheries (MOF) has been managed Korean flag ships with high target factor value (TFV) and cases about detention and deficiency released by Tokyo and Paris MOU and so on. And we defined the equation shown (5)-(7). Thirdly, the result of ISM audit are major non-conformity and minor non-conformity. These data also collected from MOF and produced by formula (8)-(9).

We found out that it's necessary to distinguish the weight among type of accidents, casualties, ship's damage and so on from interview with expert. Of course, there are differences in the same category. For example, in case of marine accident type, collision accident occupied approximately 70~80% every year in Korea. They said that the safety management level of these companies was not good through the investigation. So, expert said that collision accident have to consider for evaluating than others.

In this study, we set the weight to twelve evaluation items through the Delphi method with expert group shown in Table 8, and these weight involved to proposed SSMEI.

Table 8. The result of weight set by evaluation items

Classification	Evaluation items	Weight
Marine accident's type	collision	6.0
	sinking, overturn, fire explosion	4.0
	others	3.0
Type of casualties	dead or missing	10.0
	the insured	5.0
Ship's damage status	total loss	6.0
	moderate damage	3.0
	minor loss	1.0
Port state control inspection	detention	3.0
	deficiency	1.0
ISM audit	major non-conformity	3.0
	minor non-conformity	1.0

3.5 The result of evaluation

The number of Korean ocean-going ship operators for safety management evaluation is 119, and the number of ships is 911. In this research, we defined a conversion table from the value obtained equation (1).

As result of safety management evaluation, 42 companies with 85 ships in group1, are recorded average score to 89 points. In case of group2, the average score 84 points and 81 point in group3. And we can found out insufficient 23 companies for safety management below score 60 points shown as Figure 2.

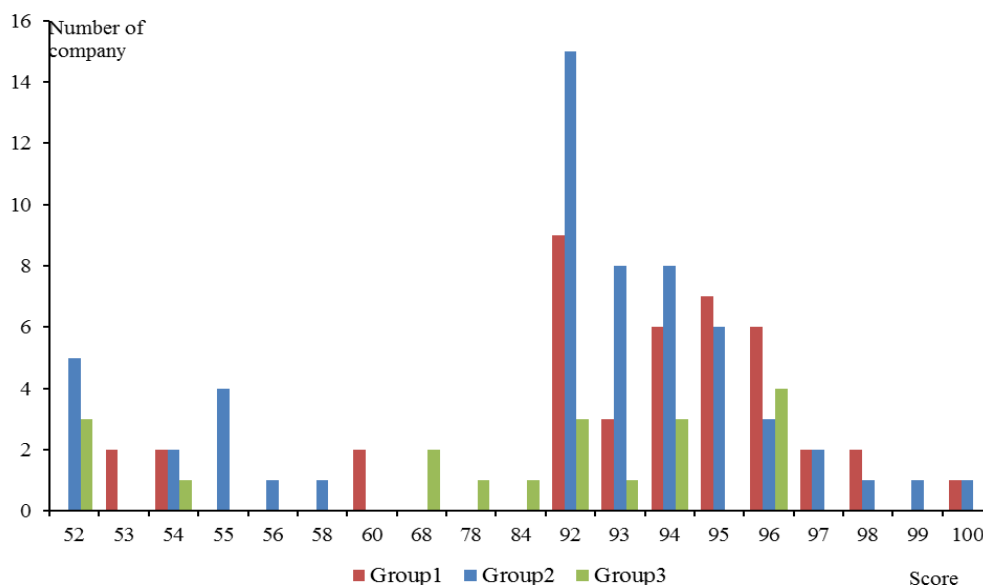


Fig 2. Result of evaluation in the ocean-going shipping companies

In case of coastal shipping companies, 474 companies with 1,438 ships are evaluated safety management by constructed tool shown as Figure 4. As result of evaluation, 234 companies with 424 ships has got average score to 88 points in group1, and score to 84 points in group2 with 130 companies of 437 ships. 110 companies with 577 ships in group3 recorded average score to 83 points. And we classified 80 coastal shipping companies below score 60 points with considering insufficient safety management shown as Figure 3.

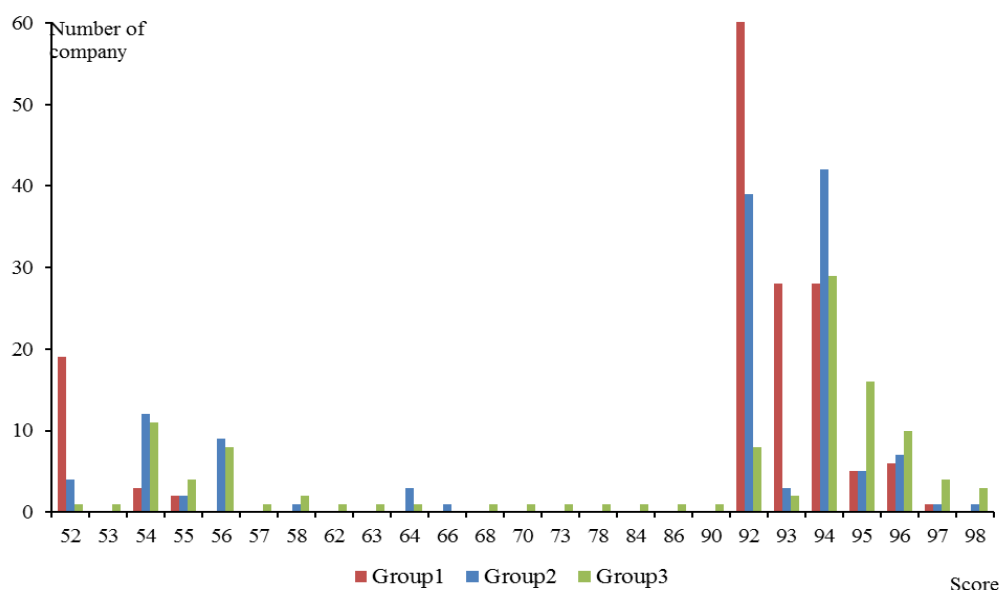


Fig 3. Result of evaluation in the coastal shipping companies

4. Conclusion

In this study, we constructed the safety management evaluation tool for shipping companies. And we carried out case study to rectify an evaluation tool against Korean ocean-going and coastal shipping companies. We evaluated 119 ocean-going shipping companies and 474 coastal shipping companies after grouping them having similar fleet size together and were able to gauge the shipping company's safety management ability in each group through this outcome. We found out the insufficient 23 ocean-going and 80 coastal shipping companies a score of less than 60.

This study is a fundamental research for evaluating shipping companies' safety management ability, thus it is essential to utilize this result for making maritime safety policy. For instance, it is important to encourage companies to participate in more actively through practicing incentives like shipping inspection commission free or reduction. Also laying the groundwork for market participants to voluntarily accommodate and utilize this evaluation in the market through applying discount premiums, when estimating insurance rates or referring it to a pre-qualification test for bituminous license bidding is significant.

In addition, e-Navigation system has been discussing in the IMO for prevention of accident and seafarer's navigation support using information communication technology (ICT). Therefore, this safety evaluation tool is useful for checking the high risk ships by ship's navigator or shore side such as VTS (Vessel Traffic Service) center.

Acknowledgement

This research was a part of the project titled "Development of the Intelligent Technology for Marine Accident Protection & Salvage" funded by the Ministry of Oceans and Fisheries, Korean

References

- Kim, H.Y. and Kim, J.H. (2013), A Study on the Construction of Safety Management Evaluation System for Shipping Company, Proceeding of International Forum on Shipping, Ports and Airport (IFSPA) 2013, 485-493.
- Kim, H.Y., Park, S.Y. and Kim, J.H. (2013), Development of Evaluation System for Ship Safety Management, Proceeding of Asia Navigation Conference.
- Kim, H.Y. and Kim, J.H. (2012), Study on Strategies for Safety Evaluation System of Shipping Company Using Imitation Strategy, Proceeding of Korean society of marine environment & safety, 196-198.
- Kang, W.S., Kim, H.Y. and Kim, J.H. (2012), A Study on the importance of Evaluation Factors for Safety Management Company Using AHP, Proceeding of Korean society of marine environment & safety, 193-195.
- Song, B.Y., Lee, D.H., Moon, D.S., Lee, H.S. and Kim, M.U. (2009), A Study on Development of Safety Index for Evaluating Railway Safety, Journal of the Korean society for railway (1) 443-449.
- Korean Maritime Safety Tribunal website: www.kmst.go.kr (Accessed in March 2013).
- Ministry of Land, Transportation and Maritime Affairs, Korea website: www.mltm.go.kr (Accessed in March 2013).
- Korea Ship Safety Technology Authority website: www.kst.or.kr (Accessed in March 2013).
- Korea Transportation Safety Authority website: www.ts2020.kr (Accessed in March 2013).

An Analysis of the Profitability of Container Shipping Lines

Wei-Ming Wu

Department of Logistics Management, National Kaohsiung First University of Science and Technology,
Kaohsiung, Taiwan. E-mail: ww@ncku.edu.tw.

Abstract

By building a theoretical model to describe the pricing behavior of an individual shipping line, this paper investigates the determinants of profitability of container shipping lines. The result reveals that the information derived from the outcomes of theoretical analysis is not sufficient for researchers to forecast the effects of variable changes to the profitability of shipping lines. In addition, the empirical results suggest that the global economic growth, the expansion of fleet capacity by an individual shipping line and technological progress have significantly contributed profit to shipping lines. By contrast, the expansion of global fleet capacity and the hiking bunker price have brought significantly negative impacts on the profitability of shipping lines. More surprisingly, the effect of deploying large vessels on profitability is not positive as expected in reflecting with the well recognized benefit of economies to scale. Overall, this paper concludes that the quantity-related but not price-related strategies play the key roles on improving the profitability of shipping lines.

Keywords: container shipping, comparative static analysis, profitability, price effect, non-price effect.

1. Introduction

The global container shipping industry is highly competitive and capital intensive. Despite of the tremendous capital requirement invested in the containerships, containers, vehicles, facilities and equipments, it is an easy task for shipping lines to provide shipping services in a new market segment by shifting vessels from other service routes. Some studies have regarded the shipping industry as a contestable market due to freely enter market without incurring much sunk cost (Jankowski and Davies, 1989; Franck and Bunel, 1991). Under an industrial surrounding with highly competitive market and notorious volatility of market demand and freights rate, typically, most shipping lines are struggling to make profit by means of cost reduction and revenue creation. For the sake of reducing operating cost and gaining market share, most shipping lines are aggressively to deploy a great number of large containerships into market over the past two decades. And therefore, the market structure and competition of global container shipping market have experienced a dramatic change by the enlargement of containerships and fleet in operation.

Furthermore, the downturn of global economy and the soaring fuel price have greatly lessened the profit of shipping lines during the past several years. Combined with the volatile market demand and bunker prices, however, the substantial profitability effect of deploying large vessels becomes vague. By developing a theoretical model, the aim of paper is focused on exploring the determinants of the profitability of shipping lines. By following the approach of comparative static analysis, some theoretical implications are uncovered to describe the impacts of the changes in variables on the profitability of shipping lines. Alternatively, an empirical study is performed to examine the theoretical implications derived from the model. By comparing the outcomes from theoretical model to the ones from empirical study, the impacts of variable changes on the profitability of a shipping line will be verified.

This paper is organized as follows. A literature review is presented in Section 2. In Section 3, a theoretical model for investigating the profitability of a carrier is developed. By applying the comparative static analysis, the impacts of the changes in variables on the profitability of a carrier are examined. In Section 4, an empirical study is performed. Finally, some conclusion is drawn in Section 5.

2. Literature Review

The theoretical justification for shipping lines introducing large vessels into market is to exploit the economies of scale achieved in maritime segment of the trip (Talley, 1990; Gilman, 1999; Cullinane and Khanna, 1999, 2000). In literature, Jansson and Shneerson (1987) shows that the unit operating cost at sea will be gradually decreased as ship size gets larger and larger. Due to the significant cost advantage in operating a large containership, under a highly competitive shipping market, no shipping line dares to be left behind in the game of expanding the vessel size in operation. However, the deployment of large containerships is not without its drawbacks. Lim (1994) points out that it is dangerous to generalize about the economies of scale derived from larger ship size. In practice, it results in withdrawing some vessels from the market, or maintaining vessels in the market but running them to be under-utilized (van der Jagt, 2003; Willmington, 2002; Imai et al., 2006; Wu, 2012). Furthermore, Lim (1998) also uncovers that adding capacity by delivering large vessels has raised the risk of over-tonnage, especially when several carriers are making the same decision and assigning large vessels to the same trade routes. Since the dropped freight rates have outpaced the cost reduction, associated with deploying large vessels, most shipping lines have not really reaped the benefits of large vessels. Evidently, the strategy of delivering both more and larger vessels into market is not a guarantee for shipping lines to secure the profitability.

Actually, the strategic consideration of entry deterrence may be another reason for shipping lines to deliver a great number of large vessels into market. Fusillo (2003) indicates that the long-lasting situation of excess capacity in global container shipping industry may be partially motivated by the strategy of deterring entry. Also, Wu (2009) demonstrates that the shipping lines with deep-sea service routes are likely to deliberately hold excess capacity to deter entry and maintain market power with higher market shares by means of aggressively deploying many large vessels. In addition, Wu (2012) shows that the global economy will greatly influence the freight rates and the profitability of shipping lines. Alternatively, Panayides, Lambertides and Savva (2011) and Wu and Lin (2014) show that the technological progress in shipping industry has gradually reduced the cost of transportation of general cargo and resulted in an improvement in operational efficiency. In shipping practice, bunker fuel cost is a considerable expense and accounts for a remarkable share of operating cost for shipping lines. Notteboom and Vernimmen (2009) indicates that the increasing bunker price in container shipping is only partially compensated through surcharge and will therefore affect earnings negatively. Evidently, the hiking bunker price has significantly increased the operating cost and reduced the profit of shipping lines.

3. Model

3.1 The Specification of Demand Function for Individual Shipping line

Under a given fleet capacity, the realized utilization of fleet capacity is an indicator for carriers to judge the real situation of shipping market demand. In shipping practice, the actual fleet utilization is typically referred as a guideline for a shipping line to adjust the level of its individual freight rate. As a result, the individual freight rate of a shipping line is generally fluctuated around the level of market freight rate which is determined by the aggregate transportation demand and supply in global container shipping market. Different from the level of market freight rate, therefore, the individual freight rate is frequently used as a tool to push the utilization of fleet capacity to the optimal level by a shipping line. The actual fleet utilization for a shipping line has played a crucial role in making the decision of pricing strategy. Accordingly, the demand function for a shipping line i can be specified as follow:

$$q_i = S_i Q - \delta_i P_i [U, \bar{P}(Q)] \quad (1)$$

where S_i is the market share earned by the shipping line. Q is the equilibrium quantity of cargos shipped in the market. P_i is the individual freight rate. δ_i is a parameter to represent the market reaction to the change of individual freight rate. Therefore, δ_i can be deemed as the freight rate elasticity of individual demand. By the law of demand, δ_i is further assumed to be positive and becomes larger as shippers' responses to the changes of freight rates are more sensitive and demanding. That is, the larger δ_i means a more competitive shipping market.

In reflecting of the concerns of shipping lines in making the pricing decision, P_i is usually related with the fleet utilization (U) and the market freight rate (\bar{P}). In order to maximize profit, a carrier is more likely to raise freight rate as the fleet utilization is steadily increased. Conversely, the deterioration of fleet utilization will push a carrier to reduce freight rate for improving its fleet utilization. Therefore, the relationship between the individual freight rate and the utilization of fleet capacity can be assumed and expressed as follow:

$$\frac{\partial P_i(U, \bar{P})_i}{\partial U} = P_U \geq 0 \quad (2)$$

As stated above, the market freight rate is viewed as a guideline for a carrier setting its individual freight rate. In general, a higher market freight rate creates more room for a shipping line to set a higher freight rate correspondingly. Therefore, the partial derivative of the individual freight rate with respect to the market freight rate can be assumed as:

$$\frac{\partial P(U, \bar{P})_i}{\partial \bar{P}} = P_{\bar{P}} \geq 0 \quad (3)$$

Since the demand in the global container shipping market is less elastic in the short-run, the increased transportation supply caused by launching more fleet capacity into market will not bring a great increase of output, but a deep drop of freight rate. In contrast, a strong growth of global trade induced by a booming global economy will pull up the transportation demand and thereby increase the levels of output and freight rate simultaneously. Accordingly, the respective impacts of global economy (G) and global containership fleet (K) on the output and freight rate of global shipping market can be assumed as follows:

$$\frac{\partial \bar{P}}{\partial G} = \bar{P}_G > 0 \quad (4) \quad \frac{\partial Q}{\partial G} = Q_G > 0 \quad (5) \quad \frac{\partial \bar{P}}{\partial K} = \bar{P}_K < 0 \quad (6) \quad \frac{\partial Q}{\partial K} = Q_K \approx 0 \quad (7)$$

In consideration of the availability of data, this study will define the market share of a shipping line as the ratio of the slot capacity installed (k) to the total slot capacity provided in the global shipping industry (\bar{K}). Thus, the market share of shipping line i can be denoted by:

$$S_i = k_i / \bar{K} \quad (8)$$

As to the fleet utilization, it is generally defined as the ratio of actual to potential output. In economic theory, the level of potential output is usually located at the point where the average cost is minimized under a given level of fixed input. Therefore, the ratio of fleet utilization for a shipping line i is measured by:

$$U_i = q_i / \bar{q}_i(k, Z, T) \quad (9)$$

where \bar{q}_i is the potential output. In reflecting with the property of shipping operation, meanwhile, the potential output, shown as the denominator in above equation, is dependent on the given levels of fleet capacity (k), ship size (Z), and technology progress (T).

Since the expansion of fleet capacity and the introduction of large containerships will push the potential output to a higher level, they will push the fleet utilization down, conditional on a given amount of containers shipped. In contrast, the technological progress represents that there will be more containers shipped with a constant bundle of input factors. By definition, the fleet utilization will be increased as the technology of shipping operation is improved. Accordingly, the impacts of fleet capacity expansion, ship size enlargement and technological progress on the ratio of fleet utilization can be assumed as follows:

$$\frac{\partial U_i}{\partial k_i} = U_k < 0 \quad (10) \quad \frac{\partial U_i}{\partial Z_i} = U_Z < 0 \quad (11) \quad \frac{\partial U_i}{\partial T_i} = U_T > 0 \quad (12)$$

3.2 Comparative Static Analysis of Profit Function

In economics, theories are tested on the basis of changes in variables when certain conditions or assumptions change. Since the explicit form of function in a model may not be known or well-specified and the data required in an empirical study may not be available, the test of theory and the quantitative prediction based on

the theory become infeasible. Instead, the comparative static analysis is frequently applied to examine the direction of changes in endogenous variables with respect to the changes in exogenous variables.

According to the function specification demonstrated in previous section, the corresponding profit function can be formatted as:

$$\Pi_i = P_i q_i - C(q_i, k_i, Z_i, T_i, B) \quad (13)$$

where B is the bunker price. Furthermore, the profit function in an implicit form can be rewritten as follow:

$$\Pi_i = f(q_i, G, \bar{K}, k_i, Z_i, T_i, B) \quad (14)$$

a) *The growth of global economy*

As to the profitability effect of global economic growth for a carrier, it can be investigated by taking the first-order partial derivative of the profit function with respect to the global economic growth, G , as follows:

$$\frac{\partial \Pi_i}{\partial G} = [q_i - \delta_i(P_i - C_q)]P_G + (P_i - C_q)S_i Q_G \quad (15)$$

In equation (15), it displays that the effect of global economic growth on the profitability of a shipping line consists of two parts, as shown in the right hand side of equation sign. In the first part, the term of $[q_i - \delta_i(P_i - C_q)]$ actually represents the accrued profit as the individual freight rate is raised by one dollar. In details, the q_i in the term of $[q_i - \delta_i(P_i - C_q)]$ represents the increased marginal revenue from the original output due to charge one more dollar. Meanwhile, δ_i units of output is decreased to cause a revenue loss by the amount of $[\delta_i(P_i - C_q)]$. In sum, the price effect with one dollar increase of freight rate is equal to $[q_i - \delta_i(P_i - C_q)]$. Hence, this part can be interpreted as the price effect of the global economic growth on the profitability of a shipping line. Under a given market share of fleet capacity deployed, by contrast, the second part on the right hand side of equation (15) measures the extra profit that is derived from enjoying a fixed portion, same as the market share, of the increased cargo shipments due to a global economic boom. Thus, it can be regarded as the effect of shipment growth on the profitability.

b) *The growth of global containership fleet*

By taking the partial derivative of profit function with respect to the variable of global fleet capacity, the impact can be evaluated as follows:

$$\frac{\partial \Pi_i}{\partial K} = [q_i - \delta_i(P_i - C_q)] \frac{\partial P_i}{\partial K} + (P_i - C_q) \left[S_i \frac{\partial Q}{\partial K} + Q \frac{\partial S}{\partial K} \right] \quad (16)$$

In fact, the term, $\partial Q / \partial K$, is negligible by referring to equation (7). Equation (16) can be rewritten as follows:

$$\frac{\partial \Pi_i}{\partial K} = [q_i - \delta_i(P_i - C_q)] [P_U U_K + P_{\bar{P}} \bar{P}_K] + (P_i - C_q) \left(-\frac{QS_i}{K} \right) \quad (17)$$

Since the two terms of $[P_U U_K + P_{\bar{P}} \bar{P}_K]$ and $(-QS_i/K)$ are negative by following equations (2), (3), (6) and (10), the sign of equation (17) will largely depend on the sign of $[q_i - \delta_i(P_i - C_q)]$, conditional on a positive profit margin, $(P_i - C_q)$. Associated with the negative term of $[P_U U_K + P_{\bar{P}} \bar{P}_K]$, meanwhile, a positive term of $[q_i - \delta_i(P_i - C_q)]$ implies a negative price effect and subsequently makes a negative profitability effect by the expansion of global fleet capacity. By contrast, a negative $[q_i - \delta_i(P_i - C_q)]$ leads to a positive price effect. But, it cannot guarantee an increase of profit for a carrier. In a case with a positive price effect, by equation (17), a carrier can make more profit only if the scale of price effect is large enough to offset the negative market share effect, $(-QS_i/K)$. The result of theoretical analysis indicates that the expansion of global fleet capacity can bring more profit for a carrier only if the shipping market is fairly sensitive to the changes in individual freight rate. Under a much sluggish market reaction to the freight rate change, otherwise, a shipping line can't collect

numerous cargo shipments by reducing its individual freight rate to make up the loss of cargo shipments due to the diluted market share by the expanded global fleet capacity.

c) *The expansion of individual fleet capacity*

The profitability effect of expanding individual fleet capacity can be investigated as follow:

$$\frac{\partial \Pi_i}{\partial k_i} = [q_i - \delta_i(P_i - C_q)]P_U U_k + (P_i - C_q)(Q/\bar{K}) - C_k \quad (18)$$

In equation (18), it includes three parts. The first one indicates the price effect induced by the declining fleet utilization due to more fleet capacity deployed by a shipping line. As discussed in other variables, the sign of this part is undetermined and largely relies on the sensitivity of market reactions to the changes in individual freight rate. The second part means the profit accrued by the growing market share with a larger fleet capacity deployed. Under a positive profit margin, it is definitely positive and interpreted as the market share effect of expanding individual fleet capacity on the profitability of a shipping line. The third part is simply the marginal cost of adding one extra slot capacity into the fleet in operation. Due to the inconsistency of signs among the three parts, the sign of equation (18) is uncertain and depends on the relative scales of the effects from the three parts.

d) *The growth of ship size*

In this study, the profitability effect of enlarging ship size can be analyzed by the following equations:

$$\frac{\partial \Pi_i}{\partial Z_i} = [q_i - \delta_i(P_i - C_q)]P_U U_Z - C_Z \quad (19)$$

In equation (19), the first part on the right hand side of equation (19) is the price effect which is induced by the worse fleet utilization due to the delivery of large vessels. The second part is the marginal cost of enlarging vessels. Given a negative term of $P_U U_Z$ by following equations (2) and (11), a significantly negative term of $[q_i - \delta_i(P_i - C_q)]$ which implies a significantly positive price effect is a necessary condition to derive a positive result in equation (19). It demonstrates that a positive profitability effect by delivering large vessels can be derived only if the market reactions to the changes of individual freight rate are highly sensitive. In other words, a highly competitive market is a necessary condition for shipping lines to possibly collect more cargos and thereby make more profit by enlarging vessel size.

e) *The technological progress*

The effect of technological progress on the profitability of a shipping line can be evaluated as follows:

$$\frac{\partial \Pi_i}{\partial T_i} = [q_i - \delta_i(P_i - C_q)]P_U U_T - C_T \quad (20)$$

Given a positive term of $P_U U_T$ by following equations (2) and (12) and a negative term of C_T , a positive $[q_i - \delta_i(P_i - C_q)]$ will certainly make equation (20) to be positive. Moreover, a negative $[q_i - \delta_i(P_i - C_q)]$ is also possible to derive a positive equation (20). Therefore, the result of empirical study will be borrowed to judge the sign of $[q_i - \delta_i(P_i - C_q)]$ in this study.

f) *The uprising bunker price*

Similarly, the profitability effect to the bunker price hike for a shipping line can be measured by the following equations:

$$\frac{\partial \Pi_i}{\partial B} = [q_i - \delta_i(P_i - C_q)]P_B - C_B \quad (21)$$

Given a positive term of P_B , it is quite easy to sense that the sign of the equation is totally dependent on the sign of profitability effect of one unit price change, $[q_i - \delta_i(P_i - C_q)]$. Clearly, the necessary condition for a positive profitability effect to the hiking bunker price is a positive price effect induced by adding a BAF surcharging on the freight rate.

3.3 The theoretical implications of comparative static analysis

According to equations (15), (17), (18), (19), (20) and (21), the results of comparative static analysis for each variable can be decomposed into two or three parts. Evidently, the signs of those results are determined by the signs of the part with the common term, $[q_i - \delta_i(P_i - C_q)]$, and the other parts. In theory, the sign of $[q_i - \delta_i(P_i - C_q)]$ is largely dependent on the market reactions to the changes of individual freight rates. However, the uncertain sign of $[q_i - \delta_i(P_i - C_q)]$ has made the results of the all price effects to be unclear, despite of the sign of the term next to $[q_i - \delta_i(P_i - C_q)]$ in each equation being clearly defined by following the assumptions set in model. By contrast, the parts other than the price effect in an equation are interpreted as non-price effect. Fortunately, the signs of non-price effects in all equations are clearly determined by the assumptions set in model. Corresponding to a positive or negative term of $[q_i - \delta_i(P_i - C_q)]$ in different cases, the sign of each part in an equation are shown in parenthesis and summarized in Table 1. It displays that some results of the comparative static analyses are definitely determined, but others are unknown and denoted with a question mark in Table 1.

Table 1. The decomposition of effects in comparative static analysis under different market reactions to the changes of individual freight rate

	Case I: $[q_i - \delta_i(P_i - C_q)] > 0$	Case II: $[q_i - \delta_i(P_i - C_q)] < 0$	Empirical Results
$\partial \Pi_i / \partial G$ in eq. (15)	(+) + (+) = + (P. E.) (S. E.)	(-) + (+) = ?	+***
$\partial \Pi_i / \partial K$ in eq. (17)	(-) + (-) = - (P. E.) (M/S E.)	(+) + (-) = ?	-*
$\partial \Pi_i / \partial k_i$ in eq. (18)	(-) + (+) - (+) = ? (P. E.) (M/S E.) (C. E.)	(+) + (+) - (+) = ?	+**
$\partial \Pi_i / \partial Z_i$ in eq. (19)	(-) - (+) = - (P. E.) (C. E.)	(+) - (+) = ?	-
$\partial \Pi_i / \partial T_i$ in eq. (20)	(+) - (-) = + (P. E.) (C. E.)	(-) - (-) = ?	+**
$\partial \Pi_i / \partial B$ in eq. (21)	(+) - (+) = ? (P. E.) (C. E.)	(-) - (+) = -	-*

Note: P. E., S. E., M/S E. and C. E. respectively denote the Price Effect, Shipment Effect, Market Share Effect and Cost Effect in a comparative static analysis.

4. Empirical Study

4.1 Data Sources

The data set for this empirical study is taken from a sample which includes the three largest container shipping companies in Taiwan. In consideration of the availability of data, the data set covers a period spanning from 1991 to 2012. The variable of profit is measured by the ratio of annual profit before tax to annual sales revenue of a shipping line. The data of profit is drawn from the annually financial statements of the three shipping lines. The rate of global economic growth is borrowed to represent the variable of global economic growth. The bunker price applied in this study is based on the price of Brent Crude Oil in international oil market. The average containership size for a shipping line is computed by dividing the total TEU slots capacity of owned and chartered-in containerships by the number of containerships deployed. The data regarding to slot capacity of global containership fleet and the slots capacity of the owned and chartered-in

containerships for the three shipping lines are all collected from the relevant issues of the *Containerisation International Yearbook*.

4.2 Estimation and Results

In order to avoid violating the independence among the exogenous variables in a regression equation, a reduced form of implicit function corresponding to equation (13) is further modified by deleting the endogenous output variable from the equation as follow:

$$\Pi_i = f(G, \bar{K}, k_i, Z_i, T_i, B) \quad (22)$$

Accordingly, the corresponding regression equation can be formatted as follow:

$$\Pi_{it} = \alpha_0 + \gamma_1 D_1 + \gamma_2 D_2 + \alpha_1 G_t + \alpha_2 K_t + \alpha_3 k_{it} + \alpha_4 Z_{it} + \alpha_5 B_t + \alpha_6 T_{it} + \varepsilon_{it} \quad (23)$$

where D_1 and D_2 are two dummy variables to allow for the differential scales of shipping operations among the three shipping lines studied.

An econometric approach of panel data is applied to estimate the coefficients of variables in equation (23). As stated above, the data set covers three Taiwanese carriers and is spanned from 1993 to 2012 to make the sample size to be 57. The results of coefficients estimation are shown in Table 2. And, the R^2 is 0.41.

Table 2. Parameters estimation results

Variables	Coefficient	t-ratio	p-value
G_t	0.019	3.26	0.002
K_t	-0.34	-1.78	0.082
k_{it}	0.02	2.11	0.04
Z_{it}	-0.062	-1.13	0.266
T_{it}	0.05	2.17	0.035
B_t	-0.09	-2.01	0.051
D_1	0.014	0.65	0.517
D_2	0.011	0.23	0.821
constant	5.73	2.01	0.05
R^2	0.41		

Of the 9 variables in the regression equation, 6 coefficients are statistically different from zero at the 10% significance level, as shown in Table 2. Among the 6 coefficients, 3 variables which include the global economic growth, the individual fleet capacity deployed, and technological progress bring positive contributions to the profitability of the shipping lines studied. By contrast, the variables of global fleet capacity deployed and bunker price present negative impacts on the shipping lines' profits. Unexpectedly, the increasing ship size has caused a negative but not significant profitability effect to the shipping lines studied.

As stated above, the result of comparative static analysis for each variable actually includes two parts, price effect and non-price effect. By comparing the signs of the two parts with the sign of corresponding empirical result in an equation, as shown in Table 1, it indicates that the sign of non-price effect in an equation is totally same as the corresponding empirical result, no matter what the case regarding the sign of $[q_i - \delta_i(P_i - C_q)]$ is.

The identical direction of signs between the non-price effect and empirical result in each equation actually implies that the price effect should be relatively weak on contributing profit to shipping lines. Otherwise, a strong price effect in an equation may overturn the non-price effect and make the resulting sign different from the corresponding empirical result. Under the Case I in Table 1, for example, a large value of $[q_i - \delta_i(P_i - C_q)]$ will augment the scales of price effects in equations (19) and (22) to surpass the non-price effects and make the resulting total effects different from the corresponding results of empirical study. Similarly, a large scale of $[q_i - \delta_i(P_i - C_q)]$ in absolute value under Case II will magnify the scales of price effects in equations (16), (18),

(20) and (21) to exceed the non-price effects and lead to the resulting signs different from the corresponding results of empirical study.

Obviously, the empirical results indicate that the non-price effect in each equation actually plays a decisive role on the profitability of shipping lines. Meanwhile, the price effect should be also trivial in determining the profitability of shipping lines. Hence, the trivial price effect has provided an evidence to show that the pricing-related strategy has no effect on escalating the profitability of a shipping line. Implicitly, it suggests that the pricing behavior applied by shipping lines to collect more cargo shipments and fill the slots capacity of large vessels deployed is useless for shipping lines to make profit. Since a shipping line usually reduce its freight rate to exploit the returns to scale of large vessels, it is also the reason why the delivery of large vessels brings in a negative but insignificant effect on the profitability of shipping lines. Alternatively, the empirical results conclude that the shipment effect of global economic growth, the market share effect of expanding individual fleet capacity, and the cost reduction of technological progress have all contributed significant profits for shipping lines. On the contrary, the reduced market share due to the expansion of global fleet capacity, the increased cost burden due to the expansion of individual fleet capacity, and hiking bunker price have brought negative impacts on the profitability of shipping lines.

5. Conclusions

At first, this paper uncovers that the information based on the outcomes of comparative static analysis is not sufficient for researchers to forecast the effects of variable changes on the profitability of shipping lines. The empirical results suggest that the global economic growth, the expansion of fleet capacity by an individual shipping line and technological progress have significantly contributed profit to shipping lines. By contrast, the expansion of global fleet capacity and the hiking bunker price have brought significantly negative impacts on the profitability of shipping lines. More surprisingly, the profitability effect of enlarging vessel size is not positive as expected in reflecting with the well recognized benefit of economies to scale. Conversely, it brings a negative but insignificant effect to the profitability of shipping lines. Since the signs of non-price effects derived from comparative static analysis are totally coincident with the ones from empirical study, it implies that the all price effects in this study are trivial on creating shipping lines' profits. However, the significant non-price effects demonstrate that the increases of cargos and market shares are effective strategies for carriers to improve profit. In addition, the cost reduction from technological progress is also important for carriers to increase profit. Overall, the findings suggest that the quantitative-related but not pricing-related strategies play the key roles on improving the profitability of shipping lines.

Reference

- Cullinane, K. and Khanna, M. (1999), Economies of Scale in Large Container Ships, *Journal of Transport Economics and Policy* 33(2):185-208.
- Cullinane, K. and Khanna, M. (2000), Economies of Scale in Large Containerships: Optimal Size and Geographical Implications, *Journal of Transport Geography* 8(3):181-195.
- Franck, B. and Bunel, J. (1991), Contestability, Competition and Regulation: The Case of Liner Shipping, *International Journal of Industrial Organization* 9: 141-159.
- Fusillo, M. (2003), Excess Capacity and Entry Deterrence: The Case of Ocean Liner Shipping Markets, *Maritime Economics and Logistics* 5(1):100-115.
- Imai, A., Nishimura, E., Papadimitriou, S. and Liu, M. (2006), The Economic Viability of Container Mega-Ships, *Transportation Research Part E: Logistic and Transportation Review* 42: 21-41.
- Jansson, J. and Shneerson, D. (1987), *Liner Shipping Economics*, London: Chapman and Hall.
- Jankowski, W and Davies J. (1989), Competition, Contestability, and the Liner Shipping Industry, *Journal of Transport Economics and Policy* 23(2):199-208.
- Lim, S. M. (1998), Economies of Scale in Container Shipping, *Maritime Policy and Management* 25(4):361-373.
- Lim, S. M. (1994), Economies of Container Ship Size: a New Evaluation, *Maritime Policy and Management* 21(2):149-160.
- Notteboom, T. E. and Vernimmen, B. (2009), The Effect of High Fuel Costs on Liner Service Configuration in Container Shipping, *Journal of Transport Geography* 17(5): 325-337.

- Panayides, P. M., Lambertides, N. and Savva, C. S. (2011), The Relative Efficiency of Shipping Companies”, *Transportation Research Part E*, 47: 681-694.
- Talley, W. (2000), “Ocean Container Shipping: Impact of a Technological Improvement, *Journal of Economic Issues* 34(4): 933-947.
- Talley, W. (1990), Optimal Containership Size, *Maritime Policy and Management* 17(3):165-175.
- van der Jagt, N. (2003), Please Listen, *Containerisation International* 36: 27.
- Willmington, R. (2002), The Bigger the Better, *Containerisation International* 35:52-53.
- Wu, W. M. (2012), Capacity Utilization and Its Determinants for a Container Shipping Line: Theory and Evidence, *Applied Economics* 44(27):3491-3502.
- Wu, W. M. (2009), An Approach for Measuring the Optimal Fleet Capacity: Evidence from Container Shipping Lines in Taiwan, *International Journal of Production Economics* 122(1):118-126.

An Analysis of the Environmental Efficiency of Chinese Container Ports based on CO₂ Emissions

Joon-Ho Na, Jian-Hua Ji, and A-Young Choi

Antai College of Economics & Management, Shanghai Jiao Tong University, Shanghai, China.

Abstract

Ports represent logistics distribution centers with production activities that require loading and unloading equipment, cargo vehicles, ships and other means of transport; these types of equipment constantly consume a substantial amount of natural fuels. Compared with more advanced countries, Chinese ports have had a relatively late start in reducing carbon dioxide (CO₂) emissions and pollutants through port planning and execution. This research evaluates the environmental efficiency of 8 Chinese container ports using the SBM-DEA method. The CO₂ emissions of ports is set as an undesirable output, and its effect on the container ports' efficiency is analyzed. The results show that CO₂ emissions have a negative effect on container port efficiency. The average environmental efficiency of the 8 Chinese container ports ranges from 0.476 to 0.764. The container ports show different degrees of inefficiency from 2005 to 2011; the reasons for the inefficiency are an excess of inputs, undesirable output factors and a lack of container throughput.

Keyword: Chinese Container Port Efficiency; Environmental Efficiency; SBM-DEA; Undesirable output; CO₂ emissions.

1. Introduction

Producers consider labor, land, capital investment and access to economic output in the general production process. The output here is the product (the desirable outputs). However, in the production process, CO₂, SO₂, noise, dust, wastewater and other substances are produced simultaneously with the expected output. Various types of pollutants occur at the same time. In the production process, all types of pollutants can be defined as undesirable outputs. In previous research, these types of output material were not included in the efficiency analyses. Recently, however, many areas are attaching greater importance to environmental problems, which leads us to consider the effect of undesirable outputs on environmental efficiency. In particular, development in relation to the environment has become a popular topic of concern in the field of international political economy.

The purpose of economic development is not only to protect the environment but also to ultimately achieve the sustainable development of human society. The World Commission on Environment and Development (WECD) issued "Our Common Future" in 1987 and formally proposed the concept of sustainable development. Sustainable development refers to the preservation of the global environment within the natural range allowed, such that economic, social and environmental sectors contribute to the balanced development of harmony.

Humankind has entered the 21st century, and the pursuit of balance between the attempt to develop and the desire to protect the environment is considered to be the pursuit of this era, exemplified, for instance, by the development of new wind vanes. Sustainable development and the future of the economy, society and the environment is the theme; these factors rely on and are inseparable from one another. Decision makers must choose methods that consider both economic development and environmental problems and must prepare rational countermeasures to solve these problems to achieve environmental protection and economic and social sustainable development. To effectively analyze both economic and environmental factors, the World Business Council for Sustainable Development (WBCSD) formally proposed the concept of environmental efficiency.

Environmental efficiency includes both economic and environmental efficiency. Representative indicators and resource inputs are presented, comparing value-added (or production material) resources, the amount of output produced and other aspects. That is, environmental efficiency results when the main economic activity in the economy, the increase in economic value added, is achieved while reducing the environmental impact of the load, leading to a win-win situation for economic development and environmental protection. Environmental efficiency is then the main economic activity in the economy: the increase in economic value added while reducing environmental impact loads to achieve both economic development and environmental protection.

A port is a logistics distribution center with production activities that require loading and unloading equipment, cargo vehicles, ships and other means of transport, all of which constantly consume substantial amounts of natural fuels. In the process, large amounts of greenhouse gas emissions and pollutants are released. Recently, the EU increased pressure on port and maritime CO₂ emissions through the establishment of constraints. In the future, there may be complete port sector CO₂ emissions constraints. A recent report of the United Nations showed that greenhouse gas emissions were more than three times the size forecasted; therefore, it is clear that port greenhouse gas emissions are also quite high.

After China's reform and economic openness policy, China's economy achieved rapid growth. Consequently, port throughput also increased rapidly. Currently, China's Shanghai and Shenzhen ports have grown to one million containers ports; along with increased throughput, CO₂ emissions are rapidly increasing.

Compared with ports in advanced countries, Chinese ports have had a relatively late start in reducing CO₂ emissions and pollutants through the planning and execution of port activities. China's ports, including Shanghai port, Tianjin port, Qingdao port, Shenzhen and other large-scale ports, have adopted many measures with the goal of green environmental construction.

In terms of executing greenhouse gas reduction countermeasures in Chinese ports, although there is a gradually increasing trend, the implementation of technology for CO₂ reduction measures stranded in the port comprehensive CO₂ to reduce solution cannot execute such initial level.

For efficiency measurement models, the nonparametric method of data envelopment analysis (DEA) and the parametric measurement method of the stochastic frontier approach (SFA) are typical models. However, these two models contain undesirable output. Therefore, the evaluation of environmental efficiency cannot reasonably handle the actual production process with its undesirable output problem because the high possibility of bias can lead to incorrect results.

To solve these problems, Tone (2004) proposed a non-radial, non-oriented DEA model, the slack-based measurement (SBM) DEA model. This model can be solved to evaluate environmental efficiency including radial and oriented issues; in addition, the analysis process can be solved in terms of efficiency occurring on slack, which is included directly in the objective function. When evaluating the environmental efficiency of a port, SBM-DEA is a more reasonable approach method.

This paper conducted a SBM-DEA model analysis of 8 Chinese container ports (Dalian, Tianjin, Qingdao, Shanghai, Ningbo, Xiamen, Guangzhou and Shenzhen) to measure environmental efficiency in the 2005-2011 period. In addition, the CO₂ emissions of each port were set as undesirable output, the impact of CO₂ emissions on port efficiency was analyzed, and policies to improve the environmental efficiency of Chinese container ports were proposed.

The remainder of the paper is organized as follows: in Section 2, we present a brief review of the literature on port efficiency and environmental efficiency with undesirable outputs. In Section 3, we propose a SBM-DEA model to measure the environmental efficiency of Chinese container ports. Based on this method, we measure the environmental efficiency of Chinese container ports in Section 4. A summary and conclusions are then provided in Section 5.

2. Literature Review

Previous empirical studies of port efficiency can be divided into those that use the DEA method (Barros and Athanassiou, 2004; Cullinane et al., 2005; Kaiser et al., 2006; Roll and Hayuth, 1993; Valentine and Gray, 2001) and those that employ the SFA method (Cullinane and Song, 2003; Cullinane et al., 2002; Estache et al., 2002; Liu, 1995).

Roll and Hayuth (1993) first attempted to use the DEA model in analyzing the efficiency of container ports. These researchers evaluated the efficiency of 20 virtual ports through a DEA-CCR model with 3 inputs and 4 outputs. Martinez-Budria et al. (1999) classified 26 container ports in Spain into three groups according to the level of complexity based on data from 1993 to 1997 and then evaluated the efficiency of those ports using a DEA-BCC model with 3 inputs and 1 output. The results showed that greater complexity was related to higher levels of efficiency.

Tongzon (2005) studied the efficiency of major international container ports; this study is based on a DEA-CCR and DEA-additive model, and 12 international container ports and 4 Austrian ports in 1996 are compared. Itoh (2002) applied the DEA window to study the efficiency of ports in Japan. The research on Tokyo and Nakoya indicates high efficiency, whereas efficiency is relatively low in Kobe and Osaka. Barros (2003a) analyzed the productivity of a Portuguese port; this research identified the effects of Portuguese government regulations on port efficiency and found that the performance of the government regulations on the port industry produced a positive effect on port efficiency.

Cullinane et al. (2005) studied the effect of port privatization on efficiency; this study selected the world's top 30 container ports and China's five ports in 2001 for analysis. The findings emphasized that port privatization did not necessarily improve port efficiency. Yen-Chun Jim Wua and Mark Goh (2010) studied ports in emerging market countries (BRICs and Next-11) in an efficiency evaluation, which they then compared to the port efficiency of developed countries. The results showed that none of the ports in developed countries were efficient. Song and Sin (2005) also evaluated the efficiency of 53 international major container ports using a DEA-CCR model based on data from 1995 and 2001.

All the studies mentioned above utilized various DEA models and input and output factors. However, these studies did not consider the effects of environmental factors on port efficiency.

Given the environment and sustainable development concerns of the international community, it is necessary to include environmental factors in the study of efficiency.

Because the DEA method is not specifically limited to the production frontier function form, it has great flexibility. Thus, the original evaluation methods are primarily used; in particular, the non-parametric efficiency analysis model DEA has been increasingly used in environmental efficiency evaluation studies.

Sarki and Talluri (2004) applied DEA efficiency in environmental research. Lee et al. (2002) estimated the non-parametric directional distance function shadow price of pollutants and demonstrated that they inefficiently expand into the production process. Lansink and Reinhard (2004) used pollutants as input variables in a weak deal-based DEA model to study the technical efficiency and potential technical growth of pig farms in the Netherlands. Bevilacqua and Braglia (2002) used the CCR model to evaluate the relative environmental performance of seven Italian oil refineries from 1993 to 1996. Vencheh and Matin (2005) established a more general model and expanded the concept of environmental efficiency. Zaim (2004) used the improved Malmquist index to measure the environmental efficiency of dynamic manufacturing changes in the United States. Sarkis (2006) used multiple DEA models to evaluate the environmental efficiency of the metal processing industry; this model was constructed based on different assumptions covering many aspects of environmental efficiency. Liu et al. (2010) suggested more general characteristics for the DEA model, considering both undesirable outputs and unexpected inputs. Selden et al. (1999) performed a decomposition of pollutants in the United States from 1970 to 1990 as affected by economies of scale, energy intensity, energy consumption structure, structural effects and technical effects. The empirical tests show that structural effects reduce pollution, although the result is not obvious, and energy intensity and technical effects reduce the pollution of the main factors. Stern (2002) studied the decomposition of sulfur dioxide emissions from 1973 to 1990 in 64 countries and showed that economies of scale and technological changes are important

causes leading to contamination; he also showed that there are large national differences based on the input and output structure on the effects of pollution.

3. SBM-DEA Model

In this section, we describe SBM-DEA model for estimating container port eco efficiency with undesirable output. Traditional DEA models do not reflect the effect of amount of slacks and undesirable output of efficiency. To solve this problem Tone (2001) proposed SBM(Slack Based Measurement)-DEA model. SBM-DEA is a non-oriented model. The model is also non-radial in that it does not force the input and outputs to be improved uniformly or equi-proportionally, and it allows the maximum possible improvement in each dimension to be computed by the model. And Tone(2004) proposed SBM-DEA model dealing with undesirable outputs.

Suppose that there are n DMUs(Decision Making Units) each having three factors: inputs, desirable(good) outputs and undesirable(bad) outputs, as represented by three vectors $x \in R^m$, $y^g \in R^{s_1}$, $y^b \in R^{s_2}$, respectively. We defined matrices X , Y^g , Y^b as follows.

$$\begin{aligned} X &= [x_1, x_2, \dots, x_n] \\ Y^g &= [y_1^g, y_2^g, \dots, y_n^g] \\ Y^b &= [y_1^b, y_2^b, \dots, y_n^b] \end{aligned}$$

Assume that $x_i > 0$, $y_i^g > 0$, and $y_i^b > 0$ ($i=1, 2, \dots, n$).

According to Tone (2004) proposed SBM-DEA model, dealing with undesirable outputs SBM model can be written as:

$$\begin{aligned} \rho^* &= \min \frac{1 - \frac{1}{m} \sum_{i=1}^m s_i^- / x_{i0}}{1 + \frac{1}{s_1 + s_2} (\sum_{r=1}^{s_1} s_r^g / y_{r0}^g + \sum_{r=1}^{s_2} s_r^b / y_{r0}^b)} \\ \text{s.t} \quad & x_0 = X\lambda + s^-, \\ & y_0^g = Y^g\lambda - s^g, \\ & y_0^b = Y^b\lambda + s^b, \\ & s^- \geq 0, s^g \geq 0, s^b \geq 0, \lambda \geq 0 \end{aligned} \tag{1}$$

And ρ^* represent SBM efficiency score, s represent slacks of inputs and outputs value; λ is weight value.

The objective function ρ^* is about s^- , s^g , s^b strictly decreasing, and $0 \leq \rho^* \leq 1$. For specific decision making unit, only when $\rho^* = 1$ and $s^- = 0$, $s^g = 0$, $s^b = 0$ have efficiency. The difference between SBM-DEA and traditional DEA model is slack valuables directly into the objective function, solving the slack problems of inputs and outputs variables simultaneously, also solve the problems of existence of the undesirable output efficiency evaluation.

4. Numerical Results and Discussion

In this section, we present and discuss the results of the application of the proposed SBM-DEA model to 8 Chinese container ports (Dalian, Tianjin, Qingdao, Shanghai, Ningbo, Xiamen, Guangzhou and Shenzhen port) for the period from 2005 to 2011.

This paper referred to the existing selection of indicators in the literature and considered data availability; berth length (m), port area (m²), the number of quay cranes and the number of yard cranes are the four variables set as input variables. The container throughput of the port is set as the output variable. Finally, to analyze the effect of the port pollutants on efficiency, the CO₂ emissions amount is set as an undesirable output. The four input variables and the output variable of container throughput are excerpted from the China Ports Yearbook. There are currently no direct statistics measuring the undesirable output of CO₂ emissions. Therefore, the ports' CO₂ emissions are calculated according to particular benchmarks. The Korea Maritime Institute (KMI) in 2009 published the "Port Areas' Response to the Climate Change Regime." This study proposed a calculation method that includes the port land sector generating capacity and the maritime sector in the calculation of CO₂, which allows a better calculation of the correct amount of CO₂ emissions.

This study uses KMI(Korea Maritime Institute)'s proposed port CO₂ emissions calculation method to calculate emissions for the 8 ports' CO₂ emissions for 2005-2011.

Table 1. Input and output data summary for Chinese container ports from 2005 to 2011

	Input variables				Output variables	
					Desirable output	Undesirable output
	Berth Length (m)	Port Area (m ²)	Gantry Cranes (ea)	Yard Cranes (ea)	TEU	CO ₂ (ton-CO ₂)
average	6238.46	3833657.73	69.20	192.63	10540536.89	313574.92
max	13678	10951137	156	458	31123809	974200.6
min	1860	730000	14	41	2158686	54352.74
SD	3349.65	2582936.09	40.87	128.99	7291438.96	246221.53

Table 2. The comparison results for the traditional efficiency value and the environment efficiency value for the 8 container ports

Year	Average efficiency score without undesirable output			Average efficiency score with undesirable output		
	CCR	BCC	SE	CCR	BCC	SE
2005	0.478	0.576	0.862	0.361(24.5)	0.575(0.2)	0.643(25.4)
2006	0.512	0.605	0.860	0.400(21.9)	0.578(4.5)	0.695(19.2)
2007	0.613	0.699	0.893	0.503(17.9)	0.670(4.2)	0.758(15.1)
2008	0.581	0.672	0.898	0.518(10.8)	0.660(1.8)	0.799(11.0)
2009	0.512	0.607	0.878	0.427(16.6)	0.575(5.3)	0.765(12.9)
2010	0.599	0.645	0.941	0.538(10.2)	0.634(1.7)	0.842(10.5)
2011	0.638	0.693	0.937	0.588(7.8)	0.740(-6.8)	0.821(12.4)
Ave.	0.562	0.642	0.896	0.476(15.3)	0.633(1.4)	0.764(14.7)

Numbers in parentheses represent the rate of change.

Table 2 shows CO₂ environmental efficiency values that do not contain the efficiency of CO₂ decreased because CO₂ has a negative influence on the efficiency of container ports. The port efficiency as measured in traditional research is structured based on the input and output evaluation of efficiency, without considering the port output of pollution and the effects of environmental factors on port efficiency. Without these considerations, the determination of efficiency does not have real significance.

Table 3. The average estimation results for 8 container ports total, for pure technical efficiency and for scale environmental efficiency from 2005 to 2011

Port	Technical Efficiency	Rank	Pure Technical Efficiency	Rank	Scale Efficiency	Rank
Dalian	0.438	4	0.832	1	0.542	8
Guangzhou	0.402	5	0.525	5	0.766	5
Ningbo	0.394	6	0.440	7	0.890	2
Qingdao	0.711	2	0.773	4	0.908	1
Shanghai	0.479	3	0.805	3	0.606	7
Shenzhen	0.747	1	0.820	2	0.890	3
Tianjin	0.363	7	0.445	6	0.829	4
Xiamen	0.276	8	0.424	8	0.652	6
Average	0.476		0.633		0.760	

The annual average environmental efficiency results for the eight Chinese container ports from 2005 to 2011, based on constant returns to scale, show an average technical environmental efficiency value of 0.476, which is a lower value for technical environmental efficiency.

Shenzhen port has the highest technical efficiency at 0.747, followed by Qingdao Port at 0.711. The lowest performing ports are Tianjin Port at 0.363 and Xiamen Port at 0.276.

Assuming variable returns to scale, environmental efficiency is measured based on the pure technical efficiency results; the 8 ports' average annual pure technical environmental efficiency is 0.633.

Of the 8 container ports in China, Dalian port presents the highest pure technical environmental efficiency (0.832), with Shenzhen (0.820) and Shanghai (0.805) ranked second and third. The pure technical environmental efficiency of Xiamen is at the lowest level (0.424).

The average scale environmental efficiency of the 8 container ports is 0.760; Qingdao (0.908), Ningbo (0.890) and Shenzhen (0.890) showed higher scale environmental efficiency. By contrast, Dalian Port (0.542) presented the lowest scale environmental efficiency level.

If a port's pure environmental technical efficiency level is low, then port operators can adjust the input factors to improve the efficiency level. If the scale efficiency is low, then port scale adjustment will improve the scale efficiency.

An analysis of the 8 Chinese container ports' technical environmental efficiency, pure technical efficiency and scale efficiency results as shown in Table 3 indicates that the pure technical environmental efficiencies of Shanghai port and Dalian port are higher than their scale efficiency; the other 6 ports (Tianjin, Qingdao, Ningbo, Xiamen, Guangzhou and Shenzhen port) have higher scale efficiency than pure technical efficiency.

Shanghai port and Dalian port can be considered inefficient because the scale is too large; however, the appropriate scale adjustment will allow the efficiency of Shanghai port and Dalian port to reach the efficiency frontier. The other 6 container ports are not achieving the optimal level of input and output for non-efficiency reasons.

Table 4 shows the trend of the annual average efficiency for the 8 container ports. The trend for average comprehensive environmental efficiency is initially increasing but declines in 2009 because the world financial crisis decreased container throughput. After 2010, the container ports' throughput recovered, and their efficiency also began to rise; 2011 showed the highest level of technical environmental efficiency. Assuming variable returns to scale for pure technical environmental efficiency, the 2011 results showed the highest level at 0.740, and 2005 showed the lowest level at 0.575. In addition, the environmental efficiency results for the 8 ports in 2010 show the highest level of port environmental efficiency at 0.842, followed by

the results for 2011.

Table 4. The estimation results for the 8 container ports' annual environmental efficiency

Year	Technical efficiency	Rank	Pure technical efficiency	Rank	Scale efficiency	Rank
2005	0.361	7	0.575	7	0.643	7
2006	0.400	6	0.578	5	0.695	6
2007	0.503	4	0.670	3	0.758	5
2008	0.517	3	0.660	4	0.799	3
2009	0.427	5	0.576	6	0.765	4
2010	0.538	2	0.634	2	0.842	1
2011	0.588	1	0.740	1	0.821	2
Ave	0.476		0.633		0.760	

All 8 ports present different degrees of inefficiency in 2005-2011; the reason for the inefficiency is high port input factors, the low container throughput and the excessive output of environmental factors (CO₂) caused by inefficiency. An analysis of the results of this study shows that the representatives' port scale (length of the berths and the port area) input waste is obvious, but their technical indicators (quay cranes and yard cranes) are also wasted. The excessive input in terms of port scale led to scale inefficiency, and the excessive input of port technical factors led to a decline in technical inefficiency.

The port plays an important role, as it offers a core national import and export logistics function to respond to future economic demand. Neighboring countries compete based on ports and are thus increasing in terms of scale and the equipment investments, not only in China but also in most countries worldwide. In such circumstances, port operators reduce excessive unnecessary input: first, they must accurately predict container port demand based on the demand for the long-term development of port expansion plans; second, they must improve and replace old equipment to achieve the effect of enlarging the ports' scale. China's port container equipment is currently a combination of 1980s equipment and new modern equipment. With aging equipment, port operation efficiency is low, and fuel consumption is high, leading to increased carbon emissions.

To improve port efficiency, the most important step is to increase port throughput. Generally, increasing port throughput will improve port efficiency; thus, port operators must improve their marketing ability to expand the market and increase container throughput. The effort of port operators is important, along with the existence of a hinterland economy, competition from neighboring ports and other complicated factors relating to the global economic situation. Through the expansion of the hinterland, container volume has been maintained; in terms of the feasibility of extending the hinterland, one strategy is to establish strategic cooperative relations with an inland port. For example, Qingdao port and Xi'an inland port established a strategic partnership; Qingdao port serves as a base for imports and exports from Xi'an to achieve the effect of partial hinterland expansion.

In terms of the port environmental efficiency analysis results, the excessive emissions of CO₂ are having a negative effect on efficiency not only for the ports but also for the entire industry. For the future of humankind and sustainable development, the reduction of carbon emissions is crucial.

5. Summary and Conclusion

In this paper, an SBM-DEA approach was proposed to assess the environmental efficiency of container ports in China by considering undesirable outputs. Using information on container port CO₂ emissions, this approach was applied to assess the efficiency of 8 Chinese container ports from 2005 to 2011. The application of an SBM model to measure container the environmental efficiency of ports is novel, particularly because our approach considers undesirable output, which has not been considered in any previous application of SBM.

The results show that CO₂ emissions have a negative effect on container port efficiency and that each container port can improve its environmental efficiency by reducing CO₂ emissions. The analysis of the eight Chinese container ports from 2005 to 2011 was divided into technical environmental efficiency, pure technical environmental efficiency and scale environmental efficiency. The analysis results show that the environmental efficiency level for the eight container ports is not high and that the efficiency trends repeatedly increase and decrease.

The 8 container ports have relatively low levels of environmental efficiency. The main reason for this low efficiency is that an expansionary port development policy has led to wasted resources, a shortage of container throughput and the use of aging equipment, and a lack of environmental awareness, leading to excessive carbon emissions. Each container port must increase imports or enact other improvements to achieve high efficiency, including improving energy savings and emissions reduction using new equipment, preventing the waste of port resources and realizing the goal of becoming a low carbon port. In addition, it is important to continue to increase container throughput through the hinterland by expanding policies to ensure the stable supply of goods.

References

- Al-Eraqi, et al. (2008), Efficiency of Middle Eastern and East African Seaports: Application of DEA Using Window Analysis, *European Journal of Scientific Research* 23(4): 597-612.
- Anderson, P. and Petersen, N. C. (1993), A procedure for ranking efficiency units in data envelopment analysis, *Management Decision* 39(10): 1261-1264.
- B.J. Kim, et al. (2009), Port Areas' Response to the Climate Change Regime, Korea Maritime Institute.
- Barros, C. and Athanassiou, M. (2004), Efficiency in European seaports with DEA: evidence from Greece and Portugal. *Maritime Economics & Logistics* 6 (2): 122-140.
- Barros, C. and Sampaio, A. (2004), Technical and allocative efficiency in airports, *International Journal of Transport Economics* 3: 355-377.
- Bonilla, M. et al. (2004), An efficiency analysis of the Spanish port system, *International Journal of Transport Economics* XXXI (3): 379-400.
- China Statistical Yearbook 2006-2010, National Bureau of Statistics of China, Beijing.
- Containerization International Yearbook 2006-2010, Containerization International Yearbook (London: Informa UK Ltd).
- Cullinane K., et al. (2002), A stochastic frontier model of the efficiency of major container terminals in Asia: assessing the influence of administrative and ownership structures, *Transportation Research A: Policy and Practice* 36: 743-762.
- Cullinane K., Song, D. (2003), A stochastic frontier model of the productive efficiency of Korean container terminals, *Applied Economics* 35: 251-267.
- Cullinane, K., et al. (2004) An application of DEA windows analysis to container port production efficiency, *Review of Network Economics* 3(2): 186-208.
- Cullinane, K., et al. (2005a), A comparative analysis of DEA and SFA approaches to estimating the technical efficiency of container ports, *Transportation Research A: Policy and Practice* 40(4): 354-374.
- Cullinane, K., et al. (2005b), The relationship between privatization and DEA estimates of efficiency in the container port industry, *Journal of Economics and Business* 57 (5): 433-462.
- Cullinane, K., et al. (2006), The technical efficiency of container ports: Comparing data envelopment analysis and stochastic frontier analysis, *Transportation Research Part A* 40 (4): 354-374.
- Chudasama, K.M. and Pandya, K. (2008), Measuring efficiency of Indian ports: An application of data envelopment analysis, *The ICFAI University Journal of Infrastructure* 6 (2): 45-64.
- Estache et al. (2002), Efficiency Gains from Port Reform and the Potential for Yardstick Competition: Lessons from Mexico, *World Development* 30(4): 545-560.
- Fare R., et al. (1989), Multilateral productivity comparisons when some outputs are undesirable: a non parametric approach, *The Review of Economics and Statistics* 71(1): 90-98.
- Fare, R., et al. (2007), Environmental production functions and environmental directional distance functions, *Energy* 32(7): 1055-1066.
- Hailu, A. and Veeman, T. S. (2001), Non-parametric productivity analysis with undesirable outputs: An application to the Canadian pulp and paper industry, *American Journal of Agricultural Economics* 83(3): 535

605-616.

- IPCC (2006), IPCC Guidelines for National Greenhouse Gas Inventories 2006.
- Itoh, H. (2002), Efficiency changes at major container ports in Japan: A window application of data envelopment analysis, *Review of Urban and Regional Development Studies* 14(2): 133–152.
- Kaiser et al. (2006), Efficiency measurement of US ports using data envelopment analysis. In: National Urban Freight Conference, Long Beach, CA, 1–3 Feb 2006, 16 pp.
- Lansink, A.O. and Reinhard, S. (2004), Investigating technical efficiency and potential technological change in Dutch pig farming, *Agricultural Systems* 79: 353–367.
- Li, S. P., et al. (2010), Explore model of developing green ports. *World shipping* 2: 34–35.
- Liu, Z. (1995), The Comparative performance of public and private enterprises: the case of British ports, *Journal of Transport Economics and Policy* 29 (3): 263–106.
- Lin, L.C. and Tseng, C.C. (2007), Operational performance evaluation of major container ports in the Asia-Pacific region, *Maritime Policy & Management* 34 (6): 535–551.
- Martinez B. (1999), A Study of the efficiency of Spanish port authorities using data envelopment analysis, *International Journal of Transport Economics* 26(2): 237–253.
- Our Common Future (1987), Report of the World Commission on Environment and Development, United Nations.
- Pittman, R. W. (1983), Multilateral productivity comparisons with undesirable outputs, *The Economic Journal* 93(372): 833–891.
- Roll, Y. and Hayuth, Y. (1993), Port performance comparison applying data envelopment analysis (DEA), *Maritime Policy and Management* 20(2): 153–161.
- Rui, C. M. and Pedro, S. (2010), Measuring the influence of congestion on efficiency in worldwide airports, *Journal of Air Transport Management* 16: 334–336.
- Sarkis, J. and Talluri, S. (2004), Eco efficiency measurement using Data Envelopment Analysis: Research and practitioner issues, *Journal of Environmental Assessment Policy and Management* 6: 91–123.
- Scheel, H. (2001), Undesirable outputs in efficiency valuations, *European Journal of Operational Research* 132: 400–410.
- Seiford, L. M. and Zhu, J. (2002), Modeling undesirable factors in efficiency evaluation, *European Journal of operational research* 142: 16–20.
- So, S. H., et al. (2007), Efficiency analysis and ranking of major container ports in Northeast Asia: an application of data envelopment analysis, *International Review of Business Research Papers* 3(2): 486–503.
- Song, JY. and Sin, CH. (2005), An Empirical Study on the Efficiency of Major Container Ports with DEA Model, *Journal of Korean Navigation and Port Research* 29(3): 195–201.
- Song, X. B. (2011), Talking about the developing status of green port in China and some suggestions, *Science and technology of ports* 11: 17–20.
- Tone, K. (2001), A slack-based measure of efficiency in data envelopment analysis. *European Journal of operational research* 130(3): 498–509.
- Tone, K. (2003), Dealing with undesirable outputs in DEA: A slacks-based measure(SBM) approach. GRIPS research report series I:0005.
- Tongzon, J. (2001), Efficiency measurement of selected Australian and other international ports using data envelopment analysis, *Transportation Research Part A* 35 (2): 107–122.
- Tongzon, J and Heng, W. (2005), Port privatization, efficiency and competitiveness: some empirical evidence from container ports (terminals), *Transportation Research Part A: Policy and Practice* 39 (5): 405–424
- United Nations (2006), United Nations Framework Convention of Climate Change.
- Valentine, V.F. and Gray, R. (2001), The Measurement of Port Efficiency Using Data Envelopment Analysis, *Proceedings of the 9th World Conference on Transport Research*, Seoul: South Korea, 22–27 July 2001.
- Wang, T., et al. (2003), Container port production efficiency: a comparative study of DEA and FDH approach, *Journal of the Eastern Asia Society for Transportation Studies* 5: 698–713.
- Wu, Y. C. and Lin, C. W. (2008), National port competitiveness: implications for India, *Management Decision* 46 (10): 1482–1507.
- Yu M. M. (2004), Measuring physical efficiency of domestic airports in Taiwan with undesirable outputs and environmental factors, *Journal of Air Transport Management* 10: 295–303.
- Zhu, J. (2003), Quantitative models for performance evaluation and benchmarking: Data envelopment analysis with spreadsheets and DEA excel solver, Kluwer academic publishers.

Law and Economics of Port Finance – Whether Port Developers can Benefit from a Low Interest Rate Environment from Financing Port Assets under the *Basel Accord*

Owen Tang

Department of Logistics and Maritime Studies, The Hong Kong Polytechnic University, Hong Kong.
Email: lgtowen@polyu.edu.hk

Abstract

This paper aims to investigate the impacts created by *Basel Accord* on port finance from a law and economics perspectives. Historically, port developments and shipping are maritime sectors that have received “too much” finance. The economic crisis in 2008 motivated researchers to investigate the ramifications for the relationship among finance-driven capitalism and its corresponding geographical and economic sectors. Instead of conducting an investigation on the general ramifications on the financing and the overall maritime sector, this paper will only concentrate investigating whether port developers can benefit from a low interest rate environment from financing port infrastructure improvements under the *Basel Accord*. This paper submits that, given the capital intensive nature of port terminal investments, both port and ship financing have become more difficult under *Basel III*. One contributing factor is that containerization increases the demands for capital resources, not just for the acquisition and operation of terminal assets, but also for purchasing related intermodal equipment. This paper also concludes that due to the shareholder primacy of current banking practices, there is a powerful incentive for financial institutions to artificially reduce the value of their risk-weighted assets, and one of the reasons is that port assets were being reclassified into risky category after the financial crisis. In the sector of port investments, the financial institutions would likely to achieve the value reduction through securitization, so that they can bargain for the risk-weight discounts in the form of off-balance-sheet transactions. To sum up, this paper concludes that with the influences of *Basel III*, port developers are less likely to enjoy the financing advantage normally can be expected under a low interest rate environment.

1. Introduction

Port developments and shipping are maritime sectors that historically have received “too much” finance (Stopford, 2009). The economic crisis in 2008 motivated researchers to investigate the ramifications for the relationship among finance-driven capitalism and its corresponding geographical and economic sectors (Dupuy and Lavigne, 2010; Pike and Pollard, 2010). Instead of conducting an investigation on the general ramifications on the financing and the overall maritime sector, this paper’s focus is concentrated on whether port developers can benefit from a low interest rate environment from financing port infrastructure improvements under the *Basel Accord*.

Basel Accord is a product of the financial sector, and the rationale to involve financial sector analysis with port development is clear. First, port terminals are by its very nature capital intensive. Second, containerization increases the demands for capital resources, not just for the acquisition and operation of terminal assets (Pallis and De Langen, 2010), but also for purchasing related intermodal equipment (Rodrigue and Hatch, 2009).

This paper aims to investigate the impacts created by *Basel Accord* on port finance from a law and economics perspectives, and it will organize as following: Section I provides a historical account of the *Basel Accord* and its possible impacts to port financing. In this section, the literature reviews were mainly concentrated on banking documents and law review articles. Section II will discuss port financing under the *Basel Accord*, and two time frames will be covered in this section, before and after the 2008 financial crisis. Specific examples will be linked to port financing in Europe and in the Far East. Section III will discuss about the Quantitative

Impact Study of the *Basel Accord*. Section IV will analyze the impacts of Basel III from the port users' perspectives (Shipowners' expectations from KPMG Survey). And in section V, this paper submits that both port and ship financing have become more difficult under *Basel III* because financial institutions inclined to reclassify port assets into risky category after the 2008 financial crisis. The financial institutions will likely to reduce the value estimation of port assets through securitization, which leads to a risk-weight discount in the form of off-balance-sheet transactions. In short, this paper concludes that with the influences of *Basel III*, port developers are less likely to enjoy the financing advantage normally can be expected under a low interest rate environment. The overall structure of the paper is as following:

I. Introduction
- <i>Basel I</i>
- <i>Basel II</i>
- <i>Basel III</i>
II. Port Financing under the <i>Basel Accord</i>
III. Results of the Quantitative Impact Study (QIS results)
IV. Analysis from the port users' perspectives (shipowners' expectations) – KPMG Survey
V. Conclusion

1.1 *Basel I*

In 1988, the *Basel Accord (Basel I)* was reached which set the common bank capital requirements in 12 industrial countries. The intent of *Basel I* was to promote the stability of the international banking system. The economic justification that drove the *Basel I* was to mitigate the perceived risk after the deregulation and globalization of financial systems during the 80s. The drafters mainly concerned about the accumulation of bad loans in developing countries (Posner and Sykes, 2013).

Under *Basel I*, bank regulators bear the obligation to scrutinize the adequacy of bank capital so as to ensure international banks (those operating in the major industrialized countries) would hold capital in proportion to their perceived credit risk. For those assets that are in the categories subject to a higher risk weighting, the bank regulators would set a higher risk-based capital requirement

In order to maintain the expected capital adequacy ratio, major international banks would have a strong economic motive to substitute out the high-risk assets (such as commercial loans) into less risky assets (such as government securities). The question is: Whether money lending out for financing port infrastructures be regarded as high-risk assets by the major international banks? If the monies used for port infrastructures be viewed as loans for high-risk assets, then prospective port developers or operators may not enjoy the financial advantage of a low-interest rate environment.

1.2 *Basel II*

Basel II was published in June 2004. One of the *Basel II* concerns was how to maintain the consistency of regulations, so that the capital requirement would not cause competitive inequality among different international banks.

The drafters of *Basel II* believed that by establishing an international standard, it could protect the international financial system should a major bank or a series of banks collapse. In theory, *Basel II* attempted to accomplish this by setting a capital management requirement so that banks could have adequate capital for the risk that relative to their lending and investment practices. Therefore, the greater risk to which a bank is exposed, the greater the amount of capital the bank needs to hold. Politically, most international bank regulators found it difficult to implement *Basel II* in the regulatory environment prior to the banking crisis of 2008. *Basel II* was effectively superseded by the 2009 *Basel III*.

1.3 *Basel III*

Basel III was designed to ensure that big banks were adequately capitalized, so that they could survive when depositors ask for their money all at once (Basel Committee on Banking Supervision, 2010).

Unlike the previous two *Basel Accords*, *Basel III* was designed in response to the 2008 financial crisis (which mainly related to the financial structures unique to the US and European banking systems), some international legal experts, such as professor Kenneth Dam from University of Chicago, believed that there were inherited difficulties in enforcing the *Basel III* (Dam, 2010). Different views were seen from the consultation stage, for example, in the period between January 2008 and August 2011, the Basel Committee opened 17 rulemaking proposals for comment, and it received 147 comments on those proposals.

In addition to set a requirement on the amount of core capital and common equity that banks must keep against their loans (at least, compared to the pre-Basel requirements in most countries), the Basel Committee took it to go further - it ventured into the use of modern financial tools, such as loss-given-default risk estimates, executive compensation strictures, as means of supervision. As result of the pressure, *Basel III* is being implemented slowly. The drafters gave internationally active banks until 2018 to adopt the new leverage ratios required under *Basel III* (Basel Committee on Banking Supervision, December 16, 2010).

2. Port Financing under the *Basel Accord*

If ports' assets were being classified into the category of high-risk assets, then the lending banks have to hold more capital, which in effect would increase the banks' holding cost for such assets. Economically speaking, any increase in financial costs would reduce the supply of credit available to port developers (Jones, 2000; Tarullo, 2008; Torre and Ize, 2010). There is a paradigm shift in viewing the risk nature of port assets before and after the 2008 economic crisis.

A paper was published in 2011 in *Maritime Policy and Management*, which analyses how a change in risk perception helped to create a bubble in port developments from 2002-2008 (Rodrigue, Notteboom, and Pallis, 2011). Prior to the crisis supply of port infrastructures was lagging behind demand. With the positive growth expectations of ocean traffic activities, this created the need to provide additional port infrastructures. Research findings before the crisis repeatedly asserted the possible capacity constraints on port facilities in light of the anticipated growth. The findings were justified in the market by several factors: (a) The scarcity of land for terminal development (particularly in developed economies); (b) excellent prospects for container growth due to the China effect; and (c) high returns on maritime related investments (in many cases 15% or more). In combination, all three factors served to attract many investors to direct capitals to the field of port developments. Notteboom and Rodrigue pointed out that terminal operating companies and investor groups often ignored the geographical proximity of their port investments, and paid record prices for port assets (Notteboom and Rodrigue, 2010). Other research findings also indicated that the pre-crisis institutional investors tended to prefer geographically proximate investments for their portfolios (Portes and Rey, 2005).

A paradigm shift has gradually occurred in the aftermath of the economic crisis. Before the crisis, the risks of port investments were being assessed from supply and demand perspectives. After the crisis, financial institutions have repositioned themselves and rediscovered the need to view port assets in relation to financial regulations. Since then, the decisions from financial institutions have assumed a central role in port development. The capital lenders would look to the territorial and specialties of the port assets in relation to their economic environments where the ports and terminals operate. Investors would consider the localized regulatory regimes, in both financial and cultural aspects, as factors to develop the extent of their investments. Before the crisis, political and cultural considerations were not a major concern for foreign investment in port assets in a particular locality. For example, when DP World announced its takeover proposal of P&O Ports' global port portfolio (which included six major US terminals where P&O operated), the United Arab Emirates based firm did not expect the proposal would encounter strong opposition from the US Congress. Eventually, DPW was forced to sell its American port operations to American stakeholder¹ following a vote by the US House of Representatives.

The paradigm shift in lenders' mindset may influence how capitals would move in or out of a particular asset type. Krugman built his model of currency crisis for explaining how a run on currency (leading to a banking crisis) can start in the short run when speculators detect that a nation's macroeconomic structure is unsustainable in the medium run (Krugman, 1979). About ten years later, Calvo built another model to capture the observations of how small changes in beliefs among currency traders can unleash cumulative cascades and

set off contagion effects (Calvo, 1987). For example, the Basel Accord was amended to allow financial institutions to set their own capital requirements in 2004, which reflected the mindset of “market discipline”, under which the market is assumed to be capable of ensuring prudent management as long as there is complete disclosure of information, particular the capital-asset ratios (Basel Committee on Banking Supervision, 2006). Port asset investments were regarded as non-high risk investments during the pre-2008 era.

Therefore, the acknowledgment of uneven geographies of future regulations on financial institutions, and how they would affect profitability opportunities and exclusion potentials of a particular asset type (Dymski, 2006), when apply in the port sector, would have the power to reverse the trend observed in the pre-crisis period, and would make lenders to reclassify port assets from low risk category to that of a high risk one.

The paradigm shift in investors’ mindset may cause capitals to out of a particular asset regardless of the level of past involved investments. For example, shortly before the 2008 crisis, highly capitalized infrastructure investors moved into a break-bulk market that used to be dominated by port-owned and operated entities, with the expectation of exploiting the upsides in the break-bulk market. In 2007, Babcock & Brown Infrastructure (BBI), the Sydney-based fund of Australia’s second-largest investment bank announced several cargo-handling acquisitions in Europe and the USⁱⁱ that made it Europe’s third-largest bulk stevedore and a leading break-bulk cargo handler (Barnard, 2008). In the aftermath of the crisis (July 2009), BBI decided to adopt a fast-track exit strategy, registering a pretax loss of US\$170 million after agreeing to sell 40% of its acquired interest in the port assets.

For some port economists, to allocate the credit away from port financing as a result of the paradigm shift would help to reduce the overall building activities for new ports. Given the limited alternatives for credit availability from the non-banking financial system, this would help to reduce oversupply of ports in certain locations. Port development in Vietnam serves as a good example for explanation. Before the crisis, multinational companies, such as Intel Corp. (INTC) and Samsung Electronics Co., set up billion-dollar factories in Vietnam, and the central and regional governments have built ports in a close geographical proximity in order to capitalize one of its natural resources - a coastline of about 2,100 miles which is located along busiest sea cargo lane in Far East. Although Deputy Transport Minister Nguyen Hong Truong remained steadfast to the national ambition of competing with Singapore and Hong Kong port industries by building more ports in a February 28, 2014 Hanoi conference, international investors observed that the whole terminal industry in Vietnam is oversupplied.

Cai Mep International Terminal is a \$260 million joint venture of APM Terminalsⁱⁱⁱ and the state-owned Vinalines and Saigon Port. The Cai Mep port has seven terminals. The newest one is operated by the military-owned Saigon Newport. Cai Mep International Terminal has to compete against the six other terminals, and is running only at 30 percent of capacity, (2 million TEU moves a year), well below its six million TEU capacity (Bizhub, 2013). Four of the terminals have no container ship customers and have to rely on business such as bulk and cruise liners. Bloomberg reporter cited Robert Hambleton (general director of Cai Mep International Terminal Co)’s expression that he wants to hear more noise from the huge container port outside his office near Ho Chi Minh City. Towering cranes at the next-door competitor are silent, without a ship on the horizon (Bloomberg News 2014). David Wignall, managing director of Seaport Consultants Asia, estimated operators in Cai Mep alone have collectively lost as much as \$1.5 billion because of terminal oversupply.^{iv}

Although some economists observe that credit would not be allocated away from port financing activities, these economists built their theories on the hypothesis that demand maritime capital is inelastic even when the lending rates are high. The competitive banks would just charge port developers a higher interest rate to compensate for the additional cost of holding more capital.

Regardless of the different views, the *Basel* regulation would certainly contribute to a decrease in the supply of overall lending credit.

3. Results of the Quantitative Impact Study (QIS results)

The Basel Committee conducted a comprehensive QIS exercise to assess the impact of capital adequacy standards announced in *Basel III* of 2009. A total of 263 banks from 23 Committee member jurisdictions participated in the QIS exercise, of which 35% participant banks were classified as Group I banks:

Group 1 banks (Tier 1 capital > €3 billion + well diversified + internationally active)	94
Group 2 banks (banks missing any one of the above features)	169
Total Participants	263

The Basel Committee made its estimate by assuming a full implementation of the final *Basel III* package, based on data as of year-end 2009. The results of the QIS exercise indicated that even Group 1 banks in aggregate would have had a shortfall of €577 billion at the end of 2009.

The drafters of *Basel III* expect the capital and liquidity standards will gradually raise the level of high-quality capital in the banking system. The long transition period provides banks with ample time to move to the new standards. The drafters see *Basel III* would cause a change in banks' profitability and behavioral responses, such as changes in bank capital or balance sheet composition by substituting away the risky assets in their lending portfolios.

4. Analysis from the port users' perspectives (shipowners' expectations) – KPMG Survey

The infrastructure improvements of a port are aiming to satisfy the needs of its ultimate users – the shipowners. Academic researchers have tended to analyze transportation issues from the perspective of derived demands (Stopford, 2009); alternatively financiers tend to look at the same set of issues from an induced demand standpoint. By providing capital to the industry would result in a growth in the demand for cargo handling. This explains why, before the economic crisis, a large wave of investment in ships and terminal assets were perceived increasingly as low risk by financial actors. As a result, port expansion was gaining strong financial backing, with relevant syndication loans heavily oversubscribed, even when the first signs of the crisis were spreading (Portworld, 2008). For example, Between 2000 and 2007, more than US\$ 36 billion poured into port terminals, almost half of it in 2007 (Rainbow, 2009).

KPMG conducted a survey on shipowners' expectations under *Basel III* Implementation, and John Luke from KPMG observes that *Basel III* would reduce the traditional capital sources of shipping financing (KPMG, 2011). KPMG conducted a survey and found that most maritime market players believed that it is necessary to develop new equity and loan financing sources (see the following table). All respondents recognize the predicament in which shipping banks find themselves and the effects of future financing in the maritime sector – in terms of both the volume of required equity capital and of the securing of loan finance.

Which future actions you plan to use in mitigating future risk?	
Procure new equity capital sources	64%
Procure new loan capital sources	47%
Sale of ships	43%

Source: KPMG Survey 2011

(collected in KPMG (2011) "Ship Financing in Flux" <http://www.kpmg.com>)

Since *Basel III's* requirements concerning capital buffer, core capital ratio and liquidity ratios are all directly related to the risks of assets that a bank would hold in its portfolios; this would force the bank to reassess the risks of holding these assets. KPMG expected that the banks will be more restrictive in granting new loans in ship financing and they will pass the rising cost of capital to the debtors. In order to successfully apply for the bank loan, the ship purchasers must demonstrate that the risks of holding a particular ship can be appropriately supported by equity.

Additionally, in order to reduce refinancing damage in default cases, international banks would adopt a stricter

attitude with breaches of credit clauses. KPMG's survey also indicated that many ship owners believed that the bank would likely to change the repayment schedule, for example, the average credit maturities of 12 to 15 years will reduce to 8 or 9 years in the foreseeable future. As a counter measure, some financiers suggest that for loans that requiring regular capital repayment, it might be better to complement the financing package by bonds. Under such arrangement, at least part of the loan does not require mid-maturity repayments.

One of the interesting findings by the KPMG survey is that some shipowners (German) see that foreign banks will adopt the *Basel III* requirements more slowly than German banks, and this will lead German shipping companies seeking overseas banks as their financing partners.

In responding to the question of how a bank would estimate the risk of holding a ship, over 90 percent of those participated in the KPMG survey stated that the banks will likely to look at the charter agreements as a mandatory component of future new financing. Besides charter agreements, the surveyed shipowners believed that banks will likely to put different value ratings on the charterers according to their verifiable creditworthiness.

5. Conclusion

It is clear that both port and ship financing have become more difficult under *Basel III*. In order to obtain bank financing during the construction phase of port infrastructures, the financial institutions are very likely to demand port developers to obtain valuable guarantees in the first place, and even for those who can successfully obtain the loan, they are expecting a rise in credit costs due to rising margins for the banks and a shortening of credit maturities. This regulatory structure had important implications in terms of shareholder value maximization. The reason is that in order to acquire more assets, financial institutions had to either raise more equity (which dilutes the profits of existing shareholders) or increase their retained earnings (which cuts into shareholder dividends). Consequently, due to shareholder primacy, there is a powerful incentive for financial institutions to artificially reduce the value of their risk-weighted assets (Torre and Ize, 2010). In the sector of port investments, the financial institutions would likely to achieve the value reduction through securitization, so that they can bargain for the risk-weight discounts in those off-balance-sheet transactions. Legal researchers pointed out that it is now widely acknowledged that expected rise of securitization would be seen in decades to come (Jones, 2000; Tarullo, 2008).

With the influences of *Basel III*, therefore, port developers are less likely to enjoy the financing advantage normally can be expected under a low interest rate environment.

References

- Barnard, B. (May 23, 2008), Euro Cash (<http://www.breakbulk.com/>).
- Basel Committee on Banking Supervision (June 2006), Sound Credit Risk Assessment and Valuation for Loans, (<http://www.bis.org/publ/bcbs126.htm>).
- Basel Committee on Banking Supervision (December 2010), Basel III: International Framework for Liquidity Risk Measurement, Standards and Monitoring. (<http://www.bis.org/publ/bcbs188.pdf>).
- Basel Committee on Banking Supervision (December 16, 2010), Basel III Rules Text and Results of the Quantitative Impact Study (<http://bis.org/press/p101216.htm>).
- Bizhub (December 11, 2013), Too Many Deepwater Ports.
- Bloomberg News (Mar 14, 2014), Too Many Vietnam Seaports Spoiling Terminal Business.
- Calvo, G. (1987), Balance-of-payments crises in a cash-in-advance economy, *Journal of Money, Credit, and Banking* 19 (1): 19–32.
- Dam, K.W. (2010), The Subprime Crisis and Financial Regulation: International and Comparative Perspectives, *Chicago Journal of International Law* 10(2): 581–637.
- Dupuy C. and Lavigne, S. (2010), Does Geography Still Matter? Evidence on the Portfolio Turnover of Large Equity Investors and Varieties of Capitalism, *Economic Geography* 86(1): 75–98.
- Dymski, G. (2006), Targets of Opportunity in Two Landscapes of Financial Globalization, *Geoforum* 37: 307–311.

- Jones, D. (2000), Emerging Problems with the Basel Capital Accord: Regulatory Capital Arbitrage and Related Issues, *Journal of Banking & Finance* 1(24): 35-58.
- KPMG (2011), Ship Financing in Flux, <http://www.kpmg.com>.
- Krugman, P. (1979), A Model of Balance of Payments Crises, *Journal of Money, Credit, and Banking* 3 (1/2): 311-325.
- Notteboom, T. and Rodrigue, J.P. (2010), The corporate geography of global terminal operators, IAME 2010 Conference Lisbon, 7-9 July (www.porteconomics.eu).
- Pallis, A.A. and De Langen, P.W. (2010), Seaports and the Structural implications of the economic crisis, *Research in Transportation Economics* 27(1): 10-18.
- Pike, A. and Pollard, J. (2010), Economic Geographies of Financialisation, *Economic Geography* 86(1): 29-51.
- Portes, R. and Rey, H. (2005), The Determinants of Cross-Border Equity Flows, *Journal of International Economics* 65: 269-96.
- Portworld (2008), Fujairah expansion wins financial backing, 8 September 2008, www.portworld.com.
- Posner, E.A. and Sykes, A.O. (July 2013), International Law and the Limits of Macroeconomic Cooperation, *Southern California Law Review* 86 (July): 1025-1061.
- Rainbow, N. (November 20, 2009), Investors start to count cost of \$36bn box terminals bet, *Lloyd's List*.
- Rodrigue, J-P. and Hatch, A. (2009). North American Intermodal Transportation: Infrastructure, Capital and Financing Issues, The Equipment Leasing and Finance Foundation, Washington DC.
- Rodrigue, J-P., Notteboom, T. and Pallis, A. (2011), The Financialization of the Terminal and Port Industry: Revisiting Risk and Embeddedness, *Maritime Policy and Management* 38(2): 191-213.
- Stopford, M. (2009), *Maritime Economics*, 3rd edition, London: Routledge.
- Tarullo, D.K. (2008), *Banking on Basel: The Future of International Financial Regulation*, Washington: Peterson Institute for International Economic.
- Torre, A. and Ize, A. (2010), Regulatory Reform: Integrating Paradigms. *International Finance* 13(1): 109-139.

ⁱ American International Group / Highstar Capital.

ⁱⁱ In late-2007, BBI paid US\$548 million for a 43% stake in a leading Antwerp stevedore company (Westerlund), 50% of a cargo handler in Germany (Seehafen Rostok Umschlagsgesellschaft), and 50% of ICS Logistics Inc, whose main operations are in Jacksonville, Fla. BBI also acquired several Finnish ports from UPM-Kymmene, it also purchased 50% of Italy's biggest dry bulk stevedore (Terminal Rinfuse Italia, with operations in Genoa, Savona and Venice). Besides, it acquired a majority stake in a Belgian stevedore with operations in Antwerp and Ghent (Manuport), and Tarragona Port Services in Spain. In addition, it moved into the booming Baltic Sea market, paying US\$140 million for Rauma Stevedoring and Botnia Shipping, which have concessions to run Rauma, Finland's third-largest port, and the smaller port of Pietarsaai.

ⁱⁱⁱ A unit of Copenhagen-based A.P. Moeller-Maersk A/S (MAERSKB).

^{iv} <http://www.seaport.com/publications/>.

The Implication in the Opening of Northern Sea Route on Maritime Sector of Malaysia Economy

*N.S.F. Abdul Rahman^{*1} and R. Rasdi*

School of Maritime Business and Management, University Malaysia Terengganu, 21030 Kuala Terengganu, Terengganu, Malaysia. ¹Email: nsfitri@umt.edu.my, Phone: +6096683940, Fax: +6096683193.

**Corresponding Author*

Abstract

The opening of Northern Sea Route as an alternative route for transporting cargoes between Far East and Europe seems highly acceptable by shipping companies due to the great saving in fuel consumption, bunker cost, operating cost, emissions and journey time. These situations will automatically affects the Malacca Strait business activity and Malaysian economy in different perspectives when the vessels sail via Suez Canal and Indian Ocean are expected to decrease. The objective of this study is to analyse the implication in the opening of Northern Sea Route on Maritime Sector of Malaysian economy by using PESTEL analysis. The main scope will be focused more on the Malacca Straits shipping activity by using a number of parameters that will be obtained from Port Klang and Port Klang Authority and discussed the implications to the Malaysia's economy.

Keywords: Marine Accident, Accident Severity, PESTEL Analysis; Maritime Transportation; Maritime Market Research.

1. Introduction

Malaysia as a leading maritime nation because surrounded by a sea is much larger than land mass. Ports and shipping are recognized as essential contributors in facilitating Malaysia's trade, hence crucial to its economic prosperity. In 2008, the country's total trade was valued at US\$335 billion, an increase of 6.8 percent from 2007. Exports rose by 9.6 percent to US\$187 billion, while imports increased by 3.3 percent to US\$147 billion, resulting in a trade surplus of US\$40 billion (Khalid. N, 2009). According to Nazery Khalid (2007), Malaysia has emerged as one of the world's most significant maritime nations but not all activities in the maritime sector in the country are conducted in line with the concept of sustainable development. The particular emphasizes the major aspects which should be given attention to with the stakeholders in the effort to introduce the philosophy of sustainable development in the local maritime sector. It underlines the need to pay heed environmental protection in developing maritime infrastructures such as a port in the advancement of maritime economic activities such as transportation, fishery and offshore oil and gas exploration and production. The set of initiatives recommended in the articles gives strategic focus on maintaining harmony between the Malaysia maritime environment and those involved in the maritime industry. It also takes into account the legal framework and the economic interest of the stakeholders in the sector toward finding convergence between exploiting the nation's maritime riches and protecting the integrity of the maritime environment in line with the concept of sustainable development.

Ports in Malaysia are established either as Federal or State Ports under the jurisdiction of the respective governments. In addition, there are also ports and jetties which are under the jurisdiction of the Marine Department, fishing ports and jetties under the jurisdiction of the Fisheries Development Authority and oil majors manning their own special ports (MIMA, 2013). In Law of Malaysia, all port management and legal activities under Act 488 Port Authorities Act 1963. In Malaysia, we have Maritime Institute of Malaysia (MIMA) that is Malaysia's primary maritime policy research institute. They provide research and consultancy support to the various government maritime agencies in policy planning and policy making to safeguard Malaysia's maritime interests. As Malaysia's foremost maritime think tank, the Maritime Institute of Malaysia

(MIMA) has the responsibility to provide maritime-related policy options and recommendations to relevant government agencies and other maritime stakeholders. According to Nazery Khalid, Senior Fellow in MIMA, the Institute has a mandate to promote and safeguard Malaysia's maritime interests in achieving its objective of becoming a globally competitive maritime nation.

2. Important of Malacca Straits

Straits of Malacca is an international navigation and crucial in the world of trading whether for international trade or local trade (Singapore Journal of International & Comparative Laws, 1998). According to IMO (2003) more than 60,000 ships pass through the Straits of Malacca every year by carrying various cargoes, from raw material to finished products from all over the world (Forbes, 2004) and 80% of vessels passing through the straits annually carrying the oil transported to Northeast Asia (Gilmartin, 2008). Malacca Straits is one of the most important shipping waterways in the world from both an economic and strategic perspectives (Gilmartin, 2008).

2.1 Vessel Navigate via Malacca Straits

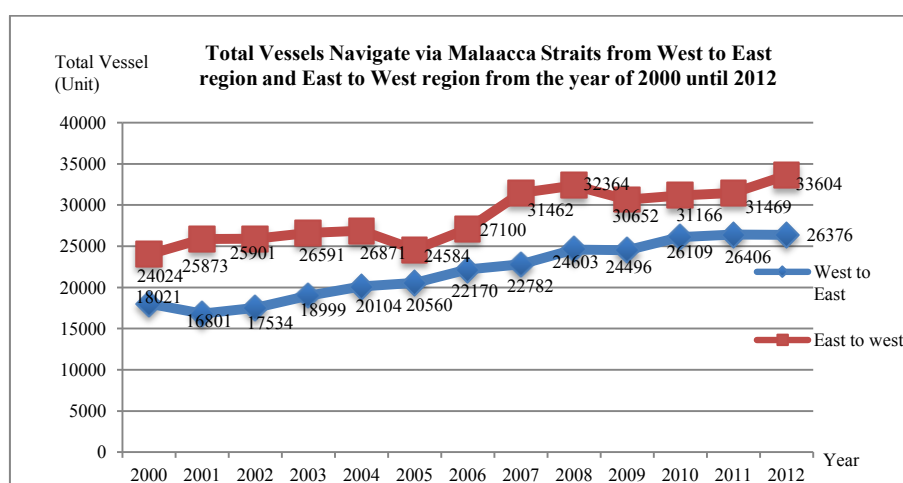


Fig 1. Vessels crossing Malacca Straits from year of 2000 until 2012

Source: Marine Department of Malaysia (2013)

Figure 1 shows that the total numbers of vessels navigate to west-bound region from the east-bound region and vice versa reported to Marine Department of Malaysia, from year 2000 until 2012. The total numbers of vessels navigate through Malacca Straits increases from year 2000 until 2008 but slightly decrease in 2005. In 2005, shows the lowest number of vessels navigate at west region because Malaysia Maritime Enforcement Agency (MMEA) states that the statistic of piracy attack in 2004 within 38 cases. The total percentage of vessel across Malacca Strait from 2004 to 2005 decrease until 8.15% from 26871 units in 2004 to 24584 units in 2005 with the lack of security handle the straits. Due to the situation, these piracy cases make shippers take other alternative and rather to navigate via longer distance than take risk to navigate through Malacca Strait. Result shows, decreasing in number of vessel from the east region to the west region. After the MMEA implemented, the percentage of vessels crossing the straits increases about 10.23% from year 2005 from 24584 units in 2005 to 27100 units in 2006 and the piracy cases is decreased in 2006.

3. Opening of Northern Sea Route

Global climate change is offering new opportunities for international transportation networks, notably with a trend of receding ice around the North Pole. If this trend continues parts of the Arctic could be used more reliably for navigation, at least during summer months and for longer periods of time. The main trans-Arctic routes include of the Northern Sea Route and Northway Passage. The Northern Sea Route along the arctic coast of Russia is the maritime route that is likely to be free of ice first and would reduce a maritime journey between East Asia and Western Europe from 21,000 km using the Suez Canal to 12,800 km, cutting transit time by 10-15 days (J. Paul Rodrigue, 2013) and The Northwest Passage crossing Canada's Arctic Ocean

could become usable on a regular basis by 2020, lessening maritime shipping distances substantially. The maritime journey between East Asia and Western Europe would take about 13,600 km using the Northwest Passage, while taking 24,000 km using the Panama Canal (J. Paul Rodrigue, 2013).



Fig 2. China's New Shipping Frontier

Source: Northern Sea Route Information Office; National Snow and Ice Data Center; Cosco; Lloyd's List (2013)

Based on the observation of Figure 2, if we compare this 2 routes, the shortest route to travel from china to Rotterdam is by using the NSR which can save up to 13days. The philosophy applied in the shipping industry is the reduction in route distance will automatically reduce the total travel time, ultimately the total fuel consumption, bunker fuel cost and vessel operating cost. Consequently, the amount of emissions produced by ships will definitely be reduced. Finally, the shipping companies' profit margin will dramatically increase without any argument.

According to Congressional Research Service report, China runs a trade surplus with the world's three major economic centers the 1) United States, 2) European Union, and 3) Japan. Since 2000, the United States has incurred its largest bilateral trade deficit with China (\$201 billion in 2005, a 25% rise over 2004). In 2003, China replaced Mexico as the second largest source of imports for the United States. China's share of U.S. imports was 14.6% in 2005, although this proportion still falls short of Japan's 18% of the early 1990s. The United States is China's largest overseas market and second largest source of foreign direct investment on a cumulative basis. U.S. exports to China have been growing rapidly as well, although from a low base. In 2004, China replaced Germany and the United Kingdom to become the fourth largest market for U.S. goods and remains the fastest growing major U.S. export market. China is purchasing heavily from its Asian trading partners with particularly precision machinery, electronic components, and raw materials for manufacturing. China is running trade deficits with Taiwan and South Korea and has become a major buyer of goods from Japan and Southeast Asia.

3.1 Current Shipping Routes Vs Alternative Routes

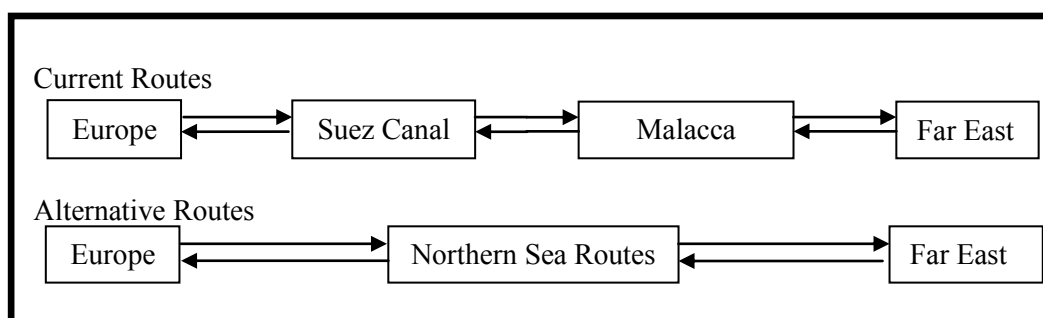


Fig 3. Current Shipping Routes Vs Alternative Routes

Source: The Geography of Transport Systems (2013)

Based on Figure 3, the today's cargo transported between Far East and Europe depending on the shipping route via Suez Canal which is located in Egypt. The canal has officially been opened to the maritime transportation industry in November 1869 (Suez Canal Authority, 2013) and the length of such a canal is 101 miles (163 kilometers) that connects the Mediterranean Sea with Gulf of Suez, Red Sea (Suez Canal Authority, 2013). By crossing the Suez Canal and Indian Ocean as a medium of connection between Far East and Europe, all ships will pass by the Malacca Straits and the potential of having port of calls is at Northport and Westport of Port Klang are very high.

4. Factor of Selected Shipping Route

There are some factors that are shipping company will compare in the selecting shipping route for the Far East Route trade incorporating between Northern Sea Route and Suez Canal. By selecting such a beneficial route, this situation will automatically affect the Malacca Strait business activity and Maritime Sector of Malaysian economy in different perspectives, a number of ports might lose their profit margin due to the possibility of having a lower number of bigger/mega ships at their port of call. Finally, the maritime industry contribution to the Malaysian economy will be reduced respectively. There are many features taken into consideration while selecting the evaluation variables. In order to conduct a comparison study, firstly, 8 variables have been obtained from literature surveys. There are 1) distance (International Association of Port and Harbors, 2012), 2) fuel consumption (The Arctic Institute, 2011) , 3) journey time (International Association of Port and Harbors, 2012), 4) speed knots (Claes Lykke Ragner,2011), 5) piracy (Northwest Passage,2012) 6) fee (International Association of Port and Harbors, 2012), 7) transport cost (International Association of Port and Harbors, 2012), and 8) cost saving (International Association of Port and Harbors, 2012),. Each variable has its specific meaning. For instance, the variable "cost saving" is defined as the total expenditure costs (including voyage cost, operational cost and capital cost) in operating a ship at a cost lower than the projected lost.

4.1 Suez Canal Vs Northern Sea Route

Table 1. A comparative of two shipping routes for the Asia-Europe trade

Element	Maritime Routes (via)		Statement
	Suez Canal (SC)	Northern Sea Route (NSR)	
Distance (nm)	11585	7356	[Far East vs. N.W. Europe] Yokohama - Hamburg Suez Route (11,585 N.M.) vs. NSR Route (7,356 N.M./-36%) The navigation distance from Northwest European port to Far East via NSR is an approximately 36% shorter compared Suez Canal route.
Fuel Consumption	High	Low	Norway to China: Shipping via the NSR save \$550,000 in fuel costs compared to the journey via Suez Canal
Journey Time	32 days (15 knots)	18 days (15 knots)	North West Europe (London) to Far East (Yokohama) Shipping via the NSR save 14 days on the journey compared to via the Suez Canal by using same speed .
Speed (Knots)	15 knots 32 days	9 knots 32 days	North West Europe (London) to Far East (Yokohama) Shipping via the NSR using speed only 9 knots on the journey compared to via the Suez Canal by using 15 knots on speed
Piracy	Yes	No	There is also much reduced level of piracy through this northern route, compared to the risk of piracy for ships in the Indian Ocean that are using the Suez Canal
Fee	Low	High	A maritime route with transshipment (T/S) includes T/S charges at T/S ports. NSR Fee USD 674 per TEU Suez Canal Fee (SDR/GT) 1st5000*7.88+ 2nd5000*5.15+ 3rd10000*4.12+ 4th20000*2.88+ 5th30000*2.6+ 70000(+)*2.11

Transport Cost	High	Low	North West Europe (Hamburg) to Far East (Yokohama) Transport cost via NSR (USD/TEU) <1123 Via Suez Canal (USD/TEU) 1299
Cost Saving	Low	High	Cost analysis may heavily depend on changes of bunker oil and ship-building prices as well as NSR, and Suez Canal fees. Thus, the shipping scenarios including navigation conditions would be a key factor to the cost analysis here. Severe competition will be expected among NSR and Suez Canals in the near future.

As describes in Table 1, obviously the NSR is classified as the best selection routes transporting cargos from Asia to Europe. For instance, Maritime Sector of Malaysia economy will be implementing when shipping companies choose NSR as the alternative maritime route because Malacca Straits was alongside with Suez Canal. If the total number of ship crossing Suez Canal decreased the total number of ship crossing Malacca Straits also decreased. According to this situation, the number of ship call at port alongside Malacca Straits which is West Port and North Port will be affected.

5. Discussion and Result

5.1 PESTEL analysis

The PESTEL framework is designed to provide managers with an analytical tool to identify different macro-environmental factors that may affect business strategies, and to assess how different environmental factors may influence business performance now and in the future (Johnson et al, 2008). The PESTEL Framework includes six types of important environmental influences: political, economic, social, technological, environmental and legal.

PESTEL analysis is a simple and effective tool used in situation analysis to identify the key external (macro environment level) forces that might affect an organization. In this study, to identify the parameter that might affect the maritime sector of Malaysia economy. Therefore, the aim of doing PESTEL is to identify the external factors that may change in the future maritime sector of Malaysia economy. Below, some characteristics in each factor are listed.

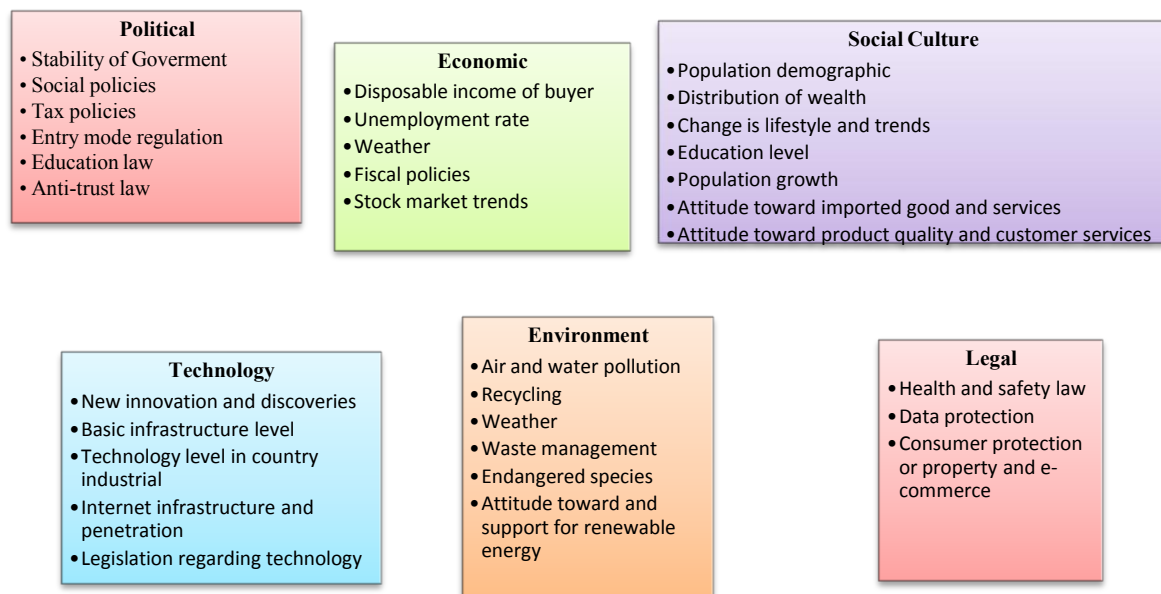


Fig 4. PESTEL analysis template

Source: Business Mate.Org; Great Business Resources

According to the PESTEL analysis, it could help this paper to determine the implication in the opening Northern Sea Route on maritime sector of Malaysia economy into different perspective that are related to this studies.

5.2 The implication in the opening Northern Sea Route to Maritime Sector of Malaysia Economy

By using PESTEL analysis the implication in the opening Northern Sea Route on maritime sector of Malaysia economy was categories into six factor 1) Political, 2) Economic, 3) Social, 4) Technology, 5) Environment and 6) Legal. Some of the implications give positive impact or positive benefits which are tending to emphasize laudable to maritime sector and also have negative impact to the Malaysian Economy which is give disadvantage impact to community or environment surrounding and related.

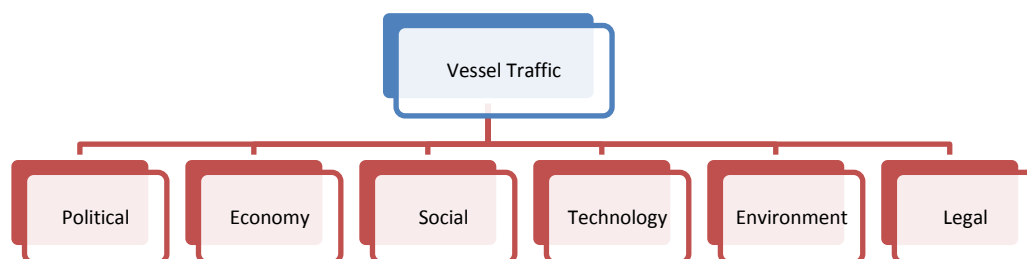


Fig 5. Conceptual Framework of the Implication in the Opening Northern Sea Route to Maritime Sector of Malaysia Economy

Each “criteria”; has a number of “sub criteria” between minimum one sub criteria and maximum five sub criteria such as “political”; “stability of government”, “economy”; “employment rate, business trade, ship call, port profit and country income”; “social”; “attitude towards imported goods and services”, “technology”; “basic infrastructure level and technology level in country industry”, “environmental”; “ship collision and emission” lastly, “legal”; “piracy and safety and security”. Each sub criteria are independently and affected when the total number of vessel traffic sails or across Malacca Straits being decreased.

Table 2. The Implication of the Opening Northern Sea Route to Maritime Sector of Malaysia Economy in Different Perspective

Perspective	Parameter	Positive	Negative	Impact
Political	Stability of Government		/	Reduce
Economy	Employment Rate		/	Reduce
	Business Trade		/	Less Profit
	Ship Call		/	Reduce
	Port Profit		/	Less Profit
	Country Income		/	Less Profit
Social	Attitude Towards Imported Goods and Services		/	Reduce
Technology	Basic Infrastructure Level		/	Normal
	Technology Level in Country Industry		/	Normal
Environmental	Ship Collision	/		Reduce
	Emission	/		Reduce
Legal	Piracy	/		Reduce
	Safety and security	/		Increase

5.2.1 Political

Political factors are basically to what degree the government intervenes in the economy. Specifically, political factors include areas such as stability of government, social policies, tax policies, entry mode regulation, education law and anti-trust law. Political factors may also include goods and services which the government wants to provide or be provided and those that the government does not want to be provided. Furthermore,

governments have great influence on the health, education, and infrastructure of a nation. In this study, the parameter that was determined that related for this study is stability of government. According to the 10th Malaysia Plan (RMK 10), the goal for the service industry is to achieve 61 percent of GDP share by 2015 with an annual growth of 7.2 percent. Under the Industrial Master Plan 3 (IMP3), non-government services are targeted to grow at an average annual rate of 7.5 percent. Construction services are also expected to increase annually by 5.7 percent. The Malaysia government is also expected to invest nearly RM687.7 billion or US\$228.384 billion dollars over the next fifteen years into services alone. In Peninsular Malaysia, some of the key industries include Rubber, oil palm processing and manufacturing, light manufacturing, pharmaceuticals, medical technology, electronics, tin mining and smelting, logging, and timber processing. The Eastern Malaysian states of Sabah and Sarawak are keenly focused on logging, petroleum producing and refining and agriculture processing. Malaysia now stable with this entire industrial player and the government is committed to provide seamless and efficient maritime cargo transportation infrastructures and services, as articulated in its Strategic Plan 2008-2015, as a means to enhance Malaysia's competitiveness (Ministry of Transport Malaysia, 2010). If the total vessels navigate at Malacca Straits decrease automatically maritime sector of Malaysia economy get negative impact.

5.2.2 *Economy*

Based on PESTEL analysis economic factors include disposal income of buyer, unemployment rate, weather, fiscal policies and stock market trends. These factors have major impacts on how businesses operate and make decisions. Exchange rates affect the costs of exporting goods and the supply and price of imported goods in an economy. There are a variety of modern definitions of economic. Some of differences may reflect evolving views of the subject or views among economists (Backhouse et al, 2008). While Scottish philosopher Adam Smith (1776) defined what was the call political economy as "an inquiry into the nature and causes of the wealth nation. Economic factors include economic growth, interest rates, exchange rates and the inflation rate. These factors have major impacts on how businesses operate and make decisions. For example, interest rates affect a firm's cost of capital and therefore to what extent a business grows and expands. Exchange rates affect the costs of exporting goods and the supply and price of imported goods in an economy. From this study focused on six parameter 1) employment rate 2) business trade 3) vessel traffic 4) ship call 5) port profit and 6) country income. Ship call is the total number of ship go to port for process discharge of loading cargo. Port of call is more about the ship port and arrival. According to Ministry of Transportation (2012) the total number of ship call at Port Klang (Westport and Northport) increasing year by year starting from year 2000 until 2003 but decreased on 2004 and 2005 almost 6.77% and 0.66% respectively from 15,150 unit vessel to 15,050 unit vessels. Malaysia ports act as gateway for the economy and facilitate much of the nation's trade, 95% of which is carried by seaborne transport. Together, ports and the shipping sector generate tremendous multiplier effects and create employment opportunities for many (Ministry of Transport, 2010). The important of port to nation 1) a vital aspect of a national transport infrastructure 2) main transport link with their trading partner in a focal point for motorways and railways system and 3) a major economic multiplier for nation's prosperity like a gateway for trade, attract commercial infrastructure and industrial activity. If the ships sail via Malacca Straits reduce the Malaysia economy will get negative impact from this situation.

5.2.3 *Social*

Social factors include the cultural aspects like population demographic, distribution of wealth, change is lifestyle and trends, education level, population growth, attitude toward imported goods and services and attitude towards product quality and customer service. Trends in social factors affect the demand for a company's products and how that company operates. For example, an aging population may imply a smaller and less-willing workforce (thus increasing the cost of labor). Furthermore, companies may change various management strategies to adapt to these social trends (such as recruiting older workers) (Johnson et al, 2008). In this study, the implication that Malaysia face when the total vessel across Malacca Straits decreased in social perspective is attitude toward imported goods and services. As know, the import export goods and services in Malaysia major transport by using sea. The product in Malaysia, like car, clothes and electrical are imported from other country because the quality and customer satisfaction for import goods. If the total number of vessel that transport import goods decreased, the customer satisfaction or attitude through import product become lower.

5.2.4 *Technology*

Technological factors include technological aspects such as new innovation and discoveries, basic information level, technology level in industry, internet infrastructure and penetration and legislation regarding technology. They can determine barriers to entry, minimum efficient production level and influence outsourcing decisions. For this study, in technology perspective only two parameter that will be affect when total number of vessel across Malacca straits reduce 1) basic infrastructure level and 2) technology level in industry. Ministry of Transport Malaysia 2010 YB. Dato' Seri Kong Cho Ha stated that Malaysia has excellent port infrastructures and good maritime institutional and regulatory framework, Malaysia is poised to grab a bigger slice of intra-ASEAN and intra-Asian trade which present lucrative trades for our ports and shipping lines. With AFTA set to become a reality by 2015, Malaysia's ports, some of which offer world-class services at very competitive cost, are set to reap the opportunities presented by a huge and integrated regional market. If the total vessel decreased using Malacca Straits so, the decrease of port service level and the technology level in industry remain unchanged.

5.2.5 *Environment*

Environmental factors include ecological and environmental aspects such as air and water pollution, recycling, weather, waste management, endangered species and attitude toward support for renewable which may especially affect industries such as trade and tourisms. Environment means the physical factors of the surroundings of human being including land, water, atmosphere, climate, sound, taste, the biological factors of animals and plants (Environment Quality Act, 1974). On scope of environment, there are two parameter include 1) ship collision and 2) emission. Both parameters brought the environment risk means any risk, hazard or chances of bad consequences that may be brought upon the environment (Law of Malaysia, 1974). According to Tsz Leung Yip, (2006) port traffic risks are of certain pattern and collision accidents are the most popular incidents when port traffic is heavy. De and Ghosh (2003) evaluated the relationship between port performance and port traffic in the context of India by applied unit root tests, co integration tests and Granger causality tests and found that a port with a better performance (e.g., higher productivity) is likely to get higher traffic. Although the cause-and-effect relationship between port performance and port traffic is yet to be defined, De and Ghosh (2003) proved that the traffic volume remains a good indicator of port performance. From year 2000 until 2012, Marine Department, Malaysia reported that the average of marine accident among these years is 7 accidents every year along Malacca Straits. In 2010, the highest total number of vessels accident recorded as much 15 vessels and around 46% from the total accident was caused by the disunity between the two vessels. Hanizah Idris, (2001) estimated every two or three minutes there is one vessel pass by the Malacca Straits. Even a bit of the negligence exist, it will cause a huge impact to the whole operation. The effected of ship collision make oil spoil and give disadvantages to marine life and will cause emission. The solution is decreased the number of oil spoil is to reduce the accident. H.M Ibrahim and Nazery Khalid, (2007) stated that arising from the increasing risk of ships accidents as a result of rising traffic in the Strait, the threat of ship-based pollution looms large. Over the years, several incidents have occurred in the Strait involving ships releasing oil and hazardous and noxious substance (HNS) into the waters. If ships sail via Malacca Straits decreased, the total number of ship collision and emission automatically is reduced. Malaysian gets positive impact from these situations.

5.2.6 *Legal*

Legal factors include health and safety law, data protection and consumer protection or property and e-commerce. For this study, the implication that Malaysia face on maritime sector include 1) piracy and 2) safety and security. Both of this parameter related to maritime activity and this illegal activity give impact to the company related. According to International Maritime Organization (IMO), a specialized agency within United Nations, "piracy" is defined as violence on the high seas or exclusive economic zones, and that it cannot occur in territorial seas, archipelagic waters or internal waters. However, in Southeast Asian, most sea robberies occur in territorial waters (Young & Valencia, 2003). Malaysia is one of the key players in the Straits of Malacca security debate because of almost half of the Straits lies in Malaysian territorial waters. Due to the colonialism history, Malaysia always sought an independent foreign policy, one with the concepts of absolute sovereignty and non-interference to its land. For Malaysia, the first and foremost is to maintain

sovereignty in her territorial waters, keeping all foreign powers out of Malaysian waters. On April 2004, Malaysian Prime Minister Najib Tun Razak stated that, “control of the straits was the sovereign prerogative of Malaysia and Indonesia, and U.S. military involvement is not welcome” (MIMA Bulletin 2004). Of all the 330 incidents worldwide reported to the IMO in 2004, 113 occurred in the South China Sea and 60 took place in the Straits of Malacca, amounting to more than half of the global total. Malaysia has to be able to defend its borders and its own territory. The world’s most dangerous waterways, notably the Strait of Malacca and the Gulf of Aden plus the high volume of maritime traffic, have made Straits of Malacca and Gulf of Aden highly vulnerable to piracy attacks because the widths of the Strait of Malacca and the Gulf of Aden vary from 35 to 135 nautical miles and from 13 to 175 nautical miles, respectively. Both chokepoints lie within the ‘hinterlands’ of piracy attacks (Kennedy K. Mbekeani and Mthuli Ncube, 2011). Based on this situation, if the total volume of maritime traffic decreased at Straits of Malacca the total volume of piracy occur is this straits will be reduced and Malaysia get positive benefits.

6. Significant of Study

This paper is important to analyses and determined the implication due to the opening of Northern Sea Route to maritime sector of Malaysia economy. This can be shown weather the economics of Malaysia become fluctuate, stable as usual or drastically will become worse. This paper also brings the development of the relationship between the implication and the economy. The beneficial of this paper is as reference for government to act in order to make sure that, our nation are ready to face the challenges if the total number of vessels sails at Malacca Straits or vessel traffic being decreased.

7. Future Expectation

A number of strategies will be proposed as part of the proactive action in facing the possible changes on maritime sector of Malaysia economy.

8. Conclusion

In all, the opening of Northern Sea Route as an alternative route for transporting cargoes from Far East and Europe affected the maritime sector of Malaysia Economy in scope of 1) political, 2) economy, 3) social, 4) technology 5) environment and 6) legal. This situation gives positive impact and negative impact to Malaysia economy especially in maritime sector. Malaysia economic professional should be preparing if this situation continue and find new method to sustain our economic as a maritime nation. Port authorities can no longer be just regulators, administrators and landlords. They have to play a variety of roles, which include marketing, attracting investors, financial planning, Business development and even customer relations. They must act as strategic partners to the terminal operators and work in concert to ensure their ports remain highly competitive (Nadzery Khalid, 2011). All port management and operation in Malaysia need to be systematic, weighing not only economic, geographical and physical factors, but also political factors as well. Further, they need to be reasonably prepared for whatever changes to the industry and to the global economy might happen. In terms of National Port Policy and National Port Authority, we suggest a study on the feasibility of establishing a proper national port policy, and even a national port authority. This will have the benefit of harmonizing cooperation between the various Federal ports, improving port planning and development, standardizing procedures and increasing competitiveness with other regional ports.

Acknowledgement

The author would like to acknowledge the University Malaysia Terengganu for the financial support.

References

- Backhouse., Roger E., and Steven Medema (2008), Economic, definition of, *The New Palgrave Dictionary of Economics*, 2rd Edition 720-22.
- Claes, Lykke Ragner (2000), Northern Sea Route Cargo Flows and Infrastructure- Present State and Future Potential.

- Forbes, V.L. (2004), *The Malacca Strait in the Context of the ISPS Code*, MIMA Conferences Papers on the Straits of Malacca: Building A Comprehensive Security Environment. Kuala Lumpur: MIMA.
- Gilmartin, H. (2008), *EU-U.S-China: Cooperation in Malacca Straits*, Hamburg, Nov. 2008.
- Hanizah, Idris. (2001), *Isu Kemalangan Kapal dan Pencemaran Laut di Selat Melaka: Satu Tinjauan*, Jati 6 : 116-137.
- Ibrahim, H.M. and Khalid, Nazery (2007), *Growing Shipping Traffic in The Strait of Malacca: Some Reflections on The Environmental Impact*: MIMA.
- IMO (2003), <http://www.marine.gov.my/misc/indexstat.html>.
- J. Paul Rodrigue. (2013), *The Geography of Transport Systems*, New York: Routledge.
- Johnson, G, Scholes, K. and Whittington, R. (2008), *Exploring Corporate Strategy*, 8th ed. FT Prentice Hall 55-57.
- Khalid. N. (2007), *Port Privation in the content of the developing nation maritime institute of Malaysia*.
- Khalid. N. (2011), *Port Klang: Leading Malaysia's Maritime Sector to Greater Heights*.
- Law of Malaysia ACT 127 - Environment Quality Act 1974, Incorporating latest amendment, Act A1102/2001.
- Ministry of Transport, Malaysia (2010), *Media Statement by YB Dato Seri Kong Cho Na, Ministry of Transport, Significant Contribution By Transport Sector Towards Malaysia's Economic Strong Growth In Second Quarter*.
- MIMA Bulletin (2004), *Straits of Malacca: Building A Comprehensive Security Environment*. Kuala Lumpur: MIMA 11 (2).
- Northern Sea Route Information Office (2013), *National Snow and Ice Data Center; Cosco; Lloyd's List*.
- Khalid, Nazery (2009), *Malaysia: A Maritime Player of Considerable Clout*.
- Rothaermel, F. T. (2012), *Strategic Management: Concepts and Cases*, McGraw-Hill/Irwin 56-61.
- Singapore Journal of International & Comparative Law (1998), *The importance of the Straits of Malacca and Singapore* 3012-322.
- Smith, Adam (1776), *An Inquiry into the Nature and cause of Wealth of Nation and Book IV as quoted in Peter Groenwegan Political economy and economy as an inquiry into the nature and causes of the wealth of nation*.
- Suez Canal Authority (2013), *Suez Canal Service*, <http://www.suezcanal.gov.eg/sc.aspx?show=24>.
- Thompson, J. and Martin, F. (2010), *Strategic Management: Awareness & Change*. 6th ed. Cengage Learning EMEA 86-88.
- World News (2013), *Ship and Bunker*, <http://shipandbunker.com/news/world/441225>.
- Young, A.J. and Valencia, M.J. (2003), *Conflation of Piracy and Terrorism in Southeast Asia: Rectitude and Utility*, *Contemporary Southeast Asia* 25(2): 269-283.

A Case Study on Slow Steaming Speed of Tanker Vessel – A Conceptual Paper

R. Md Hanafiah^{1*}, Irwin U J Ooi¹ and N.S.F. Abdul Rahman²

¹Malaysia Institute of Transport, Universiti Teknologi MARA, 40540 Shah Alam, Selangor, Malaysia.

*Email: rudiahmh@gmail.com.

²School of Maritime Business and Management, University Malaysia Terengganu, 21030 Kuala Terengganu, Terengganu, Malaysia

**Corresponding Author*

Abstract

The popularity of slow steaming is undeniable in the shipping industry. There are numerous studies concerning advantages of slow steaming based on the containership and tanker sectors, which focused on the vessels' size more than 160,000 deadweight tonnage (dwt) and have a long-haul trading route. However, there are lacks of research conducted regarding the practising of slow steaming speed on short-haul routes. As such, this paper intends to discuss the potential of practising slow steaming in the chemical tanker sector on Malaysia industry. The construction of a new model that is resulted from this study can be used by the shipping industry in decision making process. By selecting the right vessel's speed, the shipping companies are capable to control and monitor the ship performance and stay active during the global economic recession.

Keywords: Tanker; Decision Making Method; Slow Steaming; Tanker Charterer

1. Introduction

Malaysia is located at the centre within the Association of South-East Asian Nations (ASEAN) and she is close to major markets in the Far East. The economic growth of Malaysia has shift from being a producer of raw materials into a manufacturer concerned and a trader since 1970s (Brandt & Choo, 2012). According to the Department of Statistics Malaysia (2012), the country's total trade was valued at RM 1,268,782.5 million, which has increased about RM 101,131.8 million in 2011 compared to the total trade in 2010 and her major export products are petrochemical. There are a wide range of petrochemicals produced in Malaysia, such as olefins, polyolefin and aromatics. The total export of the products has risen from RM 638,822.5 million in 2010 to RM 694,548.5 million in 2011 (Department of Statistics, 2012). As on Friday, 6th September 2013; the major export products for Malaysia reported by Malaysia External Trade Statistics (2013) were electrical and electronic products (RM20.82 billion, 34.3 %), liquefied natural gas (RM5.25 billion, 8.6%), refined petroleum products (RM4.68 billion, 7.7%), chemicals and chemical products (RM3.97 billion, 6.5%) and palm oil products (RM3.65 billion, 6%).

The petrochemical industry is now an important growth industry for Malaysia amongst other chemical sub-sectors such as petroleum products, inorganic chemicals, oleochemicals and industrial gases. With 29 petrochemical plants in Malaysia which produces 39 kinds of petrochemical products, the growth in this industry has transformed Malaysia from a net importer to a major exporter of petrochemical products (Malaysian Petrochemicals Association, 2014). In mid- 1974, the government established a corporation named the 'Perbadanan Petroleum Nasional' (National Petroleum Corporation) or PETRONAS with the purpose to control and administer the exploration of the oil-based energy resource in the country.

The increasing demand for chemical products throughout the world has led to the development of tanker shipping industry in Malaysia. Tanker shipping industry provides an economical and convenient way to transport liquid bulk for the international seaborne trade at a safeties condition. All these factors contribute to the increase demand in sophisticated ships which capable of carrying a wide range of specialty cargoes in bulk, often in smaller quantities or 'parcels'.

However, the expansions of fleets in Malaysia are reported are still way beyond the rapid growth and demand of the specialised product in the shipping services' sector. According to Khalid (2009), the total of the Malaysian merchant fleets are small compared to the current global standards and only ten per cent of the country's trades are carried by the Malaysian ships. Therefore, the petroleum giant players such as PETRONAS Chemicals Group Berhad, BP, Shell and ExxonMobil which have their own cargoes have to use specialised vessels in to transport these specialised cargoes.

Hence, the purpose of this paper is to identify several factors that will in a way influence the revenues from the perspective angle of the steaming speed for the time charterer of the chemical tanker.

2. Time Charter Tanker Operation

In general, there are three types of charter in the tanker industry, namely 1) voyage charter, 2) time charter and 3) bareboat charter. Different types of charter contribute costs and revenues in a different ways. This paper will focus on the complexity of operating chemical tankers on time charter in dealing with an uncertain situation that leads to high revenue.

2.1. Nature of Time Charter Tanker Operation

A tanker is a vessel that has been designed with several compartments for transporting liquid commodities in bulk. In general, a chemical tanker is very complex in terms of its cargo equipment and a bit relatively high in its maintenance. It consists of many segregated tanks with separate pumping arrangements and coatings such as epoxy, stainless steel, marineline and zinc to resist toxic or corrosive liquids (Stopford, 2009). The chemical parcel tanker is able to carry specialised liquid cargoes namely chemical products, petroleum products, edible oils products and molasses which are hazardous in nature which is easily to explode, corrode, pollute and taint. Therefore, a tanker vessel has to be carefully handled by trained crew members due to the characteristics of such products. Following this, starting from December 2003, all of the chemical cargoes including petroleum products are required to be carried by double hull/double bottom tanker to avoid untoward disaster such as the major oil pollution incident of Exxon Valdez (1990), Erika (1999) and Prestige (2002). The structure of double-side and the mid-height deck is important in order to ensure that there is no or minimal oil outflow into the sea during collisions and grounding incidents.

Stopford (2009) mentioned that the revenue for time charter vessel involves two steps. First, revenue determining by the quantity cargo loaded measured in metric tons; and second, by establishing the price or freight rate the charterer will receive per unit/per metric ton transported. In other words, the revenue can be viewed as the product of the vessel's productivity. Vessel's productivity refers to the total cargo carrying performance, encompassing operating performance in terms of speed, cargo deadweight and flexibility in terms of obtaining backhauls cargoes. Besides, charterer also has the option to squeeze the revenue by minimizing the off-hire/idle time. The suspension of hire or known as "off-hire" time happened due to deficiency of crews, breakdown of machinery, damage to hull and any other cause preventing the operation of the vessel as guaranteed in the governing charter party such as, ship fails to proceed at any guaranteed speed.

2.2. Complexity of Running Time Charter Chemical Tanker

Generally, operating a time chartered chemical tanker confronts with a higher uncertainty global market conditions. For example, the tanker revenue can be affected by global economic situation, bunker fuel price, freight rates and environmental factor. Prior to 2008, a tanker operator earned a high level of profit margin as the industry was experiencing a period of sound growth. During the period, bank loans up to 80 per cent were easily accessible for new build vessel (United Nations Conference on Trade and Development, 2013). Thus, many shipping companies invested for large numbers of new build vessels. However, the worldwide downturn brought about by the economic and financial crisis has created an entirely new scenario. After 2008, due to the slow growth of global demand for goods and a new supply of vessels has led charter rates to drop in most markets. As a result, ship values also collapsed, causing the shipping industry to struggle with losses, loans defaults and bankruptcies. For example, General Maritime Corporation and Overseas Shipholding was filed

for bankruptcy protection in 2011 due to the collapse of freight rates and global tonnage overcapacity (United Nations Conference on Trade and Development, 2013).

In time charter hire, the charterer is responsible for the voyage costs of the vessel and also part of the fixed costs such as communication costs, fresh water costs for tank cleaning and supplying of tanks cleaning agents. Voyage costs or usually known as “variable cost” are the bunker costs, canal dues, port dues, light dues and cargo handling costs and agency fees. Among those items, bunker costs is the main contributory cost accounting for 47% of the total cost (Rowbotham, 2008). Such a statement was supported by the argument when bunker fuel price is around US\$500 per metric ton, bunker fuel cost constitutes about three quarters of the operation cost (Ronen, 2010).

On top of that, there is a specific clause on the fuel consumption for the vessel to comply. If the vessel exceeds the fuel consumption as agreed in the charter party agreement, the charterer has the right against the ship-owner for compensation. However if the fuel consumption of the vessel has been performed at its service speed and suddenly there is a change in the bunker price, the risk of change in bunker price will be for the charterer account (Velonias, 1995).

The bunker price is an on-going debatable issue since 1973. The issue is faced by many industries all over the world. Shipping industry, which activity depends prominently on oil, has not escaped from this scenario. A report by Clarkson Research Services (2014) in Figure 1 shows that the bunker price is fluctuatable and unpredictable. The price of bunker fuel has gradually increased from \$180.32 per tonnage in 2004 to \$505.62 per tonnage in 2009. The increments were about \$325.30 per ton between 2004 and 2009 and there was a sudden slight decrease about \$133.75 in 2009. However, due to uncertainty of global market condition, the bunker price remained at high level in 2013.

Complexity of operating time charter chemical tanker can be solved through vessel speed. It is believed that vessel speeds could hinder charterer's decline of vessel revenue under uncertainty conditions (Abdul Rahman, 2012; Psaraftis & Kontovas, 2012). One of the solutions is through practising slow steaming.

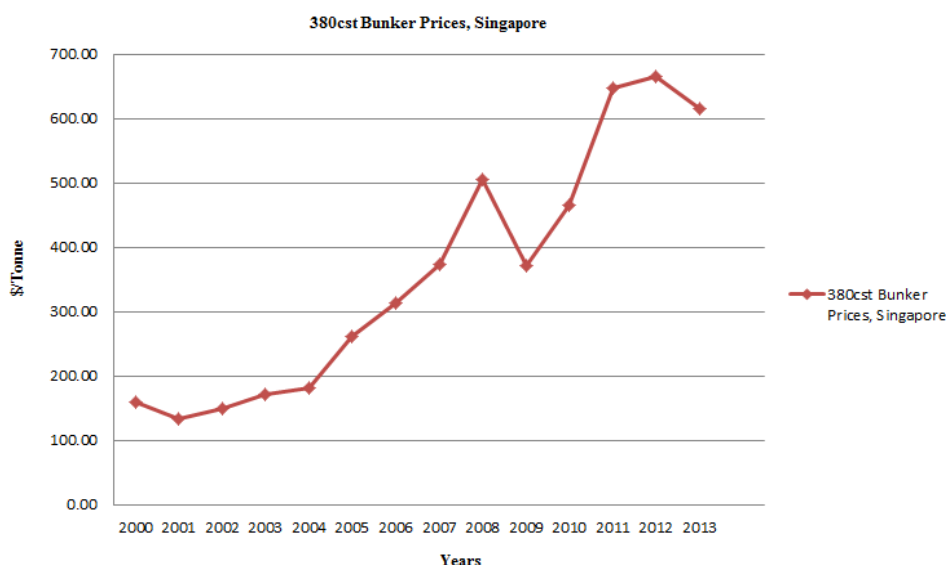


Fig 1. Bunker Price

Source: Clarkson Research Services (2014)

3. Slow Steaming

MAN PrimeServ (2012) a web survey, reported that from 200 representatives of the global container and bulk shipping industry, 149 of them had practised slow steaming. Among these respondents, 47.5 per cent of container and 80.6 per cent of bulk vessel was reported practising slow steaming. The obvious reason for almost the entire respondent practising slow steaming is to save fuel.

3.1. *Definition of Slow Steaming*

Based on previous researcher, there is no specific definition for slow steaming. According to Marine Insight (2012), slow steaming is a process of deliberately reducing the speed of cargo ships to cut down fuel consumption and carbon emissions. In a different study, Aßmann (2012), defined slow steaming as a process when a ship operates at a speed slower than its normal speed or design speed for which the ship was designed. Nikolic, A.Klanac, & P.Kumar (2011) described that by reducing the engine size, the emissions are also reduced, and so as the production of CO₂, NO_x and SO_x gasses. Although there is no standard definition used to describe slow steaming, the similarities of slow steaming can be identified. In this article, slow steaming is defined as a balancing technique to find the speed where there is potential for cost saving on bunker cost and at the same time to reduce CO₂ emissions.

3.2. *Previous Studies in Slow Steaming*

Studies related to slow steaming is increasing. These studies involved various aspects include economic model and environmental impacts (Maloni, Paul, & M.Gligor, 2013; Psaraftis & Kontovas, 2012; Fagerholt, Laporte, & Norstad, 2009; Abdul Rahman, 2012; Meyer, Stahlbock, & Voß, 2012; Wiesmann, 2010).

Many studies in slow steaming showed positive results in vessel's speed. A research finding from Nikolic et al., (2011) reported that both the ship-owner and charterer will enjoy a bigger benefit if they practice slow steaming than operate at standard ship speed. Besides that, vessels' excess capacity also shows positive outcomes toward the implementation of slow steaming (Abdul Rahman, 2012; Maloni et al., 2013; Wiesmann, 2010). In a different study, vessels' emissions in CO₂ had decreased when the vessel used slow steaming approach (Fagerholt, Laporte, & Norstad, 2009b; Lindstad, A.sbjørnslett, & Strømman, 2011, 2012). Study conducted on financial performance of tanker reported that slow steaming had the potential in helping shipping companies to stay active under uncertain global market situations (Abdul Rahman, Md Hanafiah, Ahmad Najib, & Abdul Halim, 2013). Based on positive results showed from the previous studies, it proves that there are advantages of practising slow steaming toward tanker shipping industry.

3.3. *Slow Steaming in Practice*

Prior to 1973, most of the tankers ran at their designated speed around 14 knots. However by 1975 to 1976 due to Arab-Israeli war, the bunker fuel price increased sharply. Consequently, a large number of tankers have started to reduce their sailing speed at 10 knots (Jun, 1975).

In late 2008, a combination of the recession and growing awareness on environmental impacts has caused many ship owners to adopt slow steaming as an alternative solution. Maersk Line in an effort to reduce the emission of greenhouse gasses has adapted its giant marine diesel engines to travel at super-slow speeds. As a result, fuel consumption and greenhouse gas emissions (GHG) were reduced by 30%. In addition, it was reported that Maersk Line has saved more than £65 million on fuel without suffering damage since it began to practise slow steaming (A.P.Moller - Maersk Group, 2009; Psaraftis & Kontovas, 2012).

The Maersk successful trial then lead China Ocean Shipping (Group), CKYH alliance (Lloyd's Lists, 2009) and Shipping Corporation of India; the largest Indian shipping company to practice the slow steaming approach (Henderson, 2012).

4. **Conceptual Framework of Tanker Revenue on Vessel Speeds**

There is no single principle able to completely explain the factors that affect time charter revenue. However, based on the intensive reviewed literature as mentioned in the previous section, it suggests that at least eleven parameters/factors that affect tanker revenue namely, 1) global economic conditions, 2) bunker price 3) petrochemical market demand, 4) freight rates, 5) vessel market balance, 6) voyage cost, 7) hire rate, 8) off-hire time/idle time 9) port time, 10) backhauls and 11) deadweight utilization. Based from the parameters, we have categorized each parameter under three main groups, which lead to a proposed conceptual framework as shown in Figure 2. Hence, this study focuses on these three factors as the framework for the study.

In this paper, the proposed conceptual framework is known as Conceptual Framework of Tanker Revenue on Operating Speeds (TROS). The proposed framework consists of five interrelated components. It is believed that the integration of these components would increase bunker efficiency, optimize tanker revenue and ensure reductions in greenhouse gas emissions from tanker shipping industry. Figure 2 represents general concept of the conceptual framework, which illustrates that operating speed will be the moderating variable in the relationship between the factors and the tanker revenue.

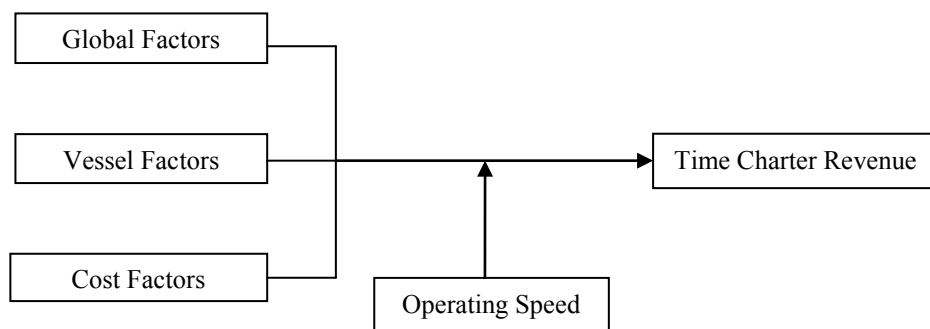


Fig 2. A Proposed Conceptual framework of TROS

4.1. Global Factors

First and foremost, one of the important aspects is the global factor. The global factor is a key success to the time charterer. This indicator consists of three components namely global economic conditions, bunker fuel price and petrochemical market demand. Since the year 2000, the tanker operators have earned a high level of profit margin (Abdul Rahman et al., 2013). However, the worldwide downturn in 2008/2009 crisis has created imbalance demand into the tanker market. The tanker market demand has decreased by 0.6% and tanker supply has increased by 19% in the middle of 2010 compared to the same period in 2008 (Institute of Shipping Economics and Logistics, 2012). In addition, the increasing of bunker fuel price has put tanker operators under pressure as bunker fuel cost constitutes a large portion of the voyage cost.

4.2. Vessel Factors

The second aspect is vessel factor. Vessel factor employs three components, focusing on fuel consumption, freight rate and vessel supply. The first criterion is 1) freight rate, 2) time usage at port and during off-hire, 3) operational planning and 4) vessel market balance.

According to Wiesmann (2010), during the falling freight rates, the shipping companies need to reduce steaming speed in operating their vessels. These argument is consistent with the discussion given by Psaraftis & Kontovas (2012) which in periods of depressed market condition, all ships will slowdown in response to price of bunkers as the players attempt to minimize their costs.

The next criterion is vessel market balance. Prior to 2008, most of the shipping companies were making order book for new tonnages. However, since late 2008 the vessel demand in market declined due to the economic and financial fallout. As a result, there are excess of new vessels delivered and have caused an oversupply of vessels during the last few years which have placed substantial pressure on the shipping industry. Such an imbalance demand has led to losses on tanker revenues.

4.3. Cost Factors

Finally, the cost factor is equally important that has to be considered to improvise the tanker revenue. The most common criteria consists of hire rate, of f-hire time (Stopford, 2009) and voyage cost (Institute of Chartered Shipbrokers, 2012). The first criteria namely hire rate refers to a sum of money paid to the ship-owner in advance at an agreed date as stipulated in the charter party agreement. During the booming period, the hire rate will be high due to the high demand of vessel at market. Therefore, the charterer is needed to

ensure that vessel productivity also increase to ensure sustainability in tanker revenue. The second criteria are off-hire time which refers to a suspension of hire due to the vessel inability to perform the service as per contract agreed.

4.4. Vessel speed

In the shipping trades, different vessels travel at different speeds. Containerships usually travel between 20.0 knots to 24.0 knots. However, tankers and big bulk carriers sail a slower compared to the containership which is between 12.0 knots to 16.0 knots. Table 1 shows a classification of tanker vessels typically employed in the tanker shipping market and its corresponding typical speeds.

Table 1. Speed of tanker shipping

Vessel Type	Ship size (dwt)	Approximate speed (knots)
Handysize	20,000-45,000	14-16
Panamax	50,000-70,000	14-16
Aframax	70,000-120,000	13-15
Suezmax	130,000-160,000	12-14
VLCC-ULCC	160,000-500,000	12-14

Source: Alizadeh and Nomikos (2009)

Meantime, there are four types of steaming speed namely 1) full steaming speed, 2) slow steaming speed, 3) extra slow steaming speed and 4) super slow steaming speed. Table 2 illustrates the types of steaming modes for containership and tanker.

Table 2. The type of steaming speed

Types of Steaming Speed	Containership (knots)	Tanker (knots)
Full Steaming Speed	23-25	14-16
Slow Steaming Speed	20-22	11-13
Extra Steaming Speed	17-19	8-10
Super Slow Steaming Speed	14-16	5-7

“Full” speed is considered as the maximum speed that has been designed by engine’s manufacturer (Abdul Rahman, 2012), which is generally 85-90 per cent of the engine’s capacity (Maloni et al., 2013). Therefore, the range of full speed for a tanker is between 14-16 knots (Maloni et al., 2013). By reducing vessel speed lower than the maximum speed, which is in between 11-13 knots, it represents “slow” steaming speed. Meanwhile, extra slow steaming speed is when the vessel operates at 8-10 knots. If the shipping companies operate their vessels less than extra slow speed, it is categorised as “super” slow steaming speed, which is approximately 5 to 7 knots.

4.5. Journey Time

Time is money for all the business industry in the world. Therefore, managing time is an important issue in the time charter business. Stopford (2009) recommended to cut cargo-handling time and to reduce backhauls in order to increase vessel productivity. Meanwhile, in a different study, Notteboom (2009) suggested to add port calls. However, it depends to the additional costs from added calls, which are more than offset by revenue growth.

5. Discussion

Based on the three elements of factor (global, vessel and cost) as explained above, there is a close relationship between every parameter with the vessel speed and journey time in determining the tanker revenue. For example, during a depressed market condition with the bunker prices are high and the demand for goods are low, the freight rates will tend to fall sharply. In order to offset these losses, thus reducing the service speed will be the option but it will affect the total voyage time of the vessel and of course it’s revenue. Alternatively

if this option is to be used then it is suggested that the shipping industry has to add a number of extra vessels to maintain the services. This will assist a ship owner or operator to stay active even though during uncertainty condition.

Hence, such a component will be employed in the future research in order to measure the cost saving impact on the chemical tanker industry with short-haul trade on slow steaming practise.

6. Conclusions

This concept paper aims to describe issues and factors that lead to TROS especially in time charter business. Most importantly this study had identified and discussed the parameters that influence TROS. At the same time, the conceptual framework of TROS has been proposed based on these parameters. However, further study is needed for analysing the effectiveness of practising the proposed conceptual framework.

Acknowledgements

The authors would like to acknowledge the financial support given for this work from Malaysia Institute of Transport (MITRANS), Universiti Teknologi Mara, Malaysia.

References

- A.P.Moller - Maersk Group (2009), Slow Steaming- the Full Story.
- Abdul Rahman, N. S. (2012). Development of Decision Making Models for Analysing a Steaming Speed of Liner Sector Containership Uncertainty, Liverpool John Moores University, England.
- Abdul Rahman, N. S. , Md Hanafiah, R., Ahmad Najib, A. F. and Abdul Halim, W. M. Z. (2013), A Decision Making Process of Tanker Steaming Speed under Uncertainty Using a Rule-Based Bayesian Reasoning Method, IAME 2013.
- Aßmann, L. (2012), Vessel Speeds in Response to Freight Rate and Bunker Price Movements - An Analysis of the VLCC Tanker Market. brage.bibsys.no. Retrieved from http://brage.bibsys.no/nhh/bitstream/URN:NBN:no-bibsys_brage_35338/1/Assman_2012.pdf.
- Brandt, T. and Choo, S. (2012), Market Watch 2012, The Malaysian Petrochemical Industry 1–15.
- Clarkson Research Services (2014), 380cst Bunker Price, Singapore.
- Department of Statistics, M. (2012), Statistics Yearbook Malaysia.
- Fagerholt, K., Laporte, G. and Norstad, I. (2009a), Reducing fuel emissions by optimizing speed on shipping routes, *Journal of the Operational Research Society* 61(3): 523–529.
- Fagerholt, K., Laporte, G. and Norstad, I. (2009b), Reducing fuel emissions by optimizing speed on shipping routes, *Journal of the Operational Research Society* 61(3): 523–529.
- Henderson, N. (2012), The Price of Slow Steaming.
- Institute of Chartered Shipbrokers (2012), Economics of Sea Transport and International Trade (Special Re.), Institute of Chartered Shipbrokers.
- Institute of Shipping Economics and Logistics (2012), Shipping Statistics and Market Review, ISL Institute of Shipping Economics and Logistics 56(4), Bremen, Germany.
- Jun, J. C. A. (1975), The Economics of Tanker Slowdown : An Observation. *Maritime Studies and Management* (24 May 2006).
- Khalid, N. (2009), Malaysia : A maritime player of considerable clout. Baird Publications (June).
- Lindstad, H., Asbjørnslett, B. E., and Strømman, A. H. (2011), Reductions in greenhouse gas emissions and cost by shipping at lower speeds. *Energy Policy* 39(6): 3456–3464.
- Lindstad, H., Asbjørnslett, B. E., and Strømman, A. H. (2012), The importance of economies of scale for reductions in greenhouse gas emissions from shipping. *Energy Policy* 46: 386–398.
- Lloyd's Lists (2009), CKYH alliance to introduce super slow steaming, Retrieved from <http://www.lloydslist.com/ll/sector/containers/article1614.ece>.
- Malaysia External Trade Statistics (2013), Trade Performance for the month of July 2013 and the period of January- July 2013 (1–13).
- Malaysian Petrochemicals Association (2014), Petrochemical Industry Retrieved from <http://www.mpa.org.my/index.php/the-industry>.

- Maloni, M., Paul, J. A. and M.Gligor, D. (2013), Slow steaming impacts on ocean carriers and shippers, *Maritime Economics & Logistics* 15: 151–171.
- MAN PrimeServ. (2012), *Slow Steaming Practices in the Global Shipping Industry*, Copenhagen, Denmark.
- Marine Insight (2012), *The Guide to Slow Steaming On Ships*, R. Kantharia, Ed., Marine Insight.
- Meyer, J., Stahlbock, R. and Voß, S. (2012), Slow Steaming in Container Shipping, 2012 45th Hawaii International Conference on System Sciences 1306–1314.
- Nikolic, P., A.Klanac and P.Kumar (2011), Economics and environmental impact of ships speed reduction for the VLCC tanker.
- Notteboom, T. E. (2009), The Time Factor In Liner Shipping Services, *Maritime Economics & Logistics* 8(1): 19–39.
- Psaraftis, H. N. and Kontovas, C. a. (2012), Speed models for energy-efficient maritime transportation: A taxonomy and survey, *Transportation Research Part C: Emerging Technologies* 26: 331–351.
- Ronen, D. (2010), The effect of oil price on containership speed and fleet size, *Journal of the Operational Research Society* 62(1): 211–216.
- Rowbotham, J. M. (2008), *Introduction to Marine Cargo Management*.
- Stopford, M. (2009), *Maritime Economics* (Third.), Routledge.
- United Nations Conference on Trade and Development (2013), *Review of Maritime Transport 2013*.
- Velonias, P. M. (1995), *Forecasting tanker freight rates*, Massachusetts Institute of Technology.
- Wiesmann, A. (2010), Slow steaming – a viable long-term option? *Wärtsilä Technical Journal* 49–55.

Optimization of Yard Truck Scheduling and Routing Model with Time-Space Network

Feng-Ming Tsai and Yu-Ming Chang

Department of Shipping and Transportation Management, National Taiwan Ocean University,
Keelung City, Taiwan

Abstract

In order to assist port operators in planning yard trucks (YT) routing and scheduling problems efficiently and decrease the pollution of yard trucks operation, this research utilizes the time-space network technique to describe the potential movements of yard trucks among all quay cranes (QC) and yard cranes (YC) in the time and space dimensions. The objective function is to minimize the total cost of operating and emission costs which considering the queuing theory with M/M/S model. The optimized number of yard trucks and its routing and scheduling can be solved by the developed model simultaneously. Since the model can be formulated as a multi-commodity network flow problem, which is characterized as NP-hard, a heuristic algorithm is proposed to efficiently solve the model. The model and algorithm can be used to evaluate a problem instance generated from the real data provided by an international port, and the analysis result could be useful references for port operators in actual practice. In this study, an experimental design of the small QC and YC operation network is considered with the import containers by YT. A preliminary result has approved that the optimized solutions can be solved by the developed model and it can be further applied to the practical operations.

Keywords: Yard Truck, Routing and Scheduling, Operating and Emission Costs, Queuing Theory, Time-space Network

1. Introduction

In recent years, shipping company has built up jumbo vessels to carry more cargos with relative low unit shipping cost, and currently the world's largest container ship has even reached the capacity of 18,000 TEU. According to the statistics by Alphaliner, it is predicted that about 42% of the vessels are more than 7,500 TEU and more than 25% of the vessels are more than 10,000 TEU from 2012 to 2016. Therefore, how to improve the efficiency for discharging and loading cargos for the port operation has become a critical issue.

In current container terminal operation, yard trucks are the main equipment that employed to deliver containers between quay and yard block while operating the inbound and outbound containers. No matter shipping companies or container terminal operators are expecting to decrease the vessel turnaround time and increase the utilization of berth by minimizing the operation time of discharging and loading tasks while the vessel berthing at quay.

As the advanced technology widely improved in port operations, the operating efficiency of QCs and YCs has been greatly promoted. Some advanced ports have switched to an automated gantry crane to replace the traditional gantry crane, such as Port of Rotterdam in Netherlands, Port of Hamburg in Germany. In addition to the aforementioned increase in QCs and YCs efficient, it is impossible to ignore the importance of YTs operations to and from the berth and container yard.

Note that the awareness of global environmental protection has increased significantly, and many ports are attempting to decrease the air pollution generated from container operation. The emission generated from yard trucks operation in the container terminal is one of the main reasons causing the air pollution in port. Therefore, the yard trucks routing and scheduling problem has become a critical issue for port operators to increase the YT operation efficiency and reduce the pollution simultaneously.

2. Literature Review

In recent years, how to optimize the scheduling or routing operation of YTs in containers loading and discharging operation have been widely studied. Most of the papers use different algorithm to solve these kinds of mix integer programming (MIP) models. Bish et al. (2001) developed an assignment problem based (APB) heuristic algorithm to assign each container to a yard location and dispatch YTs to the containers, so as to minimize the time it takes to discharge all containers from the ship. This paper was first conducting a series of proof that the vehicle-scheduling-location problem was shown to be NP-hard. Ng et al. (2007) used a genetic algorithm (GA) to minimize the makespan of all transportation jobs that discharging and loading the containers to and from the vessels. Lee et al. (2009a) proposed a GA and a greedy heuristic algorithm that based on the same concept of Ng et al. (2007) and considered the YTs waiting time at the quayside and yard block, so as to minimize the makespan of all discharging containers.

Lee et al. (2009b) considered different conditions in YTs routing between loading and discharging requests. A hybrid insertion algorithm (HIA) is designed to minimize the weighted sum of total delay of loading and discharging requests and the total travel time of YTs. Wu et al. (2012) showed how to assign the delivery tasks for YTs and tried to minimize the vessel's turnaround time. This paper used GA to solve the problem and chose three factors for evaluating the performance in the numerical tests of the model, which are the number of YTs, the number of blocks assigned for the export containers and the degree of uncertainty of operation times of QCs, respectively. In spite of the different objective, the concept of these papers was identical: optimizing the YTs routing and scheduling to minimize the containers operation time.

The time-space network technique has recently received considerable attention and had been widely used in modeling conveyance routing/scheduling problems. In a time-space network, connections within a location are realized by using a time line that connects all possible routing/scheduling events within the location. Thus, there is no need to explicitly model connections for each feasible pair of events within a location. Yan and Lai (2007) and Yan et al. (2011) used a time-space network technique to develop an optimization model to help decide an optimal ready mixed concrete (RMC) supply schedule and truck dispatching schedules/routes. In these two studies, a time-space network technique to formulate the production of RMC and the truck fleet flows had been employed. This technique can easily represent the operation of RMC production and truck dispatching due to its natural representation of conveyance routing in the dimensions of time and space.

Steinzen et al. (2010) discusses the integrated vehicle and crew scheduling problem in public transit with multiple depots. The objective was to minimize the sum of vehicle and crew costs. A time-space network representation of the underlying vehicle-scheduling problem was proposed. The numerical results showed that the approach outperformed other approaches previously exposed in other research in terms of solution quality and computational time.

Yan et al. (2012) developed a model that the time-space network technique is utilized to formulate the potential movements of cash transportation vehicles among all demand points. The model incorporates a new concept of similarity of time and space for routing and scheduling, which is expected to help security carriers formulate more flexible routing and scheduling strategies.

According to previous studies, the time-space network had been proven to solve the vehicles routing/scheduling problem efficiently. The YTs routing/scheduling between quayside and yard block was the same concept of this kind of problem. So far, this article is the first that attempt to combine YTs routing/scheduling in container terminal and time-space network in our knowledge.

3. Mathematical Model

The model developed in this study is about YT pooling problem, and a group of YTs are randomly assigned to different QC to complete all discharging tasks, so as to minimize the YTs operating cost. A time-space network technique is applied to construct a model incorporating the variation of the number of YTs and routes while minimizing the YTs operating cost. Before introducing the model, we have the following information or assumptions:

- (1) The model only considered the import containers operation.
- (2) Each YT can only carry one container in a trip.
- (3) YT can only travel between QC and YC within the designated container yard.
- (4) The task assigned to each QC is followed by uniform distribution.

3.1 *The vehicle-flow time-space networks*

The vehicle-flow time-space networks used for formulating the potential movements of YTs within certain time period and space locations are shown in Fig 1. A network is built associated with a YT. The horizontal axis represents the QC and YC served; the vertical axis stands for the time duration. The “nodes” and “arcs” are two major components in the networks. A node designates QC and YC at a specific time, except for the departure and the collection points (both are virtual point) which are associated with the YTs and are used to represent the start and end of a YT route and schedule. An arc represents an activity, such as the service assignment of a YT from departure point to a QC, a trip between QC and YC, or the non-service assignment of a YT. The arc flows express the flow of YTs in the network. Note that “the arc cost” is defined as the fixed cost or variable cost for serving the YT trip to the system for a unit flow in an arc. Five types of arcs are defined below.

3.1.1 *The traveling arc*

A traveling arc, indicated by (1) in Fig 1, represents a trip from QC to YC and travel back from YC to QC. All possible service arcs are installed within a reasonable block of time into the network. The time block for a traveling arc is the YT travel time plus the operating time at the arrival QC and YC. The arc flow, which is also a binary variable, denotes the number of YT serving the specific trip. The arc cost is the YT’s variable cost (including unit transport cost) for serving the specific trip. The arc flow’s upper bound is one, meaning that a specific trip is served by one YT. The flow’s lower bound is zero, indicating that no YT serves the specific trip.

3.1.1 *The waiting arc*

A waiting arc, indicated by (2) in Fig 1, represents the waiting of a YT at a QC or YC in a time window. The arc flow, a binary variable, denotes the number of YTs (0 or 1) held at a QC or YC within a time window. The arc cost denotes the waiting cost of YT during the time window. The arc flows upper bound is one, indicating that one YT is held at the QC or YC during the specific time window. The arc flows lower bound is zero, meaning that no YT is held at the demand point in this time window.

3.1.3 *The YT departure arc*

A YT departure arc, indicated by (3) in Fig 1, represents a start trip from the departure point (virtual point) to a QC. The arc flow, which is a binary variable, denotes the number of YTs (0 or 1) that serve the associated trip. The arc cost is a fixed cost (including the salary of the driver and equipment expenses for using the YT) for assigning a YT for 1-hour service. The arc flow’s upper bound is one, implying that the associated trip is served by one YT. The arc flow’s lower bound is zero, meaning that no YT serves the associated trip.

3.1.4 *The YT return arc*

A return arc, indicated by (4) in Fig. 1, represents an end YT trip from the node associated with a YC in every time point to the collection point (virtual point). It is used to ensure flow conservation of all arc flows in the network. The arc cost is zero, meaning that no cost is incurred while the last task of YT have finished. The arc flow is a binary variable, denoting the number of YTs (0 or 1) serving the associated trip. The arc flow’s upper bound is one, implying that the associated trip is served at most by one YT. The arc flow’s lower bound is zero, meaning that no YT serves the associated trip.

3.1.5 *The non-service arc*

A non-service arc, indicated by (5) in Fig. 1, is used to determine whether a YT is assigned to service or not. This arc flow is a binary variable. If the arc flow equals 1, it means that the YT is not assigned to service; otherwise (if the arc flow equals 0), the vehicle is assigned to service. The arc cost is zero, meaning that no cost is incurred not assigning YT to service. Since the arc flow is a binary variable, the arc flow's upper/lower bound is one/zero.

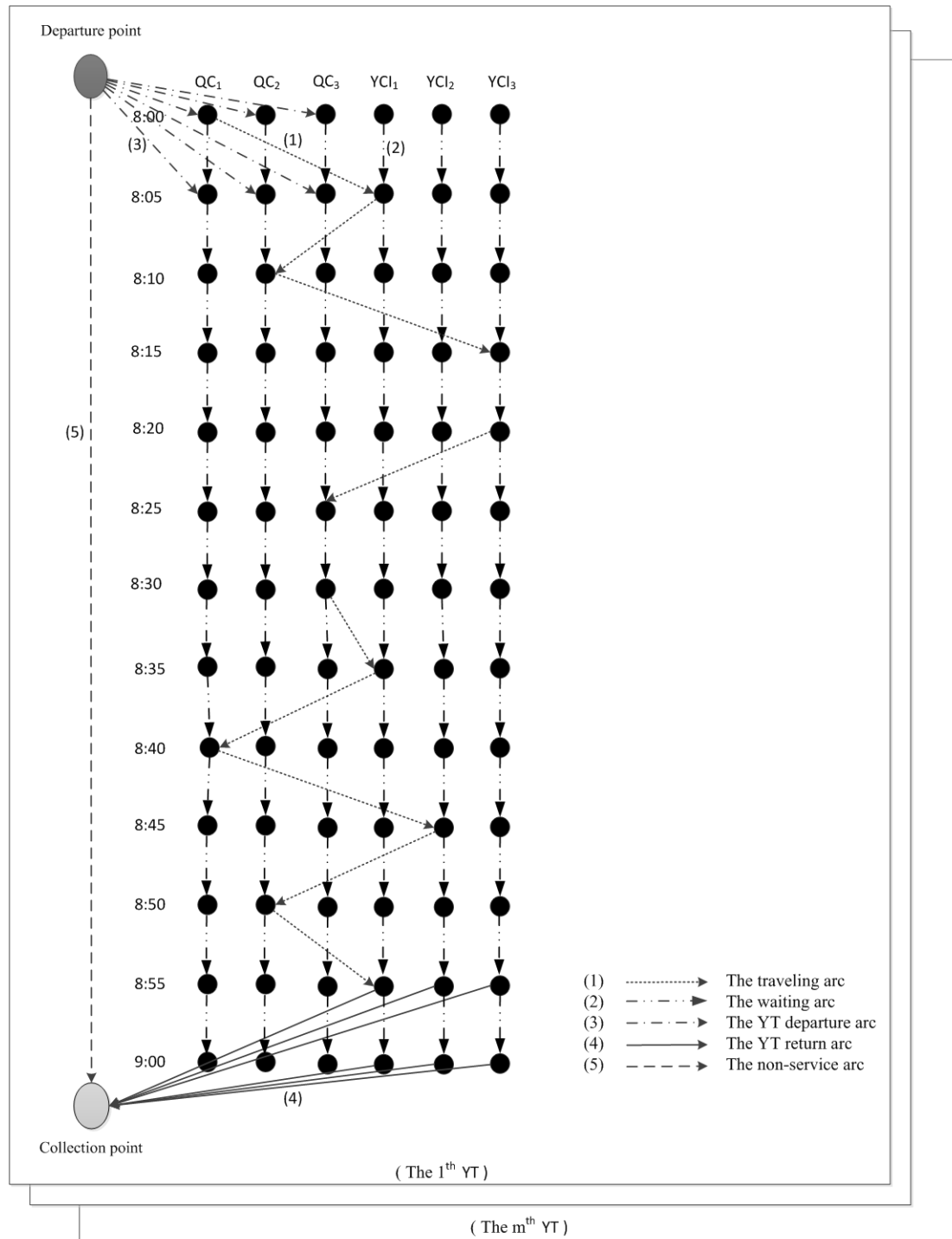


Fig 1. Vehicle-flow time-space network

3.2 Model Formulation

Before introducing the model, the notations and decision variables in the time-space network are listed below.

Parameters

C_{ij}^m : the arc (i, j) cost in the m^{th} vehicle-flow network
 I : the amount of import containers

Sets

VN^m : The set of all nodes in the m^{th} vehicle-flow network
 VQ^m : The set of all nodes of QC in the m^{th} vehicle-flow network
 VI^m : The set of all nodes of inbound block YC in the m^{th} vehicle-flow network
 VS^m : The set of all departure point in the m^{th} vehicle-flow network (virtual point)
 VD^m : The set of all collection point in the m^{th} vehicle-flow network (virtual point)
 VA^m : The set of all arcs in the m^{th} vehicle-flow network
 M : The set of all vehicle-flow networks

Decision variables

X_{ij}^m : the arc (i, j) flow in the m^{th} vehicle-flow network

The model is formulated as follows:

$$\text{Minimize } \sum_{m \in M} \sum_{(i,j) \in VA^m} C_{ij}^m X_{ij}^m \quad (1)$$

Subject to:

$$\sum_{j \in VN^m} X_{ij}^m - \sum_{k \in VN^m} X_{ki}^m = 0, \quad \forall i \in VQ^m, VI^m, \forall m \in M \quad (2)$$

$$\sum_{m \in M} \sum_{i \in VQ^m} \sum_{j \in VI^m} X_{ij}^m = I \quad (3)$$

$$\sum_{i \in VN^m} X_{oi}^m = 1, \quad \forall o \in VS^m, \forall m \in M \quad (4)$$

$$-\sum_{i \in VN^m} X_{ih}^m = -1, \quad \forall h \in VD^m, \forall m \in M \quad (5)$$

$$X_{ij}^m = 0 \text{ or } 1, \quad \forall (i, j) \in VA^m, m \in M \quad (6)$$

The objective function of Eq. (1) is to minimize the YT's operating cost which includes fixed and variable cost for serving the YT routes and schedules. Eq. (2) ensures flow conservation at every node of QC and YC in each vehicle-flow time-space network. Eq. (3) indicates that all import containers have to been delivered from QC to YC. Eq. (4) and Eq. (5) ensures flow conservation at every departure point and collection point, every layer represents one YT. Eq. (6) ensures the integrality of the arc flows.

4. Computational Experiments

In this section, we give a simple computational example to demonstrate the performance of the proposed model. The examples are solved on a personal computer equipped with Intel® Core™ i5 CPU and 4GB memory space. The computer code uses GAMS 23.7 as its optimization engine.

There are 3 QCs and 3 YCs of inbound block to serve the totally 25 TEUs of import containers which waiting for delivered, and the number of YTs are set in five. The operating time window is set from 8:00 AM to 9:00 AM, and a time interval of 5 min. The direction of YT operation must follow counterclockwise as shown in Fig 2.

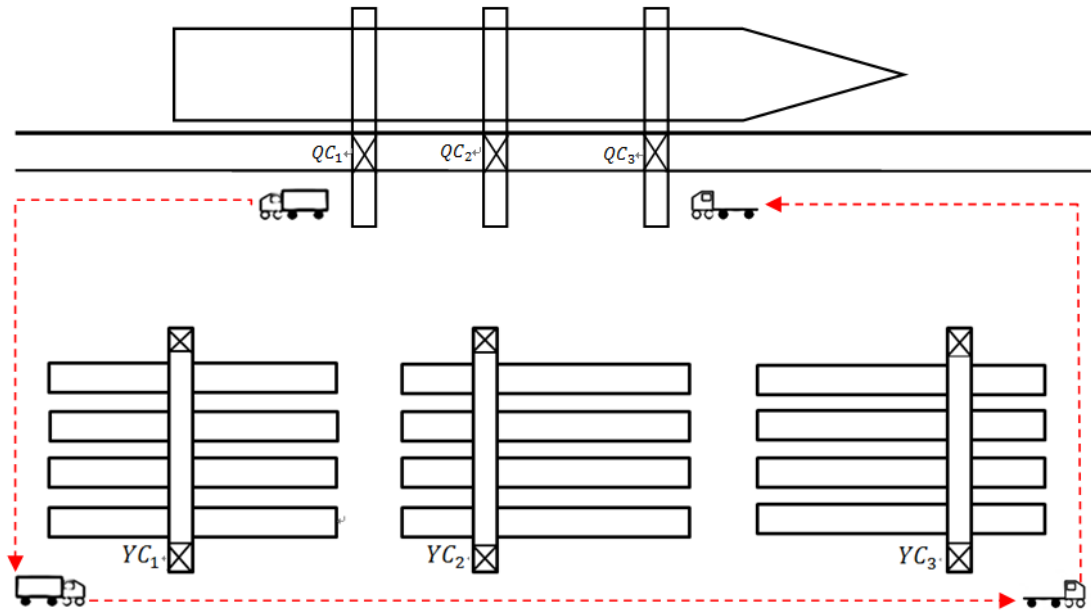


Fig 2. Direction of YT operation

We assume the YT traveling (include operating) time and waiting time between each QC and YC are 5 min. The fixed cost at a departure point is set to be NTD \$300 and the unit YT traveling (including operating) cost and waiting cost is set to be NTD \$10 and NTD \$4 per minute, respectively.

The computational results obtained the optimal value is NTD \$3,870 with all YTs employed. Furthermore, the results demonstrate the routing path and scheduling time of each YT explicitly, which may help operators making an accurate strategy. Detailed result of YT routing and scheduling is shown in Table 1. In a specific time period, each QC and YC can only serve one YT, if the destination QC/YC is occupied by YT, and the following YT is going to wait until the QC/YC is idle. In addition, the YT may terminate the work ahead of time if the containers are delivered efficiently by other YTs.

The model proposed in this paper with time-space network has shown that the YT routing/scheduling problem can be solved efficiently. In practice, operator can adjust the number of YTs and time period according to the containers that have to handle.

Table 1. Detailed result for each YT

YT	Timing												
	Route												
1	8:00	8:05	8:10	8:15	8:20	8:25	8:30	8:35	8:40	8:45	8:50	8:55	9:00
	0*	QC1	YC2	QC1	YC2	QC3	YC2	QC3	YC2	QC2	YC1	0	
2	8:00	8:05	8:10	8:15	8:20	8:25	8:30	8:35	8:40	8:45	8:50	8:55	9:00
	0	QC2	YC1	QC2	YC1	QC1	YC1	QC2	YC1	QC3	YC3	QC2	YC1
3	8:00	8:05	8:10	8:15	8:20	8:25	8:30	8:35	8:40	8:45	8:50	8:55	9:00
	QC3	YC1	QC3	YC2	QC2	YC1	QC2	YC2	QC1	YC2	QC1	YC3	0
4	8:00	8:05	8:10	8:15	8:20	8:25	8:30	8:35	8:40	8:45	8:50	8:55	9:00
	QC1	YC2	QC1	YC1	YC1	QC2	QC2	YC1	QC2	YC1	0		
5	8:00	8:05	8:10	8:15	8:20	8:25	8:30	8:35	8:40	8:45	8:50	8:55	9:00
	QC2	YC3	YC3	YC3	QC3	YC2	QC1	QC1	QC1	YC3	QC3	YC1	0

*Note: 0 denotes the virtual departure and collection point

5. Conclusion and Future Research

The YT operation in container terminal is a critical issue in the container terminal operation and had been studied for many years. An efficient scheduling and routing not only can save the cost of shipping company but increasing the revenue of terminal operator by serving more vessels. In this study, we develop a model, which is formulated as an integer multiple-commodity network flow problem to handle the YT routing and scheduling problem. A time-space network technique had been applied as the first used in the YT routing and scheduling problem in our knowledge. This approach can demonstrate the optimal path of each YT with the minimize cost compared with different number of YT, which can help the terminal operator handle YT operation efficiently.

The example in this study is a small-scale example, which does not have a complicated network. Practically, the terminal operator may face a situation that has to handle thousands of containers in 24 hours, and it will make the network become enormous. Furthermore, the results of the test show that the queue may occur in specific QC and YC. Therefore, finding a suitable algorithm to solve the model, which consider the reality operation in a reasonable time and the queue that may occur at QC and YC is one of future research topics.

References

- Bish, E. K., Leong, T. Y., Li, C. L., Ng, J. W. C. and Simchi-Levi, D. (2001), Analysis of a New Vehicle Scheduling and Location Problem, *Naval Research Logistics* 48: 363-385.
- Lee, D. H., Cao J. X. and Shi, Q. X. (2009), Synchronization of yard truck scheduling and storage allocation in container terminals, *Engineering Optimization* 41(7): 659–672.
- Lee, D. H., Cao, J. X., Shi, Q. X. and Chen, J. H. (2009), A heuristic algorithm for yard truck scheduling and storage allocation problems, *Transportation Research Part E* 45: 810–820.
- Ng, W. C., Mak, K. L. and Zhang, Y. X. (2007), Scheduling trucks in container terminals using a genetic algorithm, *Engineering Optimization* 39(1): 33-47.
- Steinzen, I., Gintner, V., Suhl, L. and Kliewer, N. (2010), A Time-Space Network Approach for the Integrated Vehicle and Crew Scheduling Problem with Multiple Depots, *Transportation Science* 44(3): 367-382.
- Wu, Y., Luo, J. B., Zhang, D. L. and Dong, M. (2012), An integrated programming model for storage management and vehicle scheduling at container terminals, *Research in Transportation Economics* 1-15.
- Yan, S. and Lai, W. (2007), An optimal scheduling model for ready mixed concrete supply with overtime considerations *Automation in Construction* 16: 734-744.
- Yan, S., Lin, H. C. and Liu Y.C. (2011), Optimal schedule adjustments for supplying ready mixed concrete following incidents, *Automation in Construction* 20: 1041-1050.
- Yan, S., Wang, S. S. and Wu, M.W. (2012), A model with a solution algorithm for the cash transportation vehicle routing and scheduling problem, *Computers and Industrial Engineering* 63: 464-473.

A Study of Cruise Passengers' Repurchase Behaviour

Lirn T.C.^{1*} and Weng H.K.²

¹Department of Shipping and Transportation Management, National Taiwan Ocean University, Taiwan.

*E-Mail: tedlirn@email.ntou.edu.tw, Tel: +886-2-24622192#3433, Fax: +886-2-24631903.

²Chinese Maritime Research Institute, Taipei, Taiwan.

**Corresponding Author*

Abstract

Passenger ship is an environmental friendly international tourism mode. Most cruise lines are keen to employ ISO14001 certified professionals, to increase fuel efficiency, and to install advance sewage water treatment system. Many nations are planning to develop their port to accommodatethese green cruise ships. This research reviews literatures to find service attributes and demographic variables influencing cruise passengers' repurchase behavior by a questionnaire survey. Eighty six copies of valid responses are received from Start Cruises passengers in September 2013. Binary logistic regression technique is employed to evaluate several model specifications affecting their repurchase intentions. There are ten attributes and variables in the best fit model. The best fit model specification indicates cruise sport facilities and banquet dinner have positive significant influences and the feeling of crowdedness has a negative influence on the passengers' repurchase behavior. Cruise carriers should improve the quality and the quantity of theirs sport facilities and banquet dinner on board and reduce the crowdedness feeling in the state room and public space on board to increase the likelihood of passengers' repurchase intention.

Keywords: Cruise Ship, Binary Logistic Regression, Repurchase Behaviour.

1. Introduction

Before 1957, more passengers used ship as a transportation vehicle to travel between Europe and the North America (Hobson, 1993). After that year, passenger liners industry has gradually positioned themselves as a major player in the tourism industry instead perceiving themselves as transportation service providers.

With growing income in the Asian developing nations, cruise travelling becomes a welcome recreation option by tourist from these countries. There are four cruise market segmentations: the mass market, the middle market, the luxury market, and the specialty market (Hobson, 1993). For the income of passengers in the mass market tends to be in the \$20,000~\$30,000 US dollars range and the average cost per passenger is between \$125 ~\$200 US dollars. Thus cruise passengers in the developing Asian nations are perceived to be the target for the mass market cruise operators when the large North American cruise market is experiencing a clearly slower growth rate (Weeden et al., 2011). However, most of the cruise ships operating in the Asian developing nations are westerners owned except the ones owned by the Star Cruises. Many economics in the Asian region are keen to provide a comfortable cruise terminal to attract cruise operators to carry passengers to visit their port cities. Hong Kong government built the Kai Tak Cruise Terminal at a cost of HK\$8.2 billion and the terminal began to operate in June 2013 (Nip, 2013). In addition to the comfortable cruise terminal and good recreational facilities on board, there are many factors influencing cruise passengers' travelling packages repurchase behaviour.

2. Motivations for Cruise Ridings

Cruise operation is the combination of transportation service and tourism service. Thus motivations for cruise ridings can be found by summarize tourism literatures and transportation mode choice literatures.

Although Papathanassis and Beckmann (2011) reviewed mainstream database and found a collection of 145 cruise-related academic publications published between 1983 and 2009, there are very limited quantitative literatures discussing the reasons to take a cruise from the cruise passengers' perspective. In a study to segment cruise passengers with price, Petrick (2005) indicates cruise ship's tangibles and intangibles attributes as well as price influences cruisers' satisfaction. These attributes include outside deck areas, overall ship conditions, inside public rooms, and state rooms (abovementioned attributes are tangible); ports of call, shore excursions, entertainment/activities, and cuisine (abovementioned attributes are intangible); perceived price, perceived value of the cruise, and money spend per day. In a research on de-motivators for taking a cruise, Hung & Petric (2010) conclude four aspects (with 20 constraints/de-motivators) for taking a cruise riding: intrapersonal, interpersonal, structural constraints, and not an option. These 20 constraints include poor health, sea-sickness, aquaphobia, no companion, poor dinner, lonely feeling, no time, work responsibilities, family obligations, too expensive, and other better travel alternatives available, etc.

Jones (2011) employs 7-point Likert scales to explore three aspects of potential tourist motivation, including, information sources, vacation attributes, and motives derived from the Leisure Motivation Scale. In a study on motivations for taking cruise holidays, Hung and Petric (2011) interview 293 undergraduate students and employ exploratory factor analysis to summarize fourteen motivating variables to take a cruise. Then they use an online survey to receive 897 responses and classify these fourteen variables into six aspects of motivators that are important to motivate them to take a cruise: social esteem & social recognition, escape/relaxation, learning/discovery & novelty/thrill, bonding, and socialization. Hung and Petric (2010) also use the previous four aspects and the structural equation modelling technique to investigate the relationship between the relationship between the four dimensions and the cruising intention. Xie et al. (2012) review literatures and summarize 28 onboard attributes perceived to be important by cruise passengers and potential cruisers. Using an exploratory factor analysis, these attributes are grouped into seven dimensions: entertainment, recreation and sport, supplementary, core, fitness & health, children, and crew attributes.

In the CLIA's 2013 North America Cruise Industry Update (CLIA, 2013), it indicates following major motivators for cruisers to pick a particular cruise line from the cruise shipowners', agents', and clients' perspectives: knowledge of cruise brand, destinations, price, wanting to try a new ship, new itineraries, and onboard facilities. According to Cruise Lines International Association's 2014 State of the Cruise Industry Report (CLIA, 2014), there are five major motivators for passengers to take cruise: value/price, destination/itineraries, cruise brand reputation, home port, and lifestyle amenities.

From the viewpoint of transportation service providers, travellers choose their transport mode according to the following possible attributes (Ben-Akiva & Lerman, 1985; Sussman, 2000): out of vehicle time (i.e. access time & egress time), in-vehicle time, waiting time, safety, security, out of vehicle cost (including access cost & egress cost), in-vehicle service quality, fares & comfort.

A summary on the above-mentioned attributes motivate passengers' cruise ship riding behaviour is summarized in the Table 1. After a cruise riding in the early August 2013, one of the authors with seven of his companions on board have discussed how to adapted these 50 attributes into a cruise passengers' repurchase intention questionnaire. There are two parts of questions in the questionnaire: the first part aims to collect the surveyees' demographic data, and the second part includes 30 questions to measure the degree of satisfaction of onboard passengers on their previous cruise riding and their stated preference on taking a ride on the similar cruise again.

3. Research Methodology and Sampling

Questionnaires were sent to surveyees who had the cruise riding experience by a government officer in the Keelung port. One hundred copies of questionnaires were handed to the surveyees and 87 copies of them are responded. One response is found to be invalid and 86 copies of them are used for the passengers' repurchase behaviour analysis.

The origin of probabilistic choice models and the concept of random utility is an idea that first appeared in mathematical psychology (Thurston, 1927). Binary logistic regression technique is a discrete choice analysis

uses the principle of utility maximization. We assume rational decision-makers select the alternative with the highest utility when several alternatives are available (Ben-Akiva & Lerman, 1985).

Our binary regression model is used to predict the natural log of the odds of having made one or the other decision. That is,

$$\ln(Odds) = \ln\left\{\frac{\hat{Y}}{1-\hat{Y}}\right\} = a + bx_1 + cx_2 + dx_3 + ex_4 + \dots \quad (1)$$

where \hat{Y} is the predicted probability of the repurchase which is coded with 1 (repurchase) rather than with 0 (reject repurchase), $1-\hat{Y}$ is the predicted probability of rejecting repurchase decision, and $x_1, x_2, x_3, x_4, \dots$ are our predictor variables, including comfort, safety, and security, etc.

Table 1. Attributes motivate passengers' cruise ship riding behavior

Disciplines Authors Attributes / Motivators	Leisure Management							Transport Management	
	Petric (2005)	Hung & Petric (2010)	Jones (2011)	Hung & Petric (2011)	Xie et al. (2012)	CLIA (2013)	CLIA (2014)	Ben-Akiva & Lerman (1985)	Sussman (2000)
1. Outside deck area	✓								
2. Overall ship condition	✓								
3. Inside public rooms	✓								
4. State rooms	✓								
5. Port of call	✓								
6. Shore Excursion	✓								
7. Entertainment / Activities	✓								
8. Cuisine	✓								
9. Perceived price	✓								
10. Perceived value of the cruise	✓								
11. Money spend per day	✓								
12. Intrapersonal reasons		✓							
13. Interpersonal reasons		✓							
14. Structural reasons		✓							
15. Information sources			✓						
16. Vacation attributes			✓						
17. Motives from the Leisure Motivation Scale*			✓						
18. Social esteem				✓					
19. Social recognition				✓					
20. Escape				✓					
21. Relaxation				✓					
22. Learning				✓					
23. Discovery				✓					
24. Novelty				✓					
25. Thrill				✓					
26. Bonding				✓					
27. Socialization					✓				
28. Entertainment					✓				
29. Recreation					✓				
30. Sport					✓				
31. Supplementary					✓				
32. Core					✓				
33. Fitness & health					✓				
34. Children					✓				
35. Crew					✓				✓

36. Knowledge of cruise brand						✓	✓		
37. Destinations						✓			
38. Price						✓	✓		✓
39. Wanting to try a new ship						✓			
40. New Itineraries						✓	✓		
41. Onboard facilities / Hug						✓	✓		✓
42. Value / Price							✓		✓
43. Home port							✓		
44. In vehicle time								✓	✓
45. Out of vehicle travelling time								✓	✓
46. Safety								✓	✓
47. Out of vehicle time (i.e. Access time & Egress time)								✓	✓
48. Out of vehicle cost								✓	✓
49. Waiting time in terminal								✓	✓
50. Security								✓	✓

*There are three dimensions which include 28 measurements in the Leisure Motivation Scale (LMS-28) (Pelletier et al., 1991). These measurements can be grouped into seven types of motivation: (1) Intrinsic motivation: to know, to accomplish, to experience stimulation. (2) Extrinsic motivation: identified, introjected (i.e. to incorporate ideas of others, or (in fantasy) of objects), external regulation. (3) Amotivation (i.e. Inability or unwillingness to participate in normal social situation).

4. Model Specifications and Findings

Using valid responses from 86 surveyees, ten model specifications are tested and four of them are shown as follows (see Table 2 - Table 5).

Table 2. Model Specification 1

Classification ^a					
Observed			Predicted		
			Repurchase		Percentage Correct
			1	2	
Step 1	Repurchase	1	75	0	100.0
		2	10	1	9.1
	Overall Percentage				88.4

^aThe cut value is .500

Variables in the equation

		B Coefficient	S.E.	Wals	df	Significance	Exp (B)	95% C.I. FOR EXP(B)	
								Lower	Upper
Step 1 ^a	Income	-.027	.247	.012	1	.913	.973	.599	1.580
	Ship Fare	.000	.564	.000	1	.999	1.000	.331	3.022
	Ship Comfort	.183	.307	.357	1	.550	1.201	.659	2.190
	Cruise Safety	1.135	.737	2.374	1	.123	3.112	.734	13.189
	Terminal Comfort	.501	.581	.744	1	.388	1.651	.529	5.157
	Cruise Casino	-.113	.360	.098	1	.754	.893	.441	1.809
	Cruise Regular Meals	.180	.491	.135	1	.713	1.198	.458	3.134
	Cruise Banquet Dinner	1.334	.738	3.266	1	.071	3.795	.893	16.125
	Constant	-11.645	4.236	7.559	1	.006	.000		

^aVariables included in the Step 1: Income, Ship Fare, Ship Comfort, Cruise Safety, Terminal Comfort, Cruise Casino, Cruise Regular Meals, Cruise Banquet Dinner.

Table 2. Model Specification 1

Classification ^a					
Observed			Predicted		
			Repurchase		Percentage Correct
			1	2	
Step 1	Repurchase	1	75	0	100.0
		2	10	1	9.1
	Overall Percentage				88.4

^aThe cut value is .500

Variables in the equation

		B Coefficient	S.E.	Wals	df	Significance	Exp (B)	95% C.I. FOR EXP(B)	
								Lower	Upper
Step 1 ^a	Income	-.027	.247	.012	1	.913	.973	.599	1.580
	Ship Fare	.000	.564	.000	1	.999	1.000	.331	3.022
	Ship Comfort	.183	.307	.357	1	.550	1.201	.659	2.190
	Cruise Safety	1.135	.737	2.374	1	.123	3.112	.734	13.189
	Terminal Comfort	.501	.581	.744	1	.388	1.651	.529	5.157
	Cruise Casino	-.113	.360	.098	1	.754	.893	.441	1.809
	Cruise Regular Meals	.180	.491	.135	1	.713	1.198	.458	3.134
	Cruise Banquet Dinner	1.334	.738	3.266	1	.071	3.795	.893	16.125
	Constant	-11.645	4.236	7.559	1	.006	.000		

^aVariables included in the Step 1: Income, Ship Fare, Ship Comfort, Cruise Safety, Terminal Comfort, Cruise Casino, Cruise Regular Meals, Cruise Banquet Dinner.

Table 3. Model Specification 2

Classification Table ^a					
Observed			Predicted		
			Repurchase		Percentage Correct
			1	2	
Step 1	Repurchase	1	72	3	96.0
		2	8	3	27.3
	Overall Percentage				87.2

^aThe cut value is .500

Variables in the Equation

		B	S.E.	Wals	df	Significance	Exp (B)	95% C.I. FOR EXP(B)	
								Lower	Upper
Step 1 ^a	Ship Fare	-.169	.625	.073	1	.787	.844	.248	2.874
	Ship Comfort	.277	.359	.597	1	.440	1.319	.653	2.664
	Cruise Safety	.365	.930	.154	1	.694	1.441	.233	8.916
	Terminal Comfort	.043	.761	.003	1	.955	1.044	.235	4.636
	Cruise Casino	-.024	.392	.004	1	.952	.976	.453	2.107
	Cruise Regular Meals	.585	.630	.863	1	.353	1.795	.523	6.164
	Cruise Banquet Dinner	1.364	.786	3.014	1	.083	3.913	.839	18.261
	Crowdedness	-1.741	.766	5.171	1	.023	.175	.039	.786
	Shore Excursion	1.057	.823	1.651	1	.199	2.878	.574	14.434
	Constant	-8.288	4.615	3.225	1	.073	.000		

^aVariable(s) entered on step 1: Ship Fare, Ship Comfort, Cruise Safety, Terminal Comfort, Cruise Casino, Cruise Regular Meals, Cruise Banquet Dinner, Crowdedness, Shore Excursion.

Table 4. Model Specification 3
Classification Table^a

Number of Observation			Predicted		
			Repurchase		Percentage Correct
			1	2	
Step 1	Repurchase	1	73	2	97.3
		2	5	6	54.5
	Overall Percentage				91.9

^aThe cut value is .500

Variables in the Equation

		B	S.E.	Wals	df	Significance	Exp (B)	95% C.I. FOR EXP(B)	
								Lower	Upper
Step 1 ^a	Ship Fare	-.391	1.075	.132	1	.716	.676	.082	5.568
	Ship Comfort	.623	.629	.982	1	.322	1.865	.544	6.398
	Cruise Safety	-.683	1.532	.199	1	.656	.505	.025	10.173
	Terminal Comfort	.659	1.509	.191	1	.662	1.933	.100	37.186
	Cruise Casino	-.060	.530	.013	1	.911	.942	.333	2.665
	Cruise Regular Meals	-.751	1.017	.544	1	.461	.472	.064	3.467
	Cruise Banquet Dinner	4.336	2.297	3.562	1	.059	76.419	.846	6899.359
	Crowdedness	-3.779	1.633	5.353	1	.021	.023	.001	.561
	Shore Excursion	1.759	1.782	.975	1	.324	5.809	.177	191.081
	Cruise Sport Facilities	3.375	1.591	4.498	1	.034	29.231	1.292	661.449
	Constant	-22.674	11.397	3.958	1	.047	.000		

^aVariable(s) entered on step 1: Ship Fare, Ship Comfort, Cruise Safety, Terminal Comfort, Cruise Casino, Cruise Regular Meals, Cruise Banquet Dinner, Crowdedness, Shore Excursion, Cruise Sport Facilities.

Table 5. Model Specification 4
Classification Table^a

Number of Observation			Predicted		
			Repurchase		Percentage Correct
			1	2	
Step 1	Repurchase	1	72	3	96.0
		2	5	6	54.5
	Overall Percentage				90.7

^aThe cut value is .500

Variables in the Equation

		B	S.E.	Wals	df	Significance	Exp (B)	95% C.I. FOR EXP(B)	
								Lower	Upper
Step 1 ^a	Crowdedness	-26.707	50.457	.280	1	.597	.000	.000	2.239E31
	Ship Comfort	3.703	6.583	.316	1	.574	40.573	.000	1.629E7
	Ship Fare	-.182	1.829	.010	1	.921	.833	.023	30.048
	Shore Excursion	21.492	40.085	.287	1	.592	2.158E9	.000	2.846E43
	Cruise Safety	-14.626	25.673	.325	1	.569	.000	.000	3.167E15
	Terminal Comfort	-.921	2.954	.097	1	.755	.398	.001	130.160
	Queuing Time Embarking	-11.600	22.524	.265	1	.607	.000	.000	1.364E14
	Cruise Sport Facilities	26.478	50.580	.274	1	.601	3.157E11	.000	3.573E54
	Cruise Regular Meals	1.302	5.223	.062	1	.803	3.678	.000	102641.889
	Cruise Karaoke	-13.932	25.845	.291	1	.590	.000	.000	8.877E15

Cruise Casino	18.566	34.410	.291	1	.590	1.156E8	.000	2.254E37
Cruise Stage Shows	-3.513	8.675	.164	1	.685	.030	.000	721433.714
Cruise Banquet Dinner	29.323	54.726	.287	1	.592	5.430E12	.000	2.077E59
Constant	-146.539	259.061	.320	1	.572	.000		

^aVariable(s) entered on step 1: Crowdedness, Ship Comfort, Ship Fare, Shore Excursion, Cruise Safety, Terminal Comfort, Queuing Time Embarking, Cruise Sport Facilities, Cruise Regular Meals, Cruise Karaoke, Cruise Casino, Cruise Stage Shows, Cruise Banquet Dinner.

Seven independent variables (ship fares, ship comfort, cruise safety, terminal comfort, cruise casino, cruise meals, and cruise banquet dinner) and one dependent variable (repurchase) are included in the first model specification. There is only one variables (i.e. Cruise Banquet Dinner) found statistically significant at 0.1 level in the model specification 1, its coefficient is 1.334. This finding implies high quality banquet dinner will increase the likelihood of our surveyees' cruise repurchase behavior. Although in a social science research, academicians tend to use a statistical significance level of 0.05 as a threshold for the test of significance. The overall correct prediction rate in the first model is 88.4% which is a satisfied result according to the social science standard.

In the second model specification, 'crowdedness' and 'shore excursion' are added into the first model's seven variables as the independent variables. Cruise banquet dinner is remained significant at 0.1 level (its coefficient is 1.364), and crowdedness is also found to be significant at 0.05 level (its coefficient is -1.741). Overall model predicted correct percentage is 87.2%.

For the third model specification, another one independent variable, 'cruise sport facilities', is added into the second model specification. Of the ten independent variables analysed, two variables ('crowdedness' and 'cruise sport facilities') are found to be significant at 0.05 level, and another one variable ('cruise banquet dinner') is found to be significant at 0.1 level. The overall correct prediction rate is as high as 91.9% which implies this is the best model among the four specifications we discussed in this section.

In the fourth model specification, three more independent variables ('queuing time for embarking', 'cruise Karaoke', and 'cruise stage shows') are added into the ten variables discussed in the third model. However, the overall correct prediction rate is reduced to 90.7% and none of the independent variables is found significant at 0.1 level.

5. Conclusions, Implications and Discussions

Cruise travelling is a combination of transportation service and leisure service. Traditional important service attributes are not found to be significant important to influence cruisers' repurchase intention in our research. Instead, three leisure attributes are found to significantly influence cruise passengers' repurchase intentions: Satisfaction on cruise banquet dinner, cruise sport facilities (positive impact), and a feeling of crowdedness (negative impact). One important independent variable, itinerary (shore excursion), reported by Lee and Ramdeen (2013) by examining 30,000 cruise voyages is not found significant important in our research.

Our surveyees are mostly passenger of Star Cruises. Star Cruises, a member of Genting Hong Kong, is perceived to rely on its casinos onboard as its major revenue resources. In our study, we found for most passengers, gambling in the casino onboard is not perceived to be a major attribute makes them come back to buy the cruise travelling package again. Gambling makes passengers nervous and is not deemed to be a kind of usual leisure activities. On the contrary, cruise casino has a negative influence on our surveyees' decision to repurchase cruise travelling package. This has a practical implication for cruise operators served the great Chinese region. Modern Chinese holiday goers aim to fully relax themselves during their holiday vacations, leisure activities such as sport activities, captain's banquet dinner invitation, and adequate state room and spacious public space onboard to avoid the feeling of crowdedness are the three major attributes attract cruise passengers to come back and repurchase cruise travelling package again. Cruise stage shows and onboard Karaoke facilities are not provided free of charge to regular passengers, thus we found negative coefficients are

associated with these two attributes. However, their negative influences on passengers' repurchase intention are not significant at even 0.1 level.

Improvement and provision of free sport hardware onboard (including swimming pool, rock climbing wall, basketball ground, golf ground, etc.) and increase the number of guests invited by the captain for a delicate banquet dinner for passengers onboard can attract previous cruise passengers to come back and repurchase the cruise travelling package again.

Possible avenues for future cruise research can focus on following two issues. (1) A survey to passengers in different segments of cruise markets and compares their passengers' repurchase intention and repurchase motivators. (2) Cruise traffics between Hong Kong, Macau, and mainland China are free from the cabotage regulation in practice. Taiwan government also allows foreign owned cruise ships carry passenger from Taiwan to its offshore islandsⁱ. The cruise cabotage regulation and its impacts on the port and tourism industry development are also highly desired.

References

- Ben-Akiva, M. and Lerman, S. (1985), *Discrete Choice Analysis*, Boston: The MIT Press.
- CLIA (2013), Cruise Lines International Association (CLIA) 2013 North America Cruise Industry Update, <http://www.cruising.org/sites/default/files/pressroom/CruiseIndustryUpdate2013FINAL.pdf> (Accessed on 22/03/2014).
- CLIA (2014), CLIA 2014 State of the Cruise Industry Report, <http://www.cruising.org/sites/default/files/pressroom/Infographic.pdf> (Accessed on 22/03/2014).
- Hobson, J. S. P. (1993), Analysis of the US Cruise Line Industry, *Tourism Management* 14(6): 453-462.
- Hung, K. and Petrick, J.F. (2010), Developing a measurement scale for constraints to cruising, *Annals of Tourism Research* 37(1): 206-228.
- Hung, K. and Petrick, J.F. (2011), Why do you cruise? Exploring the motivations for taking cruise holidays, and the construction of a cruising motivation scale, *Tourism Management* 32 (2): 386-393.
- Jones, R. V. (2011), Motivations to Cruise: An Itinerary and Cruise Experience Study, *Journal of Hospitality and Tourism Management* 18(1): 30-40.
- Lee, S. and Ramdeen, C. (2013), Cruise ship itineraries and occupancy rates, *Tourism Management* 34(Feb): 236-237.
- Mak J., Sheehy C. and Toriki S. (2010), The passenger vessel services act and America's cruise tourism industry, *Research in Transportation Economics* 26(1): 18-26.
- Nip, A. (2013), Overseas passengers return to Kai Tak with official opening of HK\$8.2b cruise terminal, 13 June, 2013, *South China Morning Post*, www.scmp.com/news/hong-kong/article/1259330/overseas-passengers-return-kai-tak-official-opening-hk82b-cruise (Accessed on 3/23/2014).
- Papathanassis A. and Beckmann I. (2011), Assessing the 'poverty of cruise theory' hypothesis, *Annals of Tourism Research* 38(1): 153-174.
- Petrick, J.F. (2005), Segmenting cruise passengers with price sensitivity, *Tourism Management* 26(5):753-762.
- Sussman, J. (2000), *Introduction to Transportation Systems*, London: Artech House.
- Thurstone, L. L. (1927), A law of comparative judgement, *Psychological Review* 34 (4): 278-286.
- Weeden C., Lester J.-A. and Thyne M. (2011), Cruise Tourism: Emerging Issues and Implications for a Maturing Industry, *Journal of Hospitality and Tourism Management* 18(1): 26-29.
- Xie H. J., Kerstetter D. L. and Mattila A. S. (2012), The attributes of a cruise ship that influence the decision making of cruisers and potential cruisers, *International Journal of Hospitality Management* 31(1): 152-159.

ⁱMak et al. (2010) study American cruise tourism industry and indicated the Passenger Vessel Services Act (PVSA) of 1886, a cabotage law which also applies to the U.S. cruise ship industry, attempts to shield U.S. maritime shipping from foreign competition, should be revoked.

A Structural Equation Analysis of Vessel Traffic Controllers' Fatigue Factors

Jin-Ru Yen*, Yu-Ying Wang, Chih-Ching Chang and Chao-Yang Chang

Department of Shipping and Transport Management, National Taiwan Ocean University, Keelung, Taiwan.

*Email: jinruyen@gmail.com

**Corresponding Author*

Abstract

Vessel traffic controllers work round the clock in order to fulfill the needs of international shipping traffic in each harbor. Due to their special work arrangement, shift work could have serious consequences on their health. Fatigue is one of them and could affect the outcome of the controller's work. The relationship between fatigue and work performance is essential for management to better schedule the controller's tasks. Additionally, factors that have a bearing on the controller's fatigue need to be investigated. A structural equation model was carried out to conduct a path analysis. The relationship among physical fatigue (PF) and mental fatigue (MF), before and after work shifts, was then identified. The results showed that sleeping quality had direct influences on the controller's fatigue, either PF or MF. In addition, PF after shifts was caused by sleeping quality, working environment, workload, PF before shifts, and MF after shifts. The MF after shifts was mainly affected by sleeping quality, workload and MF before shifts. The results indicate that workload and sleeping quality bear strong relations to the causes of fatigue. These findings are useful for management to reduce the level of controllers' fatigue and to improve shipping safety.

Keywords: Fatigue, Vessel traffic controller, Structural equation model

1. Introduction

Fatigue has been an international issue in maritime transport for decades. For example, Transportation Safety Board of Canada developed a guide for investigating fatigue and maritime accidents (TSBC, 1997). Australian Marine Pilots Association wrote a fatigue management standard operating manual (AMPA, 2000). The UK International Transport Workers' Federation (ITWF, 1997) called attention to crew fatigue issues, and suggested crew members take proper rest and physical/mental adjustment in order to improve safety. IMO (International Maritime Organization) and NUMAST (National Union of Marine, Aviation and Shipping Transport Officers, UK) both regulate the maximum work hours for vessel crew members (IMO, 2001). There is, however, little research related to the fatigue of vessel traffic controllers (VTCs).

A harbor is an important gateway for vessels to come into port/leave port, and monitoring vessels as well as providing necessary services to marine crew members in harbor area are essential for marine transport safety. Therefore, VTCs are the key element of port safety. They contact with ships and make them move safely and efficiently in a port. In an international harbor, VTCs have to be available around the clock and thus take a shift system. Working shifts is likely to cause VTCs a disruption of their biological clock and therefore influence their performances on duty (Liou et al., 2008). That is, VTC fatigue could be a potential threat to port safety. Effectively dealing with fatigue in the marine environment requires a holistic approach. Understanding factors that affect VTC fatigue and taking necessary countermeasures are essential to improve port safety.

While quantitative modeling of VTC fatigue is limited in both the academic society and the practice, the purpose of the present research is to shed light on this area and estimate a mathematical model that is able to identify key factors that affect fatigue. Specifically, empirical data obtained from VTCs in various ports located in Taiwan are calibrated using structural equation modeling (SEM) to explore fatigue factors.

There are five sections in this paper. A review of literature related to fatigue is presented in the next section. Section 3 describes the methodological context, including hypotheses of the proposed model, survey, and the specification of SEM. Section 4 presents results and findings of the empirical study. Conclusions drawn from the analysis are discussed in the final section.

2. Literature Review

According to our literature search, no study related to VTC fatigue is currently available. Most research is relating to the fatigue of vessel crew members and other marine safety issues. For example, Pollard et al. (1990) investigated shipboard crew fatigue, and suggested measures to reduce fatigue. Sandquist et al. (1996) addressed the relationship between fatigue factors (work and sleep patterns) and alertness of merchant marine personnel. McCallum et al. (1996) established procedures to investigate the relationship between marine casualties and their possible causes such as human factors and fatigue. Cantwell (1998) discussed human factors that affect marine pilot operations, including fatigue and alertness. As fatigue is a common human issue, some fatigue research in other modes of transportation is meaningful and thus reviewed hereafter.

Morris and Miller (1996) used a variety of approaches to measure the physical fatigue of pilots in U.S. Air Force and found that the fatigue level of the participants was related to their error rates of flight operation. In addition, from 1994 to 1998, there were 227 flight safety incidents reported to be associated with unfavorable shift arrangements that resulted in fatigue build-up (Goode, 2003). Yen et al. (2005, 2009) investigated pilot fatigue with various flight distances and found that fatigue level was influenced by various factors such as quality of sleep, age of pilots, and unfavorable cockpit environment. Studies have also shown that longer distance flights could contribute to higher level of fatigue compared to short ones. Harmar et al. (2002) investigate a sample of 126 male train drivers and 104 railway traffic controllers to analyze factors that affect sleepiness on duty. They found that the risk for severe sleepiness was 6 to 14 times higher in the night shift and about twice as high in the morning shift compared with the day shift. Additionally, the research identified age and shift length as two factors that affect the severity of sleepiness. Liou et al. (2008) analyzed the working condition, workload, job stress and fatigue level of Taiwanese bus drivers to investigate the relationship between the shift system and fatigue. The study found that in addition to shift work, factors that affect the fatigue level of workers include working environment, quality of sleep, and physical health. Costa (2003) discovered that shift work can exert adverse effects on physical and mental health of the workers. Fatigue has also been recognized as one of the public safety concerns (Noy et al., 2011).

3. Methodology

3.1 Hypotheses and structural equation model

On the basis of literature review in section 2, we propose the following hypotheses and establish a path analysis as illustrated in Figure 1, which will be estimated by using a structural equation model and a set of empirical data from VCTs in various Taiwan harbors.

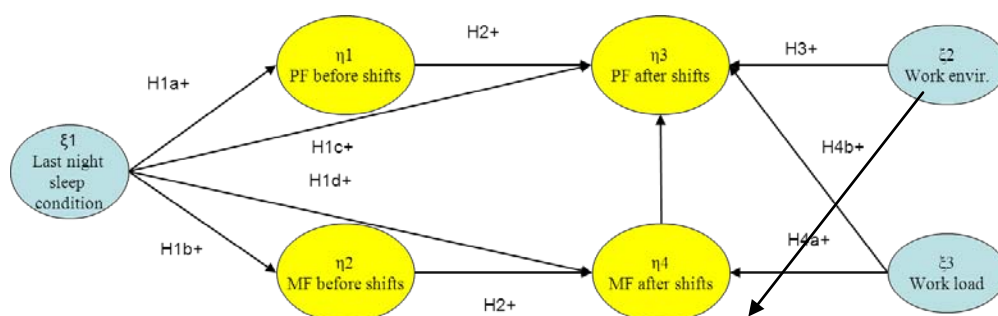


Fig 1. The hypotheses and path analysis

- H1: Sleeping quality (e.g. hard to fall asleep/wake up) of the night before duty positively affect physical fatigue (PF) and mental fatigue (MF), before and after shifts.
- H2: PF and MF before shifts positively affect PF and MF after shifts, respectively.

- H3: Work environments (e.g. seat not comfortable) positively affect PF and MF after shifts.
H4: Workloads (e.g. busy) positively affect PF and MF after shifts.
H5: MF after shifts positively affects PF after shifts.

3.2 Questionnaire design

The questionnaire used in this research is based on the one proposed by Yen et al. (2009) where pilot fatigue is of interest. There are seven sections in the questionnaire (Table 1). The first section is relating to general information about controllers, such as age, gender, height, weight, and education. The second one asks questions about the respondent's sleeping experiences at home on a typical day off, containing information about bed time, get-up time, night wake-up, and overall sleeping quality. Questions about hard to fall asleep and hard to wake up are also asked to rate them using a five-point Likert's scale where 0 corresponds to *strongly disagree* and 4 represents *strongly agree*. The third section asks the same questions as in section two, but at the night before duty. In the fourth section, participants are asked about information regarding their work and working environment such as noise, light, chair, air quality, and so forth. Questions such as noise, seat not comfortable, temperature too low, polluted air, humidity too wet, and light too weak are asked to rate them using a five-point Likert's scale with 0 corresponding to *strongly disagree* and 4 representing *strongly agree*.

The fifth section is related to controllers' fatigue level. Fatigue is generally described as a state of feeling tired, weary, or sleepy that results from prolonged mental or physical work, extended periods of anxiety, exposure to harsh environments, or loss of sleep. Therefore, participants are asked to rate their physical and mental fatigue before and after shifts. This section is modified from a similar form used by Yen et al. (2009). Participating VTCs are asked to answer 24 questions related to their physical fatigue and 19 items related to their mental fatigue. For each measured item, participants are asked to report their perceived fatigue level with respect to the statement on a scale of 0 to 4, with 0 standing for *none*, 1 for *small*, 2 for *moderate*, 3 for *high*, and 4 for *very high*. Some of the questions can be answered by controllers before shifts but some need to wait until the end of the shifts. Therefore, two separate questionnaires are used, with the first one containing questions to be answered before shifts and the second after shifts.

In the sixth section, participants are asked about their personal experiences of fatigue or nod-offs when on shifts. In the last section, participants are asked about their personal feelings of workload and job involvement, using job characteristics scale proposed by Cheng et al. (2001) and Karasek et al. (1998).

Table 1. Contents of questionnaire and the corresponding times when controllers answer them

Question sections	Before shifts	After shifts
1. General information about controllers	✓	
2. Sleeping condition at home	✓	
3. Sleeping condition at the night before duty	✓	
4. Information about current work	✓	✓
5. Level of fatigue	✓	✓
6. Personal experience about fatigue		✓
7. Personal experience about workload		✓

3.3 Sampling

Data used in this study were obtained from VTCs working in Taiwan International Ports Corp (TIPC). TIPC is a state-owned corporate that operates all international harbors and major domestic harbors in Taiwan. There are currently 98 VTCs in TIPC (including ports of Kaohsiung, Keelung, Taichung, Mailiao, Taipei, Hualien, Suao, and Anping). The survey was conducted from September 1 to October 7, 2012 and questionnaires were delivered to the whole population. A total of 95 usable questionnaires were collected, representing 96.9% of the population. The participants rated their fatigue level twice: one before shifts and the other after shifts. General information, sleeping condition at home, sleeping condition at the night before duty, and information about current work were carried out before shifts. Then information about current work, personal experiences about fatigue and workload were carried out after shifts.

3.4 Structural equation model

As illustrated in Figure 1, there are seven latent variables in the structural equation model, including three independent latent variables (IDLV) (ξ_1 – ξ_3) and four dependent latent variables (DLV) (η_1 – η_4). Each latent variable is measured by multiple indicators, which is formulated as a multi-regression and referred as a measurement equation. For example, PF is measured by 24 indicators and MF is measured by 19 indicators, as discussed in section 3.2. Additionally, DLVs are influenced by IDLVs, i.e. antecedent variables, as specified in structural equations. For example, all types of fatigue (η_1 – η_4) are assumed to be influenced by ξ_1 (last night sleeping quality), and both PF (η_3) and MF (η_4) after shifts are assumed to be influenced by ξ_2 (work environment) and ξ_3 (workload). Finally, it is assumed that MF after shifts (η_4) will affect PF after shifts (η_3). According to the assumptions made in Figure 1, we have seven sets of measurement equations as specified in equations 1 to 7. There are also four structural equations as in equations 8 to 11, whose paths and associated parameters are illustrated in Figure 2.

$$x_{i1} = \lambda_{xi1}\xi_1 + \varepsilon_{i1} \quad (1)$$

$$x_{i2} = \lambda_{xi2}\xi_2 + \varepsilon_{i2} \quad (2)$$

$$x_{i3} = \lambda_{xi3}\xi_3 + \varepsilon_{i3} \quad (3)$$

$$y_{i1} = \lambda_{yi1}\eta_1 + \delta_{i1} \quad (4)$$

$$y_{i2} = \lambda_{yi2}\eta_2 + \delta_{i2} \quad (5)$$

$$y_{i3} = \lambda_{yi3}\eta_3 + \delta_{i3} \quad (6)$$

$$y_{i4} = \lambda_{yi4}\eta_4 + \delta_{i4} \quad (7)$$

$$\eta_1 = \gamma_{11}\xi_1 + \zeta_1 \quad (8)$$

$$\eta_2 = \gamma_{21}\xi_1 + \zeta_2 \quad (9)$$

$$\eta_3 = \beta_{31}\eta_1 + \beta_{34}\eta_4 + \gamma_{31}\xi_1 + \gamma_{32}\xi_2 + \gamma_{33}\xi_3 + \zeta_3 \quad (10)$$

$$\eta_4 = \beta_{42}\eta_2 + \gamma_{41}\xi_1 + \gamma_{42}\xi_2 + \gamma_{43}\xi_3 + \zeta_4 \quad (11)$$

In equations 1 to 11, λ_{xij} is the loading of measuring indicator x_{ij} on IDLV ξ_j . Similarly, λ_{yij} is the loading of measuring indicator y_{ij} on DLV η_j . Coefficient γ_{ij} represents the direct effect of IDLV ξ_j on another DLV η_i , and β_{ij} captures the effect of DLV η_j on another DLV η_i . It is assumed that errors in measurement equations and structural equations are uncorrelated (i.e. $\text{Cov}(\varepsilon, \zeta) = 0$; $\text{Cov}(\delta, \zeta) = 0$).

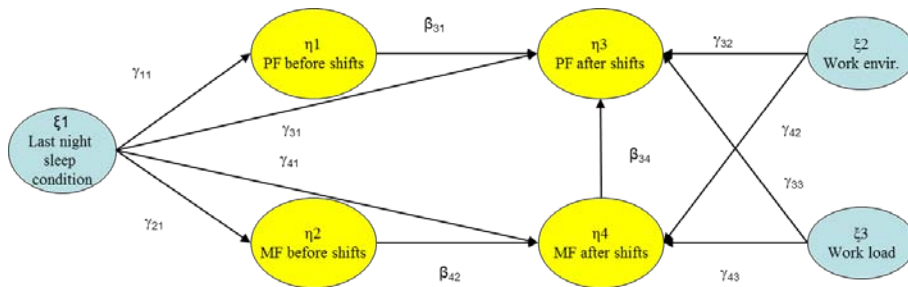


Fig 2. The paths of structural equations and associated parameters

4. Analysis

Following the validation of the measurement model, SEM can be used to estimate the structural model. Analysis was carried out using the SPSS 12.0 (2003) for Windows and LISREL 8.7 (Joreskog and Sorbom, 1996; Diamantopoulos and Siguaw, 2000) statistical packages.

4.1 The measurement model

Table 2 lists the estimation results of measurement equations, in which latent variables are measured by measureable variables. For example, the construct of latent variable "last night sleep condition" can be measured by *hard to fall asleep* and *hard to wake up*. "Work environment" can be measured by *seat not comfortable* and *wet humidity*. The latent variable of PF before shifts can be represented by the controller's

responses to the levels of four structures such as *tired*, *discomfort*, *headache*, and *slow response*, which are extracted from 24 items related to PF using factor analysis. Similarly, the latent variable of MF before shifts can be represented by *reduced ability to express* and *slow response*, which are extracted from 19 items related to MF. The latent variable of PF after shifts can be represented by the controller's responses to the levels of two structures such as *tired* and *discomfort*. The latent variable of MF after shifts can be represented by the controller's responses to the levels of *slow response*. In order to standardize the scale of the measurement model, some coefficients are set to a fixed value of 1 and their t values cannot be calculated.

Table 2. Estimation results of measurement equations

Construct	Variable	Parameter	Standardized coefficients	t value
Last night sleep condition	hard to fall asleep	λ_{x11}	0.53	4.26 ***
	hard to wake up	λ_{x21}	0.36	3.32 ***
Work Environment	seat not comfortable	λ_{x32}	0.85	5.39 ***
	humidity too wet	λ_{x42}	0.68	7.47 ***
Work load	busy	λ_{x53}	0.36	5.18 ***
	load heavy	λ_{x63}	0.68	7.47 ***
PF before shifts	tired	λ_{y11}	0.78	--
	discomfort	λ_{y21}	0.67	15.07 ***
	headache	λ_{y31}	0.70	16.15 ***
	decreased activity	λ_{y41}	0.70	11.87 ***
MF before shifts	reduced ability to express	λ_{y52}	0.65	--
	slow response	λ_{y62}	0.76	11.91 ***
PF after shifts	tired	λ_{y73}	0.80	--
	discomfort	λ_{y83}	0.88	18.28 ***
MF after shifts	slow response	λ_{y94}	0.81	--

Note: * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$.

4.2 The structural model

Estimation results illustrated in Table 3 and Figure 3 indicate that ten out of eleven parameters specified in Figure 2 support the hypotheses made in section 3.1, with the sign of the coefficients being the same as assumed. Additionally, nine coefficients are statistically significant and only one (γ_{32}) is at the margin of significance. Data in Figure 3 also show that the VTC's sleep condition at the night before duty significantly affect both his/her PF and MF, before and after shifts. This finding is similar to the result of another research (Yen et al., 2005) which found that sleeping quality significantly affects fatigue level of pilots who serves domestic or international flights. As speculated, work environment affects the VTC's PF after shifts. It, however, does not affect MF after shifts, as specified in Figure 2. On the other hand, workloads significantly affect both the VTC's PF and MF, after shifts. Specifically, as indicated in the measurement model, work environment consists of factors such as *the comfort of seats* and *humidity*. Workloads are associated with the perception of the VTC to be *busy* or with *heavy load*.

The relationships among four DLVs are also validated by the estimation results as shown in Table 3 and Figure 3. It is assumed that the VTC's PF and MF before duty will affect his/her PF and MF after duty, respectively. Both relationships are proved to be significant. Additionally, the estimated coefficient of β_{34} validates the assumption that the VTC's MF after duty affects his/her PF after duty.

Since the scale of the coefficients is standardized, their values can be used to represent their relative importance. As indicated in the numbers with shadow in Table 3, four out of the top five coefficients, i.e. γ_{11} , γ_{21} , γ_{31} , and γ_{41} , are related to "last night sleep condition." This implies that sleeping quality is the most important factor that affects the VTC's physical and mental fatigue, both before and after duty. This is also shared with the finding of another research related pilot fatigue (Yen et al., 2005). The fifth one (β_{34}) is the coefficient that represents the influence of MF after duty on PF after duty. Since both PF and MF after duty are significantly affected by the VTC's workload, workloads can be considered as another important fatigue

factor. Work environment, on the other hand, is relatively unimportant, compared with other two factors, which is also indicated by the previously mentioned research (Yen et al., 2005).

Table 3. Estimation results of structural equations

Path	Parameter	Standardized coefficients	t value
PF before shifts			
Last night sleep condition → PF before duty	γ_{11}	0.91	9.80 ***
MF before shifts			
Last night sleep condition → MF before duty	γ_{21}	1.00	10.09 ***
PF after shifts			
Last night sleep condition → PF after duty	γ_{31}	0.63	6.55 ***
Work Environment → PF after duty	γ_{32}	0.13	1.30
Work load → PF after duty	γ_{33}	0.16	2.40 **
PF before duty → PF after duty	β_{31}	0.23	3.22***
MF after duty → PF after duty	β_{34}	0.68	9.48**
MF after shifts			
Last night sleep condition → MF after duty	γ_{41}	0.61	5.85***
Work load → MF after duty	γ_{43}	0.24	2.49**
MF before duty → MF after duty	β_{42}	0.61	6.33***

Note: * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$.

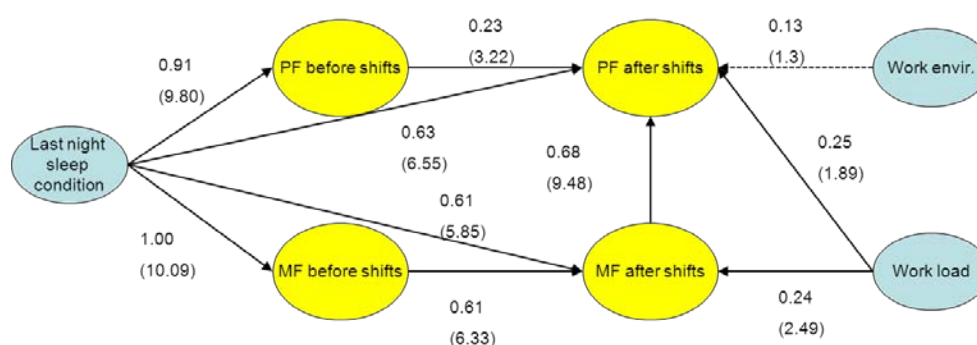


Fig 3. Estimation results of structural equations

5. Conclusion

While other safety issues related to marine transport have been addressed, quantitative research about VTC fatigue is limited. The current work sheds some light on this subject and investigates critical fatigue factors. The most important fatigue factor that influences the VTC's fatigue is sleeping quality, which is consistent with the phenomenon in shift operations where the circadian rhythm can be disrupted and sleeping quality becomes essential to improve performance. The other two fatigue factors are workloads and work environment. The former indicates that intensive workloads might cause tension and pressure on the VTC, and therefore affect his/her after-duty PF and MF. The MF also affects the PF after duty. The latter reflects relatively less comfortable environment in the space where the VTC provides services.

The present results confirm previous findings that the perceived fatigue level after duty is influenced by the level before duty, no matter what type of fatigue. This suggests that a VTC with low level of fatigue before duty will have a better chance to have lower level of fatigue after duty, again reflecting the importance of sleeping quality. The research results also reveal that the fatigue problems incurred by VTCs serving harbors in Taiwan are not unique; findings are similar to those found in pilots serving Taiwanese airlines. The research can derive some countermeasures to cope with VTC fatigue problems. For example, a controller with better sleep is most likely to have lower level of fatigue. Additionally managements are advised to carefully schedule VTCs' tasks to smooth their workloads.

Acknowledgement

The present paper is part of the results of a project granted by the National Science Council, R.O.C. under project NSC-101-2221-E-019-060. The authors are grateful for the assistance provided by Taiwan International Ports Corp.

Reference

- Australian Marine Pilots Association (2000), Fatigue management standard, Australian Marine Pilot's Association, Australia.
- Cantwell V. (1998), Human Factors in Marine Operations: Managing Fatigue, Alertness and Endurance in the Marine Pilot Operations, Maryland, United States.
- Cheng, Y., Luh, W. M. and Guo, Y. L. (2001), Reliability and validity of the Chinese version of the job content questionnaire (C-JCQ) in Taiwan workers, *International Journal of behavioral medicine* 10(1): 15-30.
- Costa, G. (2003), Shift-work and occupational medicine: an overview, *Occupational Medicine* 53: 83-88.
- Diamantopoulos, A. and Siguaw, J. A. (2000), *Introducing LISREL*, SAGE Publications, London.
- Fornell, C. and Larcker, D. F. (1981), Evaluating structural equations models with unobservable variables and measurement error, *Journal of Marketing Research* 18: 39-45.
- Goode, J. H. (2003), Are pilots at risk of accidents due to Fatigue? *Journal of Safety Research* 34: 309-313.
- Gorsuch, R. L. (1983), *Factor Analysis*, 2nd edition, Hillsdale, NJ: Erlbaum.
- Harmar, M., Sallinen, M., Ranta, R., Mutanen, P. and Muller, K. (2001), The effect of an irregular shift system on sleepiness at work in train drivers and railway traffic controllers, *Journal of Sleep Research* 11: 141-151.
- Internal Maritime Organization (IMO) (2001), *Guidance on Fatigue Mitigation and Management*.
- International Transport Workers' Federation (ITWF) (1997), *Seafarer Fatigue: Wake up to the dangers*, IMO, MSC 69/INF.10, United Kingdom.
- Joreskog, K.G. and Sorbom, D. (1996), *LISREL 8: User's Reference Guide*, Scientific Software International, Chicago.
- Karasek, R., Brisson, C. and Kawakami, N. (1998), The Job Content Questionnaire (JCQ): an instrument for internationally comparative assessments of psychosocial job characteristics, *Journal of Occupational Health Psychology* 3: 322-355.
- Liou, S. H., Loh, C. H., Chen, H. I., Lai, J. H., Cai, S. S., Wei, J. Q. and Guo, M. L. (2008), Passenger driving the shift system and fatigue-related research, The Institute of Safety and Health, Council of Labor Affairs, R.O.C.
- McCallum, M. C., & Raby, M., Rothblum A. (1996), Procedures for Investigating and Reporting Human Factors and Fatigue Contributions to Marine Casualties, Report No. CG-D-09-97, Batelle Seattle Research Center and U.S. Coast Guard Research and Development Center, Groton, Connecticut.
- Morris, T. T., and Miller, J. C. (1996), Electrooculography and Performance Indices of Fatigue During Simulated Flight, *Biological Psychology* 42: 343-360.
- Noy, Y. I., Horrey, W. J., Popkin, S. M., Folkard, S., Howarth, H. D. and Courtney, T. K. (2011), Future directions in fatigue and safety research, *Accident Analysis and Prevention* 43: 495-497.
- Pollard J. K., Sussman E. D. and Stearns M. (1990), *Shipboard Crew Fatigue, Safety and Reduced Manning*, Report No. DOT-MA-RD-840-90014, John A. Volpe National Transportation Systems Center, Massachusetts, United States.
- Rosekind, M. R., Graeber, R. C., Dinges, D. F., Connell, L. J., Rountree, M. S., Spinweber, C. L. and Gillen, K. A. (1994), Crew factors in flight operations IX: effects of planned cockpit rest on crew performance and alertness in long-haul operations, NASA Technical Memorandum 108839, Washington, DC.
- Sandquist T., Raby M., Maloney A. L. and Carvalhais T. (1996), *Fatigue and Alertness in Merchant Marine Personnel: A field study of work and sleep patterns*, Report No. CG-D-06-97, Batelle Seattle Research Center and U.S. Coast Guard Research and Development Center, Connecticut, United States.
- Transportation Safety Board of Canada (TSBC) (1997), *A guide for investigating for fatigue*, Canada.
- Yen, J. R., Hsu, C. C., Ho, H., Lin, F. F. and Yu, S. H. (2005), Identifying flight fatigue factors: a neoclassic modeling approach, *Journal of Air Transport Management* 11:408-416.
- Yen, J. R., Hsu, C. C., Ho, H. and Yu, S. H. (2009), An investigation of fatigue issues on different flight operations, *Journal of Air Transport Management* 15: 236-240.

Development of Ship Finance Center: Case of Singapore

*Sun Xi and Jasmine Siu Lee Lam**

Division of Infrastructure Systems and Maritime Studies, School of Civil and Environmental Engineering,
Nanyang Technological University, Singapore. *Tel: +65 67905276; Email address: sllam@ntu.edu.sg

**Corresponding author*

Abstract

Shipping is a highly capital intensive industry. Ship finance, as an essential sector in a maritime cluster, acts as a key function in the shipping industry. While there are studies analyzing the development of maritime centers, very little research has been conducted on understanding the development of a ship finance center. By the benefit given by its strategic location, Singapore is both a global shipping hub and an Asian banking center. Singapore is an interesting case for analyzing the development of a ship finance center. The first objective of this paper is to analyze the critical success factors of a ship finance center. The second objective is to conduct a case study of Singapore. We identify the critical success factors for an international ship finance center and classify them into three main categories: government stability and intervention, presence of a well-developed maritime cluster, and the performance of financial institutions. For maritime centers that are still in a developing stage, various initiatives in the three categories can be adopted by different centers based on their business and political environment.

Keywords: ship finance, shipping, maritime centre, maritime cluster, Singapore

1. Introduction

The shipping industry is characterized by high market volatility and a capital intensive nature. With the increasing size of the world commercial fleet and the recovery of shipping market after the collapse in 2008, the demand for capital in the shipping industry has been growing rapidly (Cai, 2011). This puts emphasis on the importance of a well-developed ship finance sector. As an essential sector in a maritime cluster, ship finance acts as a key function in the development of an international maritime center (IMC). A number of maritime cities such as Hong Kong, London, Oslo, Shanghai, and Singapore strive to attain or maintain the status of a world-class international maritime center by actively involving in the ship finance market (Zhang and Lam, 2013). Over the years, various innovative and dynamic sources of financing are made available to meet the increasing demand for capital. Besides the traditional way of bank loan, there are many other models suited to the financing of ships, structured by means of finance houses, brokers, leasing companies, shipping funds, and shipbuilding credit schemes. These models allow ship owners and operators to have an easier access to capital, both in terms of the flexibility of financing structure and the size of capital.

Given by its strategic location, Singapore is both a global shipping hub and an Asian banking center. As the gateway to South East Asia, Singapore is now the world's largest transshipment hub and bunkering port (Lam et al., 2011). In 2013, the maritime industry has contributed 7% of Singapore's Gross Domestic Product (GDP) and the total container throughput hit 32.6 million TEUs (MPA, 2013). However, with an aim to build herself into a leading IMC, Singapore's maritime service sector such as ship finance needs to be broadened and enhanced.

While various studies have been done on analyzing the development of finance centers as well as maritime clusters, very little research has been conducted on understanding the development of a ship finance center. Aiming at analyzing the critical success factors of a ship finance center as well as the landscape of Singapore's ship finance sector, this paper is organized as follows: the next section reviews the critical success factors for the development of a ship finance center in general. After that, the case study of Singapore's ship

finance sector will be presented, following by the policy implications and recommendations.

2. Critical Success Factors of a Ship Finance Center

We conducted a review of the literature, market reports, country reports, and creditable internet sources to derive the critical success factors of a ship finance center. Such factors can be categorised by three aspects, namely government, maritime cluster, and financial development as summarized in table 1.

2.1 Government aspect

The stability of the political environment is the premise of economic and social development. Henisz (2002) defined political stability as the degree to which the governing policies of a country are stable. By this definition, companies in the political stable regions are not likely to be affected by the unexpected change of policies or regulations, as the multiple veto points in government or political coalitions make it difficult to change existing policies without much political debate or warning (Kim and Li, 2012). This provides a favorable environment for business development where investors are confident to inject their money, thus bringing in both private investment and Foreign Direct Investment (FDI) which contribute to the economic growth. One favorable example is London, the long-lasting stable political environment of United Kingdom enables London to secure its place as the world's premier Maritime Centre. Since the 18th Century, political stability has been encouraging more capital and investment to London, boosting the economy and making it a leading financial center. With the increasing demand for shipping activities/services and the availability of capital, London is now one of the most established ship finance centers.

Another factor for the successful development of a ship finance center is the incentive policies from the government, which encourage the holistic development of the industry as well as shaping its structure (Bondonio and Greenbaum, 2007). This is especially essential for the developing maritime cities such as Hong Kong, Singapore, and Shanghai which are in their transitional period to grow from physical shipping centers toward having more maritime services (Zhang and Lam, 2013). For instance, the Maritime and Port Authority of Singapore (MPA) has launched the Maritime Finance Incentive (MFI) Scheme since 2006, seeking to encourage international ship owners and operators to establish their commercial shipping operations in Singapore through tax concession and exemption (MPA, 2013). The MFI Scheme also provides more alternatives in ship financing thus attracting more capital that is crucial for the development of a ship finance market. More details will be discussed in section 3.

2.2 Maritime cluster aspect

Economists define the concept of a cluster as groups of companies and institutions co-located in a specific geographic region and linked by interdependencies in providing a related group of products and/or services (Ketels, 2003). The existence of clusters enables firms and institutions to achieve a higher level of efficiency and innovation compared to the situation where they work in isolation (Chang, 2011). According to Benito et al. (2003), a cluster is established when all parts of value creating system are available, thus the development of maritime cluster in a city is based on the availability of a wide range of maritime services. In the analysis of the maritime sector in Norway, it is concluded that with a large merchant marine fleet as well as a well-developed shipping market consisting of various maritime oriented services, Norway has developed a strong and dynamic maritime cluster and actively involved in a wide range of maritime sectors (Viederyte, 2013).

Another essential factor is the evolution towards a more advanced structure of maritime cluster that enables its holistic development. This is done by enhancing the main function from purely cargo handling and distribution to high value-added maritime related services. Currently, cities such as Hong Kong and Singapore are identified as type 3 maritime clusters where the main function includes allocation of the integrated resources. Through regulations and incentive schemes, governments of these developing maritime nations/regions are directing the development of the maritime cluster to a more comprehensive status, which functions as a maritime services center with a variety of maritime services provided (Zhang and Lam, 2013).

The number of shipping related multinational corporation (MNC) regional headquarters is another success factor of a maritime cluster. MNC regional headquarters and high-order financial activities are usually located alongside (Zhao et al., 2004). They both share similar requirements for location choice, i.e. accessibility and accuracy of information to reduce asymmetric information. For example, with a favorable business and regulatory environment, Singapore has attracted over 7,000 foreign (MNCs) to have their regional activities and some 26,000 international companies maintain offices (MPA, 2013).

2.3 *Financial aspect*

As a capital intensive industry, shipping requires huge amount of capital investment with a long return period, it also bears a high risk due to the volatility of the shipping market (Cai, 2011). All these factors determine the fact that it is not likely, or even impossible for shipping firms to involve in investment activities on themselves. This stresses the importance of ship finance. Furthermore, the recent trend of the increasing size of ships makes the demand for capital even stronger, making the traditional way of financing less favorable (Drobetz and Merikas, 2013). The availability of new sources for ship finance that can provide larger capital is crucial in attracting more financial activities in a region/nation, this may include equity financing, bond issue, shipyard credit, and leasing. Some of the established shipping funds such as German KG, Norwegian KS provide an alternative in raising capital in shipping markets.

Performance of financial institutions also has a great impact on the enhancement of the ship finance sector (Molyneux et al., 2013). With local financial institutions focusing more on the ship finance sector and an increasing number of international banks with expertise on ship finance setting up their office (Marine Money Group, 2013), it will be easier and more flexible for ship owners/operators to finance their ships in terms of the size of the capital and less regulation constraint.

As another critical success factor, investor risk appetite will influence the size and type of shipping capital market. According to Gai and Vause (2006), risk appetite is defined as the willingness of investors to bear risk—depends on both the degree to which investors dislike such uncertainty and the level of that uncertainty. During peak years or recovery periods of the shipping market cycle, the uncertainty level of shipping declines, investors are more confident about the future and thus have higher risk appetite (Jarvis, 2011). Shipping capital market expands with more investors entering the market. It is the reverse for trough period and times when market collapse. A ship finance center should attract and retain investors having a risk appetite on the shipping capital market.

3. **Case Study of Singapore Ship Finance Center**

MPA has an aim to build Singapore as a leading IMC. As such, maritime services including ship finance are being broadened and enhanced. Therefore, Singapore is an interesting case for analyzing the development of a ship finance center. Located at the southern tip of Malay Peninsula, Singapore has a very small total area as a city-state. With limited natural resources and agricultural capacities, its economic growth heavily depends on development of value-added services and level of capital and investment (Jarvis, 2011). Ever since its independence in 1965, Singapore has been experiencing constant economic growth under a stable political environment. Over the years, the government of Singapore has been building its reputation as a global business and finance center by initiating incentive policies, tax system and creating a competitive business environment. US-based research institute Business Environment Risk Intelligence (BERI) ranked Singapore as the most favorable investment destination in terms of investment potential (BERI report 2011-II, 2011 August), which is assessed by the ease of access to the market, political risk, and the overall business environment.

Singapore has been building itself towards an international maritime center. A series of development initiatives including tax incentives and monetary policies are released by the MPA, aiming at attracting more ship owners, operators as well as maritime service providers to establish their business in Singapore (MPA, 2013).

MPA introduced the Maritime Sector Incentive (MSI) Scheme in June 2011, it consolidates and updates the

Tax Incentives previously offered, categorizing them into three major sectors: shipping operations, maritime leasing arrangements, and shipping support services. Among the three categories, maritime leasing award (MSI-ML Award) is the most essential one for promoting the development of ship finance sector in Singapore. It is largely based on the previous Maritime Finance Incentive (MFI) Scheme, targeting at ship leasing companies, shipping business trusts and shipping funds which provide financing services for vessels as well as the ones used for the offshore oil and gas sector (MPA, 2013).

Table 1. Critical success factors of a ship finance center

Aspect	Factor	Examples from the maritime industry	Reference
Government	1. Stable government (political stability)	The long-lasting stable political environment enables London to secure its place as the world's premier Maritime Centre. It encourages both private investment and FDI, thus bringing economic growth, more shipping activities and increasing need for maritime services such as ship finance to UK.	Kim and Li (2012) Jackowicz, Oskar and Łukasz (2013)
	2. Incentive policies	For Singapore's case, the Maritime Finance Incentive Scheme seeks to encourage international ship owners and operators to establish their commercial shipping operations in Singapore through tax concession and exemption. The MFI Scheme also provides more alternatives in ship financing thus attracting more capital that is crucial for the development of a ship finance market.	MPA (2013) Bondonio and Greenbaum (2007)
Maritime cluster	1. More advanced structure of maritime cluster that enables its holistic development	Through regulations and incentive schemes, governments of the developing maritime nations/regions such as Hong Kong and Singapore are directing the evolution of the maritime cluster to a more comprehensive status, which functions as a maritime services center instead of only physical shipping.	Zhang and Lam (2013) Othman, Bruce and Hamid (2011) Chang (2011)
	2. Availability of a wide range of maritime services	With a large merchant marine fleet and a well-developed shipping market, Norway is established as an International Maritime Centre and actively involved in a wide range of maritime sectors.	Viederyte (2013) Benito et al. (2003) Lam and Cullinane (2003)
	3. Number of shipping related MNC regional headquarters	Multinational corporations regional headquarters and high-order financial activities are usually located side by side. They both share similar requirements for location choice, i.e. accessibility and accuracy of information to reduce asymmetric information. With a favourable business and regulatory environment, Singapore has attracted over 4,200 foreign (MNCs) to have their regional activities and some 26,000 international companies maintain offices.	Sim, et al (2003) Zhao, Zhang and Wang (2004) MPA (2013)
Financial	1. Investor risk appetite	Investor risk appetite will influence the size and type of shipping capital market.	Goetz (2007) Jarvis (2011)
	2. Dynamic and innovative sources of ship financing	The increasing size of ships brings an increasing demand for capital, making the traditional way of financing less favorable. The availability of new sources for financing that can provide larger capital is crucial in attracting more financial activities. Shipping funds such as German KG, Norwegian KS provide an alternative in raising capital in shipping markets.	Cai (2011) Drobetz and Merikas (2013)

	3.Performance of financial institutions	With local financial institutions focusing more on the ship finance sector and an increasing number of international banks with expertise on ship finance setting up their office in Singapore, it will be easier and more flexible for ship owners/operators to finance their ships in terms of the size of the capital and less regulation constraint.	Marine Money Group (2013) Molyneux, Nguyen and Xie (2013)
--	---	--	---

Source: Author

The main body of the scheme is tax concession and exemption for eligible parties. By showing a strong track record, demonstrable business plan and a commitment to expand shipping and container financing operations in Singapore, these parties may apply for the MSI-ML award. Once approved, a tax concession of 10% up to 10 years or an exemption up to 5 years may apply on the qualified income of the entity. For Approved Ship Investment Managers (ASIM), there will be a concessionary tax rate of 10% on qualifying management-related income for a period of 10 years, while for leasing companies, funds, business trusts or partnerships, tax exemption for up to 5 years on their qualifying leasing income from both finance and operating leases will be applicable. The scheme has encouraged international ship owners and operators to establish their commercial shipping operations in Singapore as well as promoting alternatives in ship financing such as shipping fund and shipping trust.

Compared with other traditional maritime countries such as UK and Norway, Singapore has just stepped up efforts in developing the maritime cluster. These incentive schemes as discussed above also have a great impact on shaping the structure of the maritime cluster, directing Singapore's maritime cluster to a more advanced type that functions as a maritime services center instead of mainly physical shipping. Zhang and Lam (2013) classified world major maritime clusters into four categories based on the assessment of maritime services offered. Fisher (2004) has also identified the type of maritime services as the principle feature for different stages of maritime clusters. As one of the world's top container ports, currently Singapore port still has the main function as cargo handling and distribution. To be a leading IMC, Singapore's maritime cluster has to offer comprehensive and wide-ranging types of services. As such, maritime services including ship finance are being broadened and enhanced.

Recognized as one of the most important business and financial centers in South Asia, Singapore keeps its competitiveness through attracting regional head-quarters of MNCs (Sim et al, 2003). Zhao et al. (2004) have identified the number of MNC headquarters as an indicator of the city's international business status. Till 2013, over 7,000 MNCs have set up their business in Singapore and for the past 5 years they have brought in over \$700,000 million of foreign direct investment (Singapore Department of Statistics, 2013).

The success of business development comes together with increasing financial activities. Numerous finance companies are operating in Singapore where most of the major banks set their regional headquarters. This is especially beneficial for the maritime industry as currently lending is still the main form of ship financing in Singapore (Chang, 2011). The presence of these major banks allows ship owners and operators to acquire capital in a more efficient way especially in terms of the capital size.

Although ship finance has not been their traditional area of business for the three local banks - Development Bank of Singapore (DBS), United Overseas Bank (UOB) and Oversea-Chinese Banking Corporation (OCBC), they have been actively building up the ship finance sector for the past few years. There is a trend of growing presence of local banks in Singapore's ship finance sector. For example, DBS played a major role as the lead arranger in Singapore's first shipping trust deal, Pacific Shipping Trust in May 2006.

Another important factor for the development of Singapore's ship finance is the performance of the Asia market. The booming of the Asian economies and globalization has brought 40% of the world commercial tonnage to the East (Marine Money offshore, 2013), resulting in a strong demand for various shipping services especially the demand for capital. The shift of the weight of shipping activities towards East has a great benefit on Singapore as it brings more shipping activities and encourages the holistic development of the Singapore maritime cluster (Benito et al., 2003).

4. Policy Implications and Recommendations

Looking at the globe, currently most of the fast growing maritime centers such as Hong Kong, Shanghai, and Singapore are located in East Asia. As the raising of Asia's economy brings great opportunity for these maritime cities, the competition among them has also become more intensive.

Unlike other well-developed maritime cities in Europe such as Norway and London, the Asian cities are still in the way of building the structure of its maritime cluster. Originally, most of them functioned mainly as a container port with their key business being cargo handling. However, with the emerging of other Chinese and Malaysian ports such as Ningbo and Tanjung Pelepas which share the similar geographical advantages but have lower costs, these cities must upgrade their maritime cluster in order to maintain their competitiveness. In this case, government intervention is especially important in shaping the maritime cluster in terms of its composition and direction. A more service-oriented cluster is needed while the development of ship finance is one of the most essential parts of it. As discussed above, the critical success factors of a ship finance center consists of three main categories: government, maritime cluster, and financial performance. As such, various initiatives can be taken to encourage the buildup of a ship finance center by fulfilling the three main aspects. Experience from other maritime cities such as London can also be learned and adopted.

For Singapore's case, the costs of conducting business such as labour and rental expenses continue to increase rapidly. For future development, instead of competing by cost, Singapore should continue to strengthen the high-value added services, such as ship finance. The implication is that for Singapore to maintain its competitiveness as the global maritime hub, there must be a strong presence of financial and legal service providers (Verhetsel and Sel, 2009). To upgrade Singapore's maritime cluster to a shipping service-oriented type, more initiatives such as incentive policies should be taken by the authority to promote more dynamic sources of ship financing. By providing the market with more financing options and higher return investment opportunities, there will be an increase in investor appetite and thus boosting the demand in the ship finance market. One successful example is the establishment of shipping fund in Singapore.

Unlike Singapore whose development as a maritime center is contributed largely through active government policies, Hong Kong has been adopting a more laissez-faire policy to promote entrepreneurial inflow (Huat, 2004). The less-intervention policy of government allows a flexible business environment, promoting growth in different maritime sectors (Kriz, 2007). However, there are certain aspects where the intervention of government can bring in huge benefit. One example is that the interrelationship among different maritime sectors should be taken into consideration such that the promotion of one sector should not suppress the development of other sectors (Zhang and Lam, 2013). For instance, the promotion of ship finance sector allows easier access of capital which is beneficial for the ship building sector. While these two sectors are positively correlated, there may be other cases where the expansion of one sector will restrict other sectors. In this case, the impact of one sector on the others should be fully assessed by the government authority in order to achieve the holistic development.

The launch of Shanghai Free Trade Zone in September 2013 has made the competition among these Asian maritime centers becomes more intensive. With the tax incentive policies that allow enterprises to enjoy tax exemption and reduction for certain period based on the enterprises' operating nature, Shanghai is aiming at attracting more international business and foreign investment. There are also policies made specifically for promoting the maritime industry, such as the Chinese-invested banks within the zone are permitted to engage in off-shore business and for financial leasing companies, no minimum registered capital restriction is imposed on the set up of single machine/single ship subsidiaries. These leasing companies are also allowed to be engaged concurrently in the commercial factoring business relating to their principal business (China (Shanghai) Pilot Free Trade Zone, 2013). Additionally, the open-up to foreign investors may also have a positive impact on the trading volume of Shanghai stock exchange, bring the prosperity of China bond market and intensify the competition for capital among East Asia.

5. Concluding Remarks

This paper studies one of the important aspects of the maritime industry: the development of ship finance

center. Given the very limited literature on the topic, the study presents an original contribution to identify the critical success factors for an international ship finance center and classify them into three main categories: government stability and intervention, presence of a well-developed maritime cluster, and the performance of financial institutions. The contribution of these factors are studied and assessed by real examples of ship finance centers from various regions such as London, Norway, Hong Kong, and Singapore.

The paper is also among the first in the literature to conduct a case study of Singapore's ship finance sector. The performances of those factors listed in the three categories are studied accordingly under Singapore's environment. As an international shipping hub, Singapore has a strong presence in the physical shipping sector as a major container port and bunker center. It is also an established finance center in South Asia with most of the world major banks setting up their regional headquarters in the city-state.

Policy recommendations are given at the end of the paper based on the previous discussion. For maritime centers that are still in a developing stage, various initiatives can be adopted by different centers based on their business and political environment. In the case of Singapore, launch of government incentive policies is perceived to be an efficient way, since Singapore has been successful in that the government creates and maintains Singapore's advantages in ship finance market by providing competitive tax structures and a sound and stable financial system (Tan et al., 2004). While for Hong Kong, adaptive government intervention may be beneficial to ensure the holistic development of the maritime cluster. On the other side, Shanghai may seize the opportunity of the opening of Free Trade Zone, taking full advantage of the increasing business opportunity and enhance its ship finance market (Lai, 2006).

As a whole, this paper advances ship finance study, especially for the developing maritime centers, to a new area. The research findings presented can be applied in the enhancement of the ship finance sector. Areas for future research should seek to assess the interrelationship among ship financing and other maritime services, that is how the enhancement of ship finance sector affects the performance of other sectors in the maritime cluster. Thus a comprehensive model can be developed for the establishment of a strong maritime cluster.

Acknowledgement

We wish to acknowledge the funding support for this project from Nanyang Technological University under the Undergraduate Research Experience on Campus (URECA) programme.

References

- Benito, G.R.G., Berger, E., Forest M. and Shum, J. (2003), A cluster analysis of the maritime sector in Norway, *International Journal of Transport Management* 1 (4): 203-215.
- Bondonio, D. and Greenbaum, R. T. (2007), Do local tax incentives affect economic growth? What mean impacts miss in the analysis of enterprise zone policies, *Regional Science and Urban Economics* 37(1): 121-136.
- Cai, Y. C. (2011), Ship industry funds—innovation of shipping finance, *Shipbuilding of China* 2011(04).
- Chang, Y. (2011), Maritime clusters: What can be learnt from the south west of England, *Ocean & Coastal Management* 54 (6): 488-494.
- China (Shanghai) Pilot Free Trade Zone website: www.shftz.gov.cn (Accessed in March, 2014).
- Drobetz, W. and Merikas, A. G. (2013), Maritime financial management, *Transportation Research Part E: Logistics and Transportation Review* 52 (special issue): 1-2.
- Fisher Associates (2004), The future of London's Maritime Services Cluster: A Call for Action.
- Gai, P. and Vause, N. (2006), Measuring investors' risk appetite, *International Journal of Central Banking* 2 (1): 167-188.
- Goetz, V. P. (2007), International Banking Centres: A Network Perspective, BIS Quarterly Review Working Paper. Available at SSRN: <http://ssrn.com/abstract=1075205>.
- Henisz, W. J. (2002), The institutional environment for infrastructure investment, *Industrial and Corporate Change* 11 (2): 355-389.
- Huat, T. C. (2004), Competing International Financial Centers: A Comparative Study between Hong Kong and Singapore, Saw Centre for Financial Studies and ISEAS Conference.

- Jackowicz, K., Oskar, K. and Łukasz, K. (2013), The influence of political factors on commercial banks in central European countries, *Journal of Financial Stability* 9 (4): 759-777.
- Jarvis, D. S. L. (2011), Race for the money: international financial centres in Asia, *Journal of International Relations & Development* 14(1): 60-95.
- Ketels, C. H. M. (2003), The development of the cluster concept: present experiences and further developments. Dr. Christian Ketels, Harvard Business School, Paper Prepared for NRW Conference on Clusters, Duisburg, Germany.
- Kim, P.H. and Li, M.X. (2012), Injecting demand through spillovers: Foreign direct investment, domestic socio-political conditions, and host-country, *Journal of Business Venturing* 29 (2): 210-231.
- Kriz, P. N. (2007), Comment on Hong Kong and Shanghai: Yesterday, Today and Tomorrow, *Financial Sector Development in the Pacific Rim, East Asia Seminar on Economics* (18), University of Chicago Press.
- Lai, K. (2006), Developing Shanghai as an International Financial Centre: Progress and Prospects, Discussion Paper 4, China Policy Institute, University of Nottingham.
- Lam, J. S.L., Chen, D., Cheng, F. and Wong, K. (2011), A assessment of the competitiveness of ports as bunkering hubs: empirical studies on Singapore and Shanghai, *Transportation Journal* 50(2): 176-203.
- Lam, J. S. L. and Cullinane, K. (2003), Shanghai as an international maritime centre: Implications for the East Asian regional economy, *Proceedings of the Eastern Asia Society for Transportation Studies*, Fukuoka, Japan, 29 Oct - 1 Nov 2003.
- Marine Money Offshore website: www.marinemoneyoffshore.com/node/3971 (Accessed in January, 2014).
- Maritime and Port of Authority website: www.mpa.gov.sg (Accessed in January, 2014).
- Molyneux, P., Nguyen, L. H., and Xie, R. (2013), Foreign bank entry in South East Asia, *International review of financial analysis* 30: 26-35.
- MPA Leading International Maritime Centre (IMC) website: www.mpa.gov.sg/sites/maritime_singapore/what_is_maritime_singapore/leading_imc.page (Accessed in January, 2014).
- Ng, A. Y. and Gujar, G. C. (2009), Government policies, efficiency and competitiveness: The case of dry ports in India, *Transport Policy* 16(5): 232-239.
- Othman, M. R., Bruce, G. J. and Amid, S. A. (2011), The strength of Malaysian maritime cluster: The development of maritime policy, *Ocean & Coastal Management* 54 (8): 557-568.
- Sim, L., Ong, S., Agarwal, A., Parsa, A. and Keivani, R. (2003), Singapore's competitiveness as a global city: development strategy, institutions and business environment, *Cities* 20(2): 115-127.
- Singapore Department of Statistics, Foreign Equity Investment in Singapore website: www.singstat.gov.sg, (Accessed in February 2014).
- Verhetsel, A. and Sel, S., (2009), World maritime cities: From which cities do container shipping companies make decisions?, *Transport Policy* 16(5): 240-250.
- Viederyte, R. (2013), Maritime cluster organizations: Enhancing role of maritime industry development, *Procedia - Social and Behavioral Sciences* 81: 624-611.
- Zhang, W. and Lam, J.S.L. (2013), Maritime cluster evolution based on symbiosis theory and Lotka-Volterra model, *Maritime Policy & Management* 40(2): 161-176
- Zhao, X. B. S., Zhang, L. and Wang, D. T. (2004), Determining factors of the development of a national financial center: the case of China, *Geoforum* 35(5): 577-592.

An Improvement of Productivity in Container Terminal by Simulation Modeling: Case of Bangkok Port

Pantakan Saengaram^{1*}, Veerachai Gosasang² and Nuttapon Boonchokhuay²

¹Department of Industrial Engineering, Faculty of Engineering, Chulalongkorn University, Bangkok, Thailand. Email: pantakan92@gmail.com

²Port Authority of Thailand, Bangkok, Thailand

**Corresponding author*

Abstract

Bangkok Port is the major port of Thailand. There are many constraints effecting to the overall efficiency of container terminal, consisting of overall equipment effectiveness (OEE) and berth occupancy. Nowadays, the berth's productivity of Bangkok port is significantly lower than the maximum berth's productivity.

Container terminal operation comprised of subsystems which are influenced each other. Therefore, computer simulation modeling is a useful tool for analyzing the performance of container terminal. This model is adopted to analyze the performance efficiency (PE) of gantry crane, mainly affecting to OEE. The result of simulation illustrated that PE of gantry crane on both loading and discharging process was inefficient. Consequently, five scenarios were tested in simulation models and proposed for this paper in order to find out the best methodology for improvement PE, or the berth's productivity.

Keywords: Overall Equipment Effectiveness, Efficiency of Gantry Crane, Simulation, Performance Efficiency, Berth Capacity, Container Yard, Yard Truck, Congestion

1. Introduction

Bangkok Port is the essential river port of Thailand which can service both import and export container throughput 1.34 million TEUs per year. One factor affecting to demand of import and export container is GDP (Japan International Cooperation Agency, 1994). The GDP of Thailand tends to increase continuously but an increasing of capacity of container terminal is limited for several years. Consequently, Bangkok Port is lacking of an opportunity to service the entire demand. Moreover, an increase of overall efficiency of Gantry Crane is important for container operation at Bangkok Port. This efficiency consists of berth occupancy and OEE, consisting of performance efficiency, availability rating and quality rating. Increasing performance efficiency is the most practical way to study and improve. Currently, the productivity of gantry crane is clearly lower than its maximum.

Container terminal is a complex system where conceals many factors of this problems. There are many activities in container terminal affecting each other. Hence, simulation modeling is to analyze and test the result of improvement as quantitative analysis.

Simulation is a proper tool to solve these problems. Before implementing the new processes into the real system, we merely test those in the simulation model and consider the result whether the new one is significantly better. Furthermore, the information flow of Bangkok Port is excellent, so it is comfortable to collect the historical data and feed into the simulation model. Owing to good information flow and clear problems about productivity which affect to PE, Bangkok Port is a good case study to solve problems by simulation modeling.

In addition to OEE, berth occupancy is another thing which can be improved. Currently, berth occupancy is 65%. However, the Bangkok Port has 7 berths, so it is possible to extend berth occupancy with new ship

scheduling. After improving OEE and berth occupancy, it will increase overall efficiency of gantry crane which definitely increases berth capacity eventually.

The structure of this paper is organized as follows: Section 2 reviews the relevant literature. Section 3 presents the research methodology. Section 4 presents the results. Section 5 presents discussion of the results. Finally, some conclusions and contributions are provided in Section 6.

2. Literature Review

Container Terminal is a complex system which contains subsystems influencing each other. The dynamic of event occurs because of uncertainty entities in the system. Thus, it is quite difficult to evaluate the actual efficiency of the port. A tool having played a vital role in solving this issue over last several years is simulation modeling. Simulation modeling is the way we duplicate the process and constraint of real system during one period into computer for computing output we needs. These outputs are created for evaluating system or testing the transformation of the system in computer before implementing in the real system. Shannon (1975) defined simulation as the process we simulate the real system and make an experiment to study the behavior of the real system beneath mathematical formula, conditions, and the logic of system in order to analyze situation of system, or test the ideas of improvement system. Huang (2008) studied the capacity container terminal by simulating all processes in container terminal as one integrated system. Adam (2009) identified bottleneck and then propose the best scenario to increase capacity of container terminal by simulation. Pope et al. (1995) studied the effect of container terminal to traffic on the road with his simulation modeling Gambardella et al. (2001) allocated the resources in container terminal by testing on simulation model. Therefore, these are substantial evidences to support the importance of simulation modeling in container terminal.

3. Methodology

Forecasting methodologies includes four steps as follow:

Step1: Define efficiency

The efficiency that we studied to improve is performance efficiency (PE) of gantry crane which can improve overall efficiency (OEE) at last. Performance Efficiency is the comfortable and possible way to improve because it's about the speed of machine which is controllable. On the other hand, availability rating is more difficult to improve because of unavoidable activities such as cast anchor and setup time of equipment. Figure1 shown of what overall capacity consists.

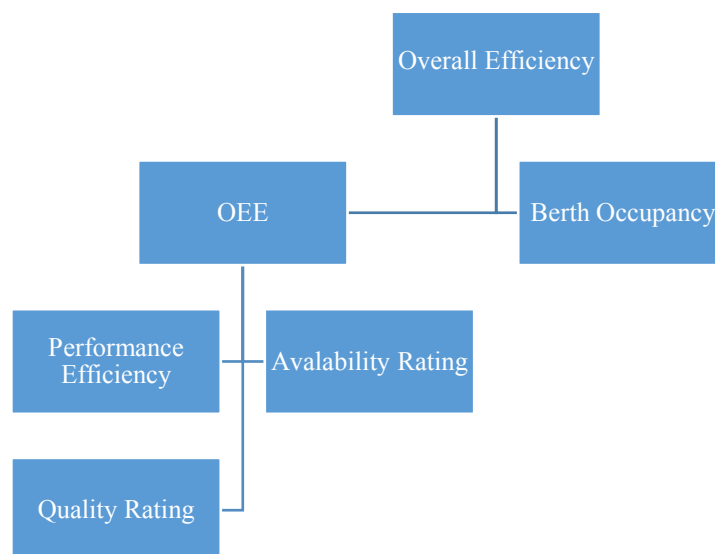


Fig 1. The component of overall efficiency

Berth Occupancy is defined as total time ships stay in a berth to total available time. OEE is defined as total time a gantry crane creates value to total time ship stay in a berth.

Step 2: Why-Why Tree Analysis

The first step to increase PE is identifying the causes why PE is lower than expectation. Thus, the qualitative analysis will be proposed by why-why tree diagrams. This helps to brainstorm among people from many different departments. Afterwards, we could find many root causes. However, we choose some of these to consider which were possible to solve in the real world of working. They consist of

1. Too many trucks to pick their containers which affect to congestion.
2. There is a queue of yard trucks waiting for RTG in a container yard because there are too many trucks that go to the same block of the container yard.
3. Considering some positions of the container yard, a yard truck takes a lot of time to reach there because of the inefficiency of routing plans.
4. Some kinds of container are stored outside of the container terminal which is too far and very time-wasting.
5. If containers in the container yard are full, some containers need to be stored outside of the container terminal for emergency plans.

Step 3: Simulation Modeling

Simulation modeling is the quantitative analysis to measure the problems. We analyze some root causes from why-why tree diagrams and test solutions by simulating in each scenario. This simulation model includes all activities in container terminal, since all of activities affected to each other of the container operation. Activities consist of discharge, loading and import picking. The output from simulation is a decision support before implement with the real system.

Step 3.1: Designing

The first step of simulation is designing input, output, and structure of model. Details are shown in figure 2.

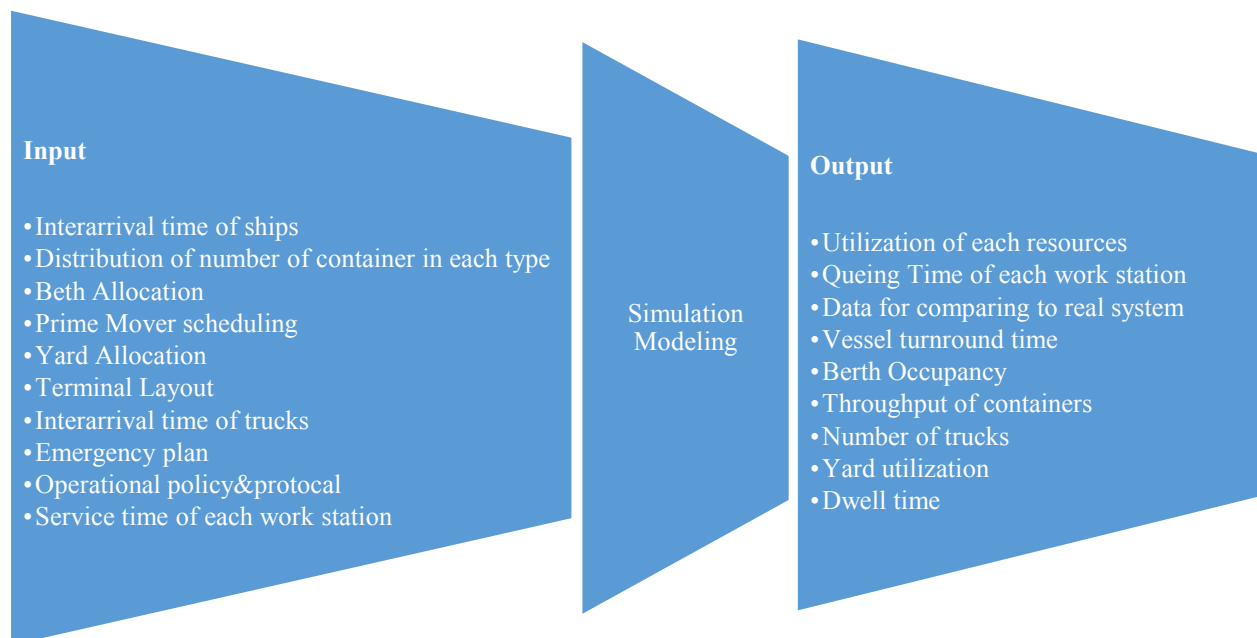


Fig 2. Design of simulation model

Step 3.2: Input Data Analysis

Input data was collected by stop watch method, database, Google earth and interview. The time period is one month which is in October 2013 when the number of throughput was highest. Input data is the representing data from past which was analyzed as distribution formula by Chi-Square test with confident interval at 95%. The example is shown in figure 3. These formula will be the representative of whole data which will generate random number in simulation model.

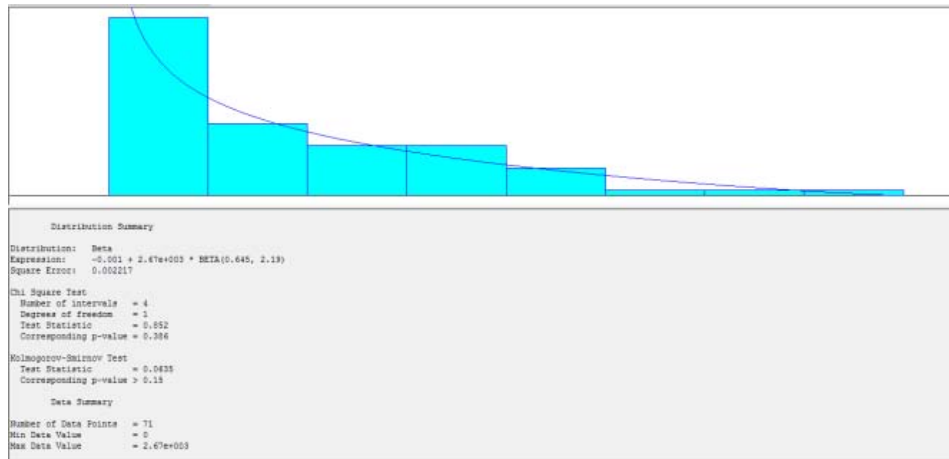


Fig 3. Generating the distribution of input data

Step 3.3: Replication Analysis

Discrete-Event Simulation is based on probability and Mathematical formula. The output results in each time may be not somewhat stable. Thus, it indispensably needs to find the average of output results. If we run the model several times, output results will reach one value and affects to decrease half-width. This shows the stable of the result. To find the number of replication of simulation, we can calculate from equation (1).

$$\frac{1}{R} = \frac{H}{\bar{x}} \quad (1)$$

R is number of replications

H is number of replications we run in the first time

H is Half-Width from the first run

To find number of replications, the model was run 10 replications at the first time in order to check half-width of berth occupancy, one of important outputs. The result shows that half-width was 6 which is around 10% of mean. To get more accuracy result, we try to reduce half-width into 5% of mean, so we calculated from equation (1) with half-width at 3.23

$$\frac{1}{R} = \frac{3.23}{\bar{x}}$$

After simulating 35 reps, half-width of output of berth occupancy drop to 2% of mean which was little better than expectation.

Step 3.4: Warm Up Period Analysis

Generally, the simulation model of container terminal is non-terminating system. Initially, the system in the model is unstable until the time pasts one period. This period is called as warm up period which the system is in steady state. For instance, in the case of container terminal, there is no container in the container yard in the beginning of simulation. Afterwards, the number of container will be escalated until reaching the steady state of container yard utilization. The output data when it isn't in steady state will not be calculated. Therefore, it is very important to calculate this warm up period in order to get accuracy results.

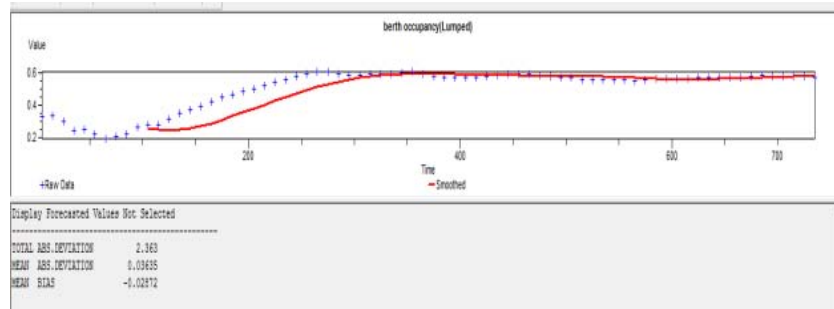


Fig 4. Warm Up Period Analysis

The result from figure 4 shows that berth occupancy is in steady state when simulation model was run for 350 hours from 744 hours

Step 3.5: Validation

In order to verify the accuracy of this simulation model, it needs to compare the output result and real data at the period we studied. With one sample hypothesis t-test at 95% confident interval, it showed that the output result including berth occupancy, yard utilization and throughput equaled to the mean of real data.

Table 1. The result of hypothesis t-test

Result	P-value	α
Berth Occupancy	0.268	0.05
Yard Utilization	0.970	0.05
Throughput	0.839	0.05

4. Result

The result after running model at 35 replications and 350 hours of warm up period is shown in figure 5 and table 2.

Replications: 35 Time Units: Hours				
User Specified				
Output				
Output	Average	HalfWidth	Minimum Average	Maximum Average
berth occupancy	0.6621	0.04	0.4239	0.9348
export container	24978.29	1,117.14	19012.50	31383.75
FCL size40 Import	13381.60	571.68	10626.00	16606.00
Import FCL size20	11677.91	464.90	9214.00	14625.00
Total throughput	58059.57	2,291.60	44939.00	70834.75
utilizaion of Gantry for discharge	0.2339	0.02	0.1321	0.3152
utilization of discharge	0.2604	0.03	0.1347	0.5436
Utilization of Gantry for loading	0.1818	0.01	0.1133	0.2373
utilization of loading	0.2446	0.01	0.1534	0.3195
Yard Utilization	0.6063	0.03	0.3970	0.7107

Fig 5. Output result

Table 2. Comparing output and real data

Result	Output	Real data
Berth Occupancy	66.21%	69%
Yard Utilization	60.43%	60%
Throughput	58,060 TEUs	57,839 TEUs
PE of discharge	89.8%	-
PE of loading	74.3%	-
OEE	62.5%	-

5. Discussion

5.1 Scenarios Generation

- Increasing number of yard trucks to optimal number.
- Changing policy of discharge operations. Generally, a group of containers of a ship must be stored at only 2 blocks of container yard. With this scenario, we change that those containers of a ship can be stored anywhere in container yard where RTG is not busy.
- Allowing to stored containers in the container yard to 80% of maximum capacity of yard. Currently, the allowance is 70% of maximum capacity of the container yard.
- Reserving one block in the container yard to temporally store export containers and import containers which are not FCL containers. The cycle time of the yard truck will be shorter because of shorter distance.
- Combining scenarios 2, 3 and 4 together because each scenario solved different root causes. Moreover, all don't need to invest more in fixed cost. Additionally, the number of yard truck could be less because of low utilization of yard trucks.

5.2 Scenarios Evaluation

Table 3. Output result from each scenario

Scenario	1	2	3	4	5
PE of Discharge	98.7%	92.2%	95.5%	91.1%	99.5%
PE of Loading	98.2%	74.4%	74.3%	98.3%	98.3%
Number of Yard Truck for Discharge	15	14	14	14	12
Number of Yard Truck for Loading	17	14	14	14	5
OEE	75.2%	63.9%	65.1%	72.1%	75.5%

After evaluating the scenario from simulation model, OEE from scenario 1 and 5 better than the original one significantly. However, scenario 1 is needed to invest more fix cost by purchasing more yard trucks. On the other hand, scenario didn't need to invest in fix cost because it just changed operations policy and plan. Additionally, it can save cost by reducing the yard trucks and yard truck driver because the cycle time of the yard truck is reduced with new operations plans. Therefore, scenario 5 seems to be an interesting and potential option.

6. Conclusion and Contribution

The comparison of five scenarios of simulation model, the best solution is scenario 5. This scenario increases the highest number of OEE because it solves many different root causes without investment. Moreover, it even reduces number of trucks both discharge and loading processes.

There are three benefits if these are implemented. Firstly, berth capacity will be increased 20.4% if we increase only OEE. Secondly, berth capacity will be increased 49% if we increase OEE and berth occupancy to 80%. Thirdly, if we would like to maintain the same capacity, we can save operating cost due to faster service time of a ship. In conclusion, increasing OEE by focusing on performance efficiency of gantry crane is one of ways that we can increase berth capacity or save operating cost without an investment. More profitability affects to higher competitive advantage in cost leadership which means lower logistics cost of import and export goods.

Table 4. Conclusion of benefits

Plan	Benefit
Increase OEE to increase berth capacity	-Increase berth capacity 20.4% -Increase revenue 890 million Thai Baht/year - Reduce cost by reducing number of yard trucks
Increase OEE and Berth Occpancy to	-Increase berth capacity 49%

increase berth capacity	-Increase revenue 2.2 billion Thai Baht/year - Reduce cost by reducing number of yard trucks
Increase OEE to reduce operating cost	- Reduce cost by reducing number of yard trucks and operating cost such as over time labor cost and electricity cost.

Contribution

1. Increasing only OEE to increase capacity with implementing scenario 5, OEE would be 75.5% which affects to increase capacity for 20.4%. The total maximum capacity which was calculated from equation (2) would be 1,241,856 containers. Then Bangkok Port will increase revenue for 890 million baht if there is enough demand.

$$\text{Berth Capacity} = \text{Maximum Berth Capacity} \times \text{OEE} \times \text{Berth Occupancy} \quad (2)$$

2. Increasing OEE and Berth Occupancy

With an increasing of OEE, service time per ship will be decreased 1.71 hours if we service the same number of container per ship. Additionally, it is possible to increase berth capacity to 80% because Bangkok Port has 7 points of berths and service time is faster. Therefore, the capacity can be increased 49%.

3. Increasing OEE, but maintain same capacity

If Bangkok Port still maintains the same capacity because of the consistence of demand or other reasons, they can still reduce operating cost. With increasing in OEE, service time for one ship is faster, so man-hour per one ship can be decreased. This saves operating cost such as over time labor cost and electricity cost.

Acknowledgement

Thanks to Asst Prof Dr. Paveena Chaowariteongse, professor of Chulalongkorn University, for her patient guidance, enthusiastic encouragement and useful critiques of this study, and Mr. Thiemo Brans, project director of Chauchawal Royal Haskoning, for consulting in simulation model of container terminal and useful critiques of this study.

References

- Adam S. (2008), Simulation and Analysis of Port Bottlenecks: The Case of Male, A thesis for the Degree of Master of Applied Science (Transport Studies) at Lincoln University.
- Gambardella, L.M., Mastrolilli, M., Rizzoli, A.E. and Zaffalon, M. (2001), An optimization methodology for intermodal terminal management, *Journal of Intelligent Manufacturing* 12: 521–534.
- Huynh, N. N. and Walton, C. M. (2005), Methodologies for reducing truck turn time at marine container terminals. Research Report SWUTC/05/167830-1, Southwest Region University Transportation Center, Center for Transportation Research, The University of Texas at Austin TX 78712.
- Huang S.Y, Hsu W-J, Chen C., Ye R. and Nautiyal S. (2008), Capacity analysis of container terminals using simulation techniques, *Int. J. Computer Applications in Technology* 32 (4): 246-253.
- JICA (1994), Final Report for the Study on Modernization of Bangkok Port in the Kingdom of Thailand 1:199-202.
- Pope, J.A., Rakes, T.R., Rees, L.P. and Crouch, I.W.M. (1995), A network simulation of high-congestion road traffic flows in cities with marine container terminals, *Journal of the Operational Research Society* 46 (9): 1090–1101.
- R.E. Shannon (1975), *Systems Simulation: The art and Science*, Prentice-Hall, Englewood, Cliffs, NJ.

The Impact of Information Sharing and Risk Pooling on Bullwhip Effect Avoiding in Container Shipping Markets

Shaorui Li¹, Yujie Shi¹, Chin-Shan Lu² and Yi Liao¹

¹Department of Logistics Management, Southwestern University of Finance and Economics, Chengdu, 610074, China. Email: lisr@swufe.edu.cn

²Department of Logistics and Maritime Studies, The Hong Kong Polytechnic University, Hong Kong.

Abstract

The bullwhip effect is a well-known phenomenon in supply chains. It refers to the effect that demand variability amplifies as one moves upstream in the supply chain towards the manufacturer. This symptom has been observed across most industries and resulting in increased cost. In this paper, we propose an integrated analytical model to quantify the beneficial impact of information sharing and risk pooling on the bullwhip effect. Our study focuses on a model consisting of a manufacturer, a wholesaler and two retailers, in which the lead time is not negligible. Following the order-up-to policy, the simple moving average technique is implemented for demand forecasting. The suggested approach reduces the amplification of demand variability across the three-stage supply chain significantly. Numerical analysis demonstrates that our method dominates the existing approaches which utilize either information sharing or risk pooling separately in terms of controlling the bullwhip effect. Moreover, we further apply our approach in Shanghai and Hong Kong container shipping market. Considering the container shipping company as the manufacturer, the freight forwarding agent as the wholesaler and the shippers as retailers, we investigate the bullwhip effect in such a system and indicate that our approach can improve the supply chain's performance dramatically.

Keywords: Bullwhip effect, Information sharing, Risk pooling, Shipping market.

1. Introduction

The demand information distortion within a supply chain, known as the bullwhip effect, suggests that the variability of orders placed is increased as we travel up in the supply chain (Chen et al., 2000). The bullwhip effect makes supply chain planning extremely difficult. For example, the increased variability of orders generally needs participants in the supply chain to raise the safety stocks to keep the service level and results in unnecessary inventory holding cost. This study analyses a three-stage supply chain to investigate how to control the bullwhip effect. We aim to explore the impact of the integration of the information sharing and risk pooling strategies on the bullwhip effect in the supply chain with a single manufacturer, a single-wholesaler, and two retailers.

As the bullwhip effect usually induces the loss of control and tremendous efficiencies of the supply chain (Lee, and Billington, 1993), it has received considerable concern in academic, for example, Geary et al., (2006), Miragliotta (2006), Bhattacharya and Bandyopadhyay (2011), Giard and Sali (2013). Since research of Lee et al., (2004) identifies the five main reasons causing the bullwhip, diverse strategies of mitigating the bullwhip have been put forward. A simple rule for choosing appropriate forecasting methods is established (Zhang, 2004). Bayraktar et al. (2008) investigate how the exponential smoothing forecasts affect the bullwhip effect for electronic supply chain. In addition, Potter and Disney (2006) study the selection of optimal batch size to avoid the bullwhip. Furthermore, methodology based on control engineering has also been proposed by Dejonckheere et al. (2003). Recently, Chen and Lee (2012) develop some formulas that describe the traditional bullwhip measure as a combined outcome of several important drivers, such as finite capacity, batch-ordering, and seasonality.

Very little research has been done on the bullwhip effect in global ocean transport networks (Glas et al. 2013). In a case study of an Asian-European automotive supply chain, Glas et al. (2013) analyse endogenous causes

of the bullwhip-effect. Harrison and Fichtinger (2013) consider the relationship between time-related variables in global ocean transportation networks and the shipper's inventory level. They focus on the fill rates with daily and weekly sailings, and examine the impacts of variability of those issues on the shipper's inventory management system. Hong (2006) discusses the existence of the bullwhip effect in shipping markets, using the five features proposed by Lee et al., (2004).

Among many viable solutions, information sharing is one of the frequent suggestions for reducing the bullwhip effect, i.e., to provide each stage of a supply chain with complete information on the actual customer demands. Here, information sharing refers to centralized information (Chen et al., 2000). There have been a number of studies that have investigated how information sharing affects the bullwhip (e.g., Chen et al., (2000), Lee et al.,(2000). Wu et al. (2008) make a further discussion on three levels of information sharing and analyze their effects on demand variation, concluding that a higher level of information sharing could decrease the inventory level significantly. Nevertheless, all these studies address on the performance of centralized information, which suggests that the combination of information sharing with other techniques still remains an open research area.

Recently, risk pooling is implemented to keep down the bullwhip effect in a three-stage supply chain with a single manufacturer, a single wholesaler, and two retailers in Sucky (2009). However, information sharing and the lead time are negligible in Sucky's research. Therefore, we extend Sucky's research by integrating information sharing and risk pooling in a three-stage supply chain with a single manufacturer, a single wholesaler, and two retailers. To the best of our knowledge, there is no research related to such an integration approach. We concentrate on the bullwhip effect across the supply chain and demonstrate how the integration of information sharing and risk pooling can significantly reduce the order variability. Different from Sucky (2009)'s study, lead times are also incorporated into our model which makes our analysis more realistic. In this paper, we follow the order-up-to policy while the simple moving average technique is employed for demand forecasting. Through intensive numerical experiments, we illustrate that the strategy integrating both information sharing and risk pooling could substantially reduce the bullwhip effect. In this research, we aim to not only suggest a theoretic strategy, but also provide the handful solution for business. Thus, we also implement our method in Shanghai's international shipping market and explore how to reduce the bullwhip effect by utilizing information sharing and risk pooling simultaneously. Largely impacted by international trade, international shipping service often faces the challenge of excess or insufficient capacity, which causes serious consequences for international shipping industry. As illustrated in our analysis, with the help of the proposed policy, the bullwhip effect can be dramatically lessened which indicates that our advice is quite promising.

The rest of this paper is organized as follows: Section 2 gives some assumptions and notations. Section 3 presents an analytical model and compares the bullwhip effect in four different circumstances. Section 4 conducts a numerical study and shows the impact of our approach on the bullwhip effect in Shanghai shipping market. Section 5 ends this paper with some concluding remarks.

2. Assumptions and Notations

2.1. Assumptions

We make the following assumptions:

- The three-stage supply chain considered in this paper consists of a single manufacturer, a single wholesaler, and two retailers, where each retailer directly serves the customers and receives replenishment from the wholesaler. The wholesaler, in turn, receives replenishment from the manufacturer.
- Demands from the retailers are assumed to be known, which are independent and identically distributed.
- All stages of the supply chain utilize the same order-up-to policy and the same moving average forecasting technique.
- In the order-up-to system, each stage reviews the inventory at the beginning of every period and makes the target inventory level. Afterwards, all stages place the orders for that period and fill their customers' demands with on-hand inventory.

- Shortages are allowed and the unfilled demands are backlogged.
- The ordering and production lead times are constant.

2.2. Notations

The following notations will be used throughout the remainder of this paper. Other symbols will be introduced as need.

2.2.1. Parameters

- $D_{Rj,t}$: demand of retailer j ($j=1, 2$) in period t .
 L_k : the ordering lead time plus the review time for stage k .
 z : safety factor chosen to meet a desired service level.
 N : moving period for the simple moving average.
 $Cov(\cdot, \cdot)$: covariance.
 ρ_D : covariance coefficient.

2.2.2. Decision Variables

- $\bar{q}_t^{(k)}$: order quantity from stage k to stage $k+1$ in period t without risk pooling.
 $q_t^{(k)}$: order quantity from stage k to stage $k+1$ in period t with risk pooling.
 $\bar{y}_t^{(k)}$: desired order-up-to level of stage k in period t without risk pooling.
 $y_t^{(k)}$: desired order-up-to level of stage k in period t with risk pooling.

2.2.3. Functions

- $E(D_{Rj,t})$: estimated mean of retailer j ($j=1, 2$)'s demand in period t .
 $Var(D_{Rj,t})$: estimated variance of retailer j ($j=1, 2$)'s demand in period t .
 $Var(\bar{q}^{(k)})$: variance of stage k 's order quantity without centralized information or risk pooling for the complete planning period.
 $Var(q^{(k)})$: variance of stage k 's order quantity with risk pooling but without centralized information for the complete planning period.
 $Var'(\bar{q}^{(k)})$: variance of stage k 's order quantity with centralized information but without risk pooling for the complete planning period.
 $Var'(q^{(k)})$: variance of stage k 's order quantity integrating risk pooling and centralized information for the complete planning period.
 $Var(D)$: variance of the realized demands of the two retailers for the complete planning period.
 $Var(D_{Rj})$: variance of the realized demand of retailer j ($j=1, 2$) for the complete planning period.

3. Model and Solution

3.1. Bullwhip effect under consideration of lead times

In order to quantify the bullwhip effect in the order-up-to system, similar to Sucky (2009), firstly, we analyse a three-stage supply chain consisting of a single manufacturer, a single wholesaler, and a single retailer; it will be extended to a more complex supply network later. In addition, this paper considers the ordering lead time.

Define D_t as the retailer's stochastic and stationary demand, and $q_t^{(1)}$ as the wholesaler's order quantity in any period t . Let L_1 indicate the ordering lead time plus the review time for the wholesaler. Then,

$$\begin{aligned} q_t^{(1)} &= y_t^{(1)} - y_{t-1}^{(1)} + D_{t-1}, \\ y_t^{(1)} &= E(D_t) + z\sqrt{\text{Var}(D_t)}, \\ E(D_t) &= \left(\frac{L_1}{N}\right) \sum_{i=t-L_1}^{t-1} D_i = \left(\frac{L_1}{N}\right) (D_{t-1} + D_{t-2} + \dots + D_{t-L_1}), \\ \text{Var}(D_t) &= \left(\frac{1}{N}\right) \sum_{i=t-L_1}^{t-1} (L_1 D_i - E(D_t))^2 = \left(\frac{1}{N}\right) \left((L_1 D_{t-1} - E(D_t))^2 + \dots + (L_1 D_{t-L_1} - E(D_t))^2 \right) \end{aligned}$$

where $y_t^{(1)}$ is the wholesaler's desired order-up-to level, $E(D_t)$ the estimate of mean demand, and $\sqrt{\text{Var}(D_t)}$ the estimate of the standard deviation for the retailer's demand, and $z=0$ indicates a risk neutral decision, and $z>0$, a risk adverse decision (Sucky, 2009).

Consequently, the wholesalers order quantity can be written as:

$$q_t^{(1)} = E(D_t) + z\sqrt{\text{Var}(D_t)} - E(D_{t-1}) - z\sqrt{\text{Var}(D_{t-1})} + D_{t-1} = \left(1 + \frac{L_1}{N}\right) D_{t-1} + \left(-\frac{L_1}{N}\right) D_{t-L_1} + z(\sqrt{\text{Var}(D_t)} - \sqrt{\text{Var}(D_{t-1})}).$$

Assuming $z=0$, the lower bound on the variance of the wholesaler's order quantity can be derived as:

$$\text{Var}(q^{(1)}) = \left(1 + \frac{L_1}{N}\right)^2 \text{Var}(D_R) + \left(-\frac{L_1}{N}\right)^2 \text{Var}(D_R) = \left(1 + \frac{2L_1}{N} + \frac{2L_1^2}{N^2}\right) \text{Var}(D_R)$$

where $\text{Var}(D_R)$ denotes the variance of the retailers demand for the complete planning period, $\text{Var}(q^{(1)})$ the variance of the wholesaler's order quantity for the complete planning period. Hence, the lower bound on bullwhip effect for the wholesaler can be expressed as:

$$\frac{\text{Var}(q^{(1)})}{\text{Var}(D_R)} = 1 + \frac{2L_1}{N} + \frac{2L_1^2}{N^2}. \quad (1)$$

$$\text{Var}(q^{(1)}) - \text{Var}(D_R) = \left(\frac{2L_1}{N} + \frac{2L_1^2}{N^2}\right) \text{Var}(D_R). \quad (2)$$

3.2. With and without risk pooling

In the following, we extend this approach to address a supply chain including two retailers.

Without considering risk pooling between the two retailers, the order-up-to level of the wholesaler in period t is calculated as:

$$\bar{y}_t^{(1)} = (E(D_{R1,t}) + E(D_{R2,t})) + z(\sqrt{\text{Var}(D_{R1,t})} + \sqrt{\text{Var}(D_{R2,t})}). \quad (3)$$

Then, for the complete planning period, the variance of the two retailers' demands is derived from (3) as:

$$\text{Var}(D) = \text{Var}(D_{R1}) + \text{Var}(D_{R2}) + 2\sqrt{\text{Var}(D_{R1})}\sqrt{\text{Var}(D_{R2})}. \quad (4)$$

Thus, the lower bound on the variance of the wholesaler's order quantity is given by:

$$\text{Var}(\bar{q}^{(1)}) = \left(1 + \frac{2L_1}{N} + \frac{2L_1^2}{N^2}\right) \text{Var}(D) = \left(1 + \frac{2L_1}{N} + \frac{2L_1^2}{N^2}\right) (\text{Var}(D_{R1}) + \text{Var}(D_{R2}) + 2\sqrt{\text{Var}(D_{R1})}\sqrt{\text{Var}(D_{R2})}).$$

We now get a lower bound on absolute increase in variability of the wholesaler's order quantity relative to the variance of the retailers' demands without risk pooling while $z=0$ (the decision maker is risk neutral) as:

$$\text{Var}(\bar{q}^{(1)}) - \text{Var}(D) = \left(\frac{2L_1}{N} + \frac{2L_1^2}{N^2}\right) (\text{Var}(D_{R1}) + \text{Var}(D_{R2}) + 2\sqrt{\text{Var}(D_{R1})}\sqrt{\text{Var}(D_{R2})}). \quad (5)$$

If risk pooling between the two retailers is considered, the order-up-to level of the wholesaler in period t is of the form:

$$\tilde{y}_t^{(1)} = E\left(\sum_{j=1}^2 D_{Rj,t}\right) + z\sqrt{\text{Var}\left(\sum_{j=1}^2 D_{Rj,t}\right)} = E\left(\sum_{j=1}^2 D_{Rj,t}\right) + z\sqrt{\text{Var}(D_{R1,t}) + \text{Var}(D_{R2,t}) + \text{Cov}(D_{R1,t}, D_{R2,t})}. \quad (6)$$

The demands of the two retailers are correlated with a coefficient $-1 \leq \rho_D \leq 1$. We obtain:

$$y_t^{(1)} = E\left(\sum_{j=1}^2 D_{Rj,t}\right) + z\sqrt{\text{Var}(D_{R1,t}) + \text{Var}(D_{R2,t}) + 2\rho_D\sqrt{\text{Var}(D_{R1,t})}\sqrt{\text{Var}(D_{R2,t})}}.$$

For the complete planning period, the variance of the two retailers' demands is derived from (6) as:

$$\text{Var}\left(\sum_{j=1}^2 D_{Rj,t}\right) = \text{Var}(D_{R1,t}) + \text{Var}(D_{R2,t}) + 2\rho_D\sqrt{\text{Var}(D_{R1,t})}\sqrt{\text{Var}(D_{R2,t})}. \quad (7)$$

The lower bound on absolute increase in variability of the wholesaler's order quantity relative to the variance of the retailers' demands with risk pooling while $z = 0$ is as follows:

$$\text{Var}(q^{(1)}) - \text{Var}\left(\sum_{j=1}^2 D_{Rj,t}\right) = \left(\frac{2L_1}{N} + \frac{2L_1^2}{N^2}\right)\left(\text{Var}(D_{R1,t}) + \text{Var}(D_{R2,t}) + 2\rho_D\sqrt{\text{Var}(D_{R1,t})}\sqrt{\text{Var}(D_{R2,t})}\right). \quad (8)$$

Comparing (5) and (8), we can see that while $-1 \leq \rho_D \leq 1$, the bullwhip effect is lower while risk pooling is employed.

3.3. With centralized/decentralized information

It is known (Chen et al., 2000) that when $z = 0$, the variance of the order quantity in a k -stage supply chain with centralized information can be expressed as:

$$\text{Var}(q^{(k)}) = \left(1 + \frac{2}{N} \sum_{i=0}^k L_i + \frac{2}{N^2} \left(\sum_{i=0}^k L_i\right)^2\right) \text{Var}(d). \quad (9)$$

On the contrary, the variance of the order quantity in a k -stage supply chain neglecting information sharing is:

$$\text{Var}(q^{(k)}) = \prod_{i=0}^k \left(1 + \frac{2L_i}{N} + \frac{2L_i^2}{N^2}\right) \text{Var}(d). \quad (10)$$

In (9) and (10), the retailer is noted as stage 0, and L_i represents the ordering lead time plus the review time for stage k . In addition, $\text{Var}(d)$ indicates the total variance of demands from the final customers.

3.4. Bullwhip effect in four different scenarios

We now conduct the problem in a three-stage supply chain with two retailers in four different scenarios. Different from Sucky's supply chain in which the bullwhip effect is considered at the wholesaler, this study focuses on the manufacturer who is the start point of the supply chain. Firstly, we consider the two scenarios with decentralized information (as shown in Fig.1).

3.4.1. With decentralized information and without risk pooling (Scenario 1)

Adapting the results in (4) and (10), we derive the lower bound of the variance of the manufacture's production quantity:

$$\text{Var}(q^{(-2)}) = \left(1 + \frac{2L_2}{N} + \frac{2L_2^2}{N^2}\right) \left(1 + \frac{2L_1}{N} + \frac{2L_1^2}{N^2}\right) \left(\text{Var}(D_{R1,t}) + \text{Var}(D_{R2,t}) + 2\sqrt{\text{Var}(D_{R1,t})}\sqrt{\text{Var}(D_{R2,t})}\right).$$

The absolute increase of the variance of the manufacture's production quantity relative to the variance of the two retailers' demands can be expressed by:

$$\text{Var}(q^{(-2)}) - \text{Var}(D) = \left(\frac{2(L_1 + L_2)}{N} + \frac{2(L_1^2 + L_2^2)}{N^2} + \left(\frac{2L_2}{N} + \frac{2L_2^2}{N^2}\right)\left(\frac{2L_1}{N} + \frac{2L_1^2}{N^2}\right)\right) \left(\text{Var}(D_{R1,t}) + \text{Var}(D_{R2,t}) + 2\sqrt{\text{Var}(D_{R1,t})}\sqrt{\text{Var}(D_{R2,t})}\right)$$

3.4.2. With decentralized information and risk pooling (Scenario 2)

From (7) and (10), we have:

$$Var(q^{(2)}) = \left(1 + \frac{2L_2}{N} + \frac{2L_2^2}{N^2}\right) \left(1 + \frac{2L_1}{N} + \frac{2L_1^2}{N^2}\right) (Var(D_{R1}) + Var(D_{R2}) + 2\rho_D \sqrt{Var(D_{R1})} \sqrt{Var(D_{R2})}).$$

Obviously,

$$Var(q^{(2)}) - Var\left(\sum_{j=1}^2 D_{Rj}\right) = \left(\frac{2(L_1 + L_2)}{N} + \frac{2(L_1^2 + L_2^2)}{N^2} + \left(\frac{2L_1}{N} + \frac{2L_1^2}{N^2}\right) \left(\frac{2L_2}{N} + \frac{2L_2^2}{N^2}\right)\right) (Var(D_{R1}) + Var(D_{R2}) + 2\rho_D \sqrt{Var(D_{R1})} \sqrt{Var(D_{R2})}).$$

Next, information centralization is considered in the model (as shown in Fig.2), in which both the manufacturer and the wholesaler make decisions based on the retailers' demands and inventory data.

3.4.3. With centralized information and without risk pooling (Scenario 3)

From (4) and (9), the absolute increase of the variance of the manufacture's production quantity relative to the variances of the two retailers' demands is given by:

$$Var(\bar{q}^{(2)}) - Var(D) = \left(\frac{2}{N} \sum_{i=1}^2 L_i + \frac{2}{N^2} \left(\sum_{i=1}^2 L_i\right)^2\right) (Var(D_{R1}) + Var(D_{R2}) + 2\sqrt{Var(D_{R1})} \sqrt{Var(D_{R2})}).$$

3.4.4. With centralized information and risk pooling (Scenario 4)

From (7) and (9), the absolute increase of the variance of the manufacture's production quantity relative to the variances of the two retailers' demands is as follows:

$$Var(q^{(2)}) - Var\left(\sum_{j=1}^2 D_{Rj}\right) = \left(\frac{2}{N} \sum_{i=1}^2 L_i + \frac{2}{N^2} \left(\sum_{i=1}^2 L_i\right)^2\right) (Var(D_{R1}) + Var(D_{R2}) + 2\rho_D \sqrt{Var(D_{R1})} \sqrt{Var(D_{R2})}).$$

3.5. Comparison and discussion

We now compare the bullwhip effect in the above four scenarios.

Proposition. Integrating strategies of information sharing and risk pooling can better mitigate the bullwhip effect than employing either of them separately.

Proof. Let parameters B_1, B_2, B_3 and B_4 represent the bullwhip effect at the manufacturer in the four scenarios.

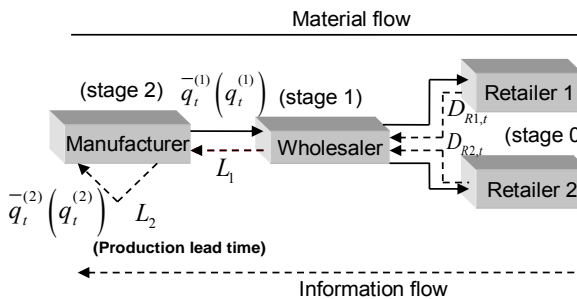


Fig. 1. Supply chain with decentralized informa

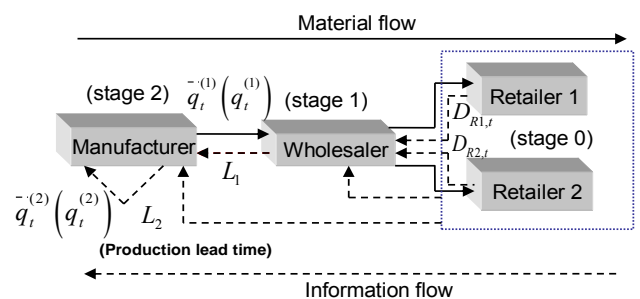


Fig. 2. Supply chain with centralized information.

The bullwhip effect measured by the absolute increase is as follows:

$$B_1 = Var(\bar{q}^{(2)}) - Var(D) = \left(\frac{2(L_1 + L_2)}{N} + \frac{2(L_1^2 + L_2^2)}{N^2} + \left(\frac{2L_2}{N} + \frac{2L_2^2}{N^2}\right) \left(\frac{2L_1}{N} + \frac{2L_1^2}{N^2}\right)\right) (Var(D_{R1}) + Var(D_{R2}) + 2\sqrt{Var(D_{R1})} \sqrt{Var(D_{R2})}).$$

$$B_2 = Var(q^{(2)}) - Var\left(\sum_{j=1}^2 D_{Rj}\right) = \left(\frac{2(L_1 + L_2)}{N} + \frac{2(L_1^2 + L_2^2)}{N^2} + \left(\frac{2L_1}{N} + \frac{2L_1^2}{N^2}\right)\left(\frac{2L_2}{N} + \frac{2L_2^2}{N^2}\right)\right) \left(Var(D_{R1}) + Var(D_{R2}) + 2\rho_D \sqrt{Var(D_{R1})} \sqrt{Var(D_{R2})}\right).$$

$$B_3 = Var(q^{(2)}) - Var(D) = \left(\frac{2}{N} \sum_{i=1}^2 L_i + \frac{2}{N^2} \left(\sum_{i=1}^2 L_i\right)^2\right) \left(Var(D_{R1}) + Var(D_{R2}) + 2\sqrt{Var(D_{R1})} \sqrt{Var(D_{R2})}\right).$$

$$B_4 = Var(q^{(2)}) - Var\left(\sum_{j=1}^2 D_{Rj}\right) = \left(\frac{2}{N} \sum_{i=1}^2 L_i + \frac{2}{N^2} \left(\sum_{i=1}^2 L_i\right)^2\right) \left(Var(D_{R1}) + Var(D_{R2}) + 2\rho_D \sqrt{Var(D_{R1})} \sqrt{Var(D_{R2})}\right).$$

Apparently, $B_1 > B_2, B_1 > B_3; B_2 > B_4, B_3 > B_4 \Rightarrow B_1 > B_4$. Therefore, the increase in variability across a three-stage supply chain is lower while information sharing and risk pooling are considered simultaneously, comparing with the scenario in which neither of the two strategies is performed or only either of them is considered.

Additionally, we have $B_1 - B_4 > B_1 - B_2, B_1 - B_4 > B_1 - B_3$, where $B_1 - B_4$ measures absolute increase of the bullwhip effect while considering both strategies of information sharing and risk pooling, $B_1 - B_2$ and $B_1 - B_3$ indicate the reduction of the bullwhip effect while only either strategy is taken into account. Thus, we can see integrating strategies of information sharing and risk pooling can decrease the bullwhip effect more effectively than utilizing either of them separately.

4. Avoiding the bullwhip effect in container shipping markets

4.1. Numerical comparison

Before measuring our strategy on the bullwhip effect in shipping markets, we first perform some numerical studies to validate the theoretical findings using the benchmark data (Sucky, 2009). As Sucky (2009) did not deal with the lead time, we let $L_1 = 2, L_2 = 3$ be the ordering and production lead time plus the review time for the wholesaler and the manufacturer, respectively. Still, the numerical experiment to explore the bullwhip effect at the manufacturer is supplemented in the three-stage supply chain. All stages follow the same order-up-to policy and we use 2-period moving averages ($N = 2$). We define the managerial determined factor that indicates the number of estimated standard deviations of demand to be kept as safety stock, $z = 2.33$.

Fig.3, 4, 5 and Fig.6 measure the bullwhip effect at the manufacturer in scenario 1, 2, 3 and 4, respectively. Concretely, Fig.3 shows the bullwhip effect without using any strategy; Fig.4 is derived by only adopting Sucky (2009)'s approach; Fig.5 is derived by only adopting Chen et al. (2000)'s approach and Fig.6 shows the benefit of reducing the increase in variability by our integration approach.

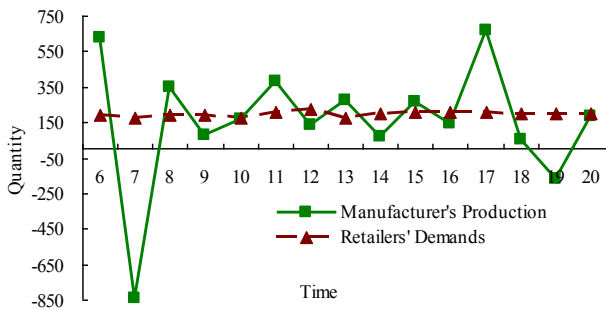


Fig.3 The bullwhip effect with decentralized information and without risk pooling

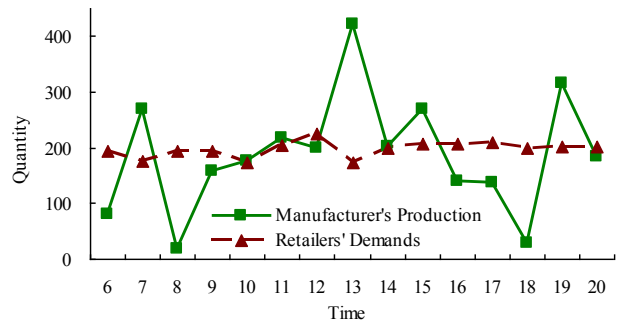


Fig.4 The bullwhip effect with decentralized information and risk pooling

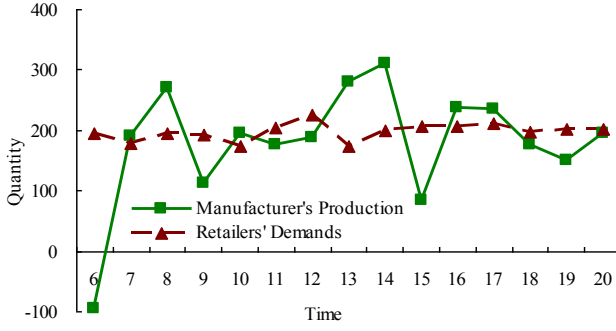


Fig.5 The bullwhip effect with centralized information and without risk pooling

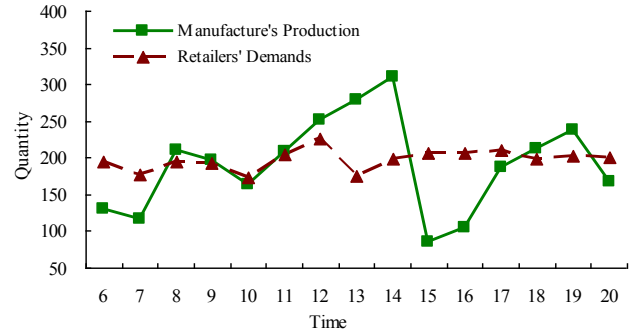


Fig.6 The bullwhip effect with centralized information and risk pooling

On the other hand, Table 1 shows the bullwhip effect expressed by absolute and relative increase in variability of the manufacturer's order quantity to the variances of the retailers' demands in the four scenarios mentioned above. We can see that the bullwhip effect is considerably lower in the supply chain by integrating strategies of information sharing and risk pooling. The absolute increase significantly decreases 96.7% comparing with the scenario in which neither information sharing nor risk pooling is considered. In the meantime, the value decreases 63.6% comparing with Sucky (2009)'s approach and decreases 57.1% comparing with Chen et al. (2000)'s approach.

Table 1. Bullwhip effect measurements in four scenarios

Strategies		Without risk pooling	With risk pooling
Decentralize information	Absolute increase	$Var(\bar{q}_t^{(2)}) - Var(D)$	$Var(q_t^{(2)}) - Var(D)$
		122794.3	10998.5
	Relative increase	$Var(\bar{q}_t^{(2)}) / Var(D)$	$Var(q_t^{(2)}) / Var(D)$
		44.1	8.6
Centralized information	Absolute increase	$Var'(\bar{q}_t^{(2)}) - Var(D)$	$Var'(q_t^{(2)}) - Var(D)$
		9333.6	4001.1
	Relative increase	$Var'(\bar{q}_t^{(2)}) / Var(D)$	$Var'(q_t^{(2)}) / Var(D)$
		3.4	3.2

Therefore, we come to an important result in controlling the bullwhip effect. Integrating strategies of information sharing and risk pooling can deal with the increase in variability across the supply chain effectually, better than utilizing either of them separately.

4.2. Mitigating the bullwhip effect in container shipping markets

In global supply chains, seasonal fluctuations and changes in the economy often lead to mismatching of the supply and demand, which strongly affects the efficient and cost-effective operations of shipping companies (United Nations, 2013). In such an ocean shipping supply chain, the bullwhip effect affects transport capacity needs more than the actual demand amplification is (Towill 2005). In what follows, we analyse the bullwhip effect in Shanghai and Hong Kong container shipping market by the developed analytical model.

We use the monthly ocean container exports (*Shanghai Statistics* and *Marine Department of Hong Kong*) of 2013 ('000 TEUs) of Shanghai and Hong Kong as the transport service demands of shippers. Based on our surveys, the average lead time of the freight forwarding agent and the container shipping company is set to 0.6 month (18 days) and 0.8 month (24 days), respectively, which indicates the time from the shippers proposing their transport demands to the customs formalities necessary for export finished and from the customs

formalities necessary finished to the cargoes reaching the consignees. Similar to Sucky (2009), we set the safety factor, $z=2.33$ to represent the desired service level.

As mentioned previously, in our study, we regard the container shipping company as the manufacturer, the freight forwarding agent as the wholesaler and the shippers as retailers respectively. The container shipping company's shipping plan is based on the freight forwarding agent's shipping request which is highly contingent on the shippers' transport need. All three stages follow the same order-up-to policy and a 2-period moving average forecasting technique is used, therefore, at the third stage, the needed transport capacity of the container shipping company is result in period 7 to12. Fig.7 and 8 quantify the bullwhip effect in the container shipping market, respectively without using any strategy and using our approach (i.e., employing strategies of centralized information and risk pooling). Comparing Fig. 7 and 8, we can see that the bullwhip effect in the container shipping market is considerably lower in the supply chain by integrating the strategies of information sharing and risk pooling.

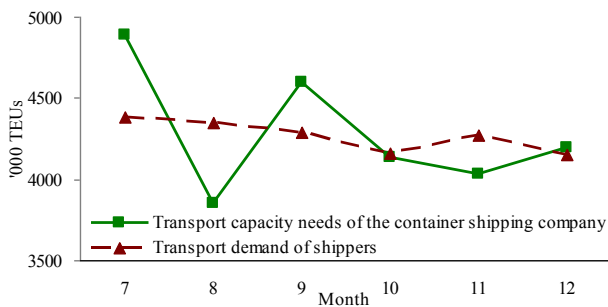


Fig.7 The bullwhip effect in Shanghai and Hong Kong container shipping markets

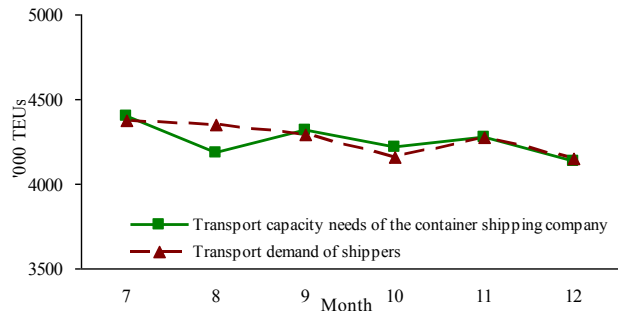


Fig.8 The bullwhip effect in Shanghai and Hong Kong container shipping markets using our strategy

Table 2 measures our approach on the bullwhip effect in Shanghai and Hong Kong container shipping market by absolute and relative increases in variability of the transport capacity need of the container shipping company to variances of the shippers' transport demands. We can see that the absolute and relative increases significantly decrease 99.89% and 93.94.7% respectively, comparing with neither information sharing strategy nor risk pooling strategy is employed. It is clearly, our approach significantly reduced the bullwhip effect in the container shipping service supply chain.

Table 2. The impact of our approach on bullwhip effects in Shanghai and Hong Kong container shipping markets

Measurement	The bullwhip effect without using any strategy	The bullwhip effect using our strategy
Absolute increase	$Var(\bar{q}_t^{(2)}) - Var(D)$	$Var(q_t^{(2)}) - Var(D)$
	139603.8	160.2
Relative increase	$Var(\bar{q}_t^{(2)}) / Var(D)$	$Var(q_t^{(2)}) / Var(D)$
	16.5	1.0

Certainly, the above discussion could shed some lights on managerial insights. First, it is highly recommended that the container shipping company and the freight forwarding agent could share their information; especially the direct access to the shippers' shipping needs. With the accurate container shipping demand information, the container shipping company could make timely adjustments to its marketing strategy as well as shipping plans to improve its profitability. Secondly, the container shipping company and the freight forwarding agent may work together to smooth shipping demands and achieve the most appropriate match in the overall supply chain. In summary, it is quite obvious that with the help of information sharing and risk pooling, the bullwhip effect can be reduced effectively and efficiently.

5. Conclusions

In this paper, we propose an analytical integrated model to investigate the impact of information sharing and

risk pooling on the bullwhip effect in a three-stage supply chain. Our approach achieves a remarkable improvement in controlling the bullwhip effect, it outperforms the existing approaches which utilize either information sharing or risk pooling separately. We expect that the developed approach will be helpful to the practical supply chain management in counteracting the distorted information. Additionally, it is clear the bullwhip effect in container shipping market can be reduced considerably by implementing the method in Shanghai and Hong Kong international container shipping market. More importantly, the proposed method is quite straightforward and can be easily applied in practice without introducing too much administrative cost.

References

- Bayraktar, E., Lenny Koh, S. C., Gunasekaran, A., Sari, K. and Tatoglu, E. (2008), The role of forecasting on bullwhip effect for E-SCM applications, *International Journal of Production Economics* 113(1):193-204.
- Bhattacharya, R. and Bandyopadhyay, S. (2011), A review of the causes of bullwhip effect in a supply chain, *The International Journal of Advanced Manufacturing Technology* 54(9-12):1245-1261.
- Chen, F., Drezner, Z., Ryan, J. K. and Simchi-Levi, D. (2000), Quantifying the bullwhip effect in a simple supply chain: The impact of forecasting, lead times, and information, *Management science* 46(3): 436-443.
- Chen, L. and Lee, H. L. (2012), Bullwhip effect measurement and its implications. *Operations Research* 60(4): 771-784.
- Dejonckheere, J., Disney, S. M., Lambrecht, M. R. and Towill, D. R. (2003), Measuring and avoiding the bullwhip effect: A control theoretic approach. *European Journal of Operational Research* 147(3): 567-590.
- Geary, S., Disney, S. M. and Towill, D. R. (2006), On bullwhip in supply chains — historical review, present practice and expected future impact, *International Journal of Production Economics*: 101(1): 2-18.
- Giard, V. and Sali, M. (2013), The bullwhip effect in supply chains: a study of contingent and incomplete literature, *International Journal of Production Research* 51(13): 3880-3893.
- Glas, A. H., Kleemann, F. C. and Essig, M. (2013), Bullwhip-effect and countermeasures: case study of an Asian-European automotive supply chain, *Business and Management* 5(2).
- Harrison, A. and Fichtinger, J. (2013), Managing variability in ocean shipping, *International Journal of Logistics Management* 24(1): 7-21.
- Hong, L. (2006), Research on bullwhip effect in shipping market (In Chinese), *Navigation of China* 1:016.
- Lee, H. L. and Billington, C. (1993), Material management in decentralized supply chains, *Operations Research* 41(5): 835-847.
- Lee, H. L., Padmanabhan, V. and Whang, S. (2004), Information distortion in a supply chain: the bullwhip effect, *Management science* 50(12): 1875-1886.
- Lee, H. L., So, K. C. and Tang, C. S. (2000), The value of information sharing in a two-level supply chain, *Management Science* 46(5): 626-643.
- Marine department of the government of the Hong Kong special administrative region <http://www.mardep.gov.hk/hk/home.html>.
- Miragliotta, G. (2006), Layers and mechanisms: A new taxonomy for the bullwhip effect, *International Journal of Production Economics* 104(2): 365-381.
- Potter, A. and Disney, S. M. (2006), Bullwhip and batching: an exploration, *International Journal of Production Economics* 104(2): 408-418.
- Shanghai Statistics, <http://www.stats-sh.gov.cn/>.
- Sucky, E. (2009), The bullwhip effect in supply chains — An overestimated problem? *International Journal of Production Economics* 118(1): 311-322.
- Towill, D.R. (2005), The impact of business policy on bullwhip induced risk in supply chain management, *International Journal of Physical Distribution & Logistics Management* 35(8): 555-575.
- United Nations (2013), *Review of Maritime Transport 2013*, New York and Geneva.
- Wu, Y. N. and Edwin Cheng, T. C. (2008), The impact of information sharing in a multiple-echelon supply chain, *International Journal of Production Economics* 115(1): 1-11.
- Zhang, X. (2004), The impact of forecasting methods on the bullwhip effect, *International Journal of Production Economics* 88(1): 15-27.

Is New Emission Legislation Stimulating the Implementation of Sustainable (Retrofitting) Maritime Technologies?

Laurence Stevens, Christa Sys, Thierry Vanelander and Edwin van Hassel

University of Antwerp, Department of Transport and Regional Economics, University of Antwerp, Antwerp

Abstract

There is a significant increase in the attention given to green maritime ship technologies due to the growing importance of sustainable operations. The driving force behind the increase of this importance is the implementation of several new legislative actions taken by the International Maritime Organisation (IMO) and the European Union (EU). One of the main questions that arises is whether this new emission legislation stimulates the implementation of sustainable retrofitting maritime technologies?

In this paper, a framework is developed that will allow linking the different emission legislation initiatives in different countries with the technical solutions that could be used to fulfill the legislation. Based on this framework, the main research question will be answered.

Keywords: Sustainability, emission legislation, maritime technologies, retrofitting, maritime pollution policies

1. Introduction

There is a significant increase in the attention given to green maritime ship technologies due to the growing importance of sustainable operations. The driving force behind the increase of this importance is the implementation of several new legislative actions taken by the IMO and EU.

In order to frame international shipping from an environmental perspective, it can be stated that it contributes to about 3% of global CO₂ emissions (Eide *et al.*, 2009) while transporting almost 90% of the world trade (Laffineur, 2012). From this perspective, the contribution of international shipping is small. However, there are more emissions than only CO₂. Maritime shipping is a large contributor to NO_x and SO_x emissions. It is therefore necessary that the maritime sector should improve its efforts to reduce these emissions.

Policies by different international organizations and institutions impose international environmental standards to their member states to limit the emission of greenhouse gases. Business as usual could have a direct and short-term impact on human life and health and it will have a global and long-term impact on climate change (Laffineur, 2012). As a consequence, limiting exhaust emissions has become an important item for these organizations. In this analysis the new legislation is taken as a given and it is not analysed how the legislation has been developed. For this analysis reference is made to Sys *et al* (2012).

The question is how ship owners will react to this new legislation. More specifically: are ship-owners going to implement new innovative technologies in either their new building projects or are they going to retrofit their existing ships due to this new legislation?

This paper is structured as follows. In section 2, an overview of the applied methodology will be given. The third section will give an overview of the emission legislation. Section 4 will deal with the potential technical solutions that can be applied to reduce emissions. The next sections will give the analyses on how the developed legislation relates to the technologies. A framework will be developed to analyse whether these new technologies will be implemented due to the new legislation. The paper ends with a number of conclusions.

2. Applied Methodology

In order to answer the main research question, first, an overview of the emission legislation is given in this section. This overview will be constructed based on a literature review. Secondly, an additional overview is constructed with the possible technical solutions to reduce emissions either due to a reduction of fuel consumption or only by pure emission-reducing techniques. This overview was constructed via a desk study. The latter comprises different reports, studies and articles. It results in an overview of various emission reduction techniques. For all of these technologies, it is indicated whether it is only applicable for newbuildings or whether it can be installed as a retrofitting effort (i.e. installed on an existing ship).

After these two overviews, a framework will be developed to link the previously mentioned policies with the new maritime technologies. This framework will be used to analyse the applicability of these new technologies to either newbuilding projects or retrofitting projects.

3. Developments of Emission Legislation in International Shipping

Four large developments regarding emission legislation in international shipping can be distinguished among, namely MARPOL ANNE X VI, the energy efficient design index (EEDI), the Ship Energy Efficient Management Plan (SEEMP) and the White paper of the EU (European Commission, 2011). These four regulation initiatives are discussed in more detail in this section.

3.1. MARPOL Annex VI Developments of emission legislation in international shipping

Annex VI, which contains the regulations regarding sulphur emissions by ships, is the newest addition to the MARPOL convention. The revised Annex VI (into force on 1 July 2010) has been adopted by 72 member states, representing 94.3% of the total world tonnage. Regulation 14 of MARPOL Annex VI states that the sulphur content of any fuel used on board of a ship must be reduced to 0.5% from January 1st., 2020. Inside an Environmental Control Area (ECA), however, the limits for SO_x and particulate matter must be further reduced from 1.00% (since July, 1st. 2010) to 0.10 %, effective from 1 January 2015 (IMO, 2013).

Next to studies of classification societies (DNV, 2009 and 2012; ...) and engine manufacturers (MAN Diesel A/S, 2011; Wartsilla, 2009; ...), the subject also attracted the attention of (academic) researchers. Initial studies focussed on short sea shipping (a.o. Entec, 2009; Kalli, et al., 2009; Notteboom et al., 2010). All these studies have been commissioned by certain maritime actors. The papers of Corbett et al. (2003), Karim (2010), Sys, et al. (2012) emphasizes deep sea shipping and pay attention to the modal impact and economic impact of the emission legislation. The forthcoming papers by Cullinane and Bergqvist (2014) and Jiang, et al. (2014) address the decision what measures and strategies to implement and the timing of such decisions from the perspective of private operators.

3.2 EEDI and SEEMP

The Marine Environment Protection Committee (MEPC), a committee of the IMO, did make amendments to the MARPOL 73/78. From January 1, 2013, the Ship Energy Efficiency Design Index (EEDI) and the Ship Energy Efficient Management Plan (SEEMP) will be mandatory for all vessels over 400 gross tonnage (IMO, 2011, Laffineur, 2012, Harrison, 2012). These systems attempt to further enhance the reduction of greenhouse gas emissions.

Due to the long lifespan of a vessel, up to thirty years, the replacement of engines will only happen in the long run. It is to be said that old engines are much bigger polluters than the newer engines (Van Laer, 2012). By making EEDI and SEEMP regulation mandatory, a further reduction of exhaust greenhouse gases will be reached. The additional commitment of the IMO could reduce the emission of greenhouse gases to between 180 and 240 million tons on an annual basis as a consequence of the EEDI regulation alone (IMO, 2011).

The EEDI is a benchmark on the energy efficiency set to reduce exhaust gas on newly-built vessels. It is a non-prescriptive measure that helps the industry decide which technologies should be installed on a specific

ship design. When the emission of CO₂ is above this benchmark, the design of the vessel has to be changed. As long as the energy efficiency is below the target, the ship designers and builders are free to choose the most cost-efficient technologies to comply with the regulations (IMO, 2010). The formula to calculate the EEDI is given here below.

In the numerator of formula 1, the first two factors represent the emissions produced by the main and auxiliary engines respectively; while the third factor denotes the emissions produced by the shaft generators. The last part in the numerator represents the energy saving technologies. The denominator of the formula refers to the work (unit known from physics) that is performed by the ship in tonne.nm or TEU.nm.

$$EEDI = \frac{\left(\prod_{j=1}^M f_i \right) \left(\sum_{i=1}^{nME} P_{EM(i)} \cdot C_{FME(i)} \cdot SFC_{ME(i)} \right) + (P_{AE} \cdot C_{FAE} \cdot SFC_{AE})}{f_i \cdot Capacity \cdot V_{ref} \cdot f_w} + \frac{\left(\prod_{j=1}^M f_i \cdot \sum_{i=1}^{nPTI} P_{PTI(i)} - \sum_{i=1}^{neff} f_{eff(i)} \cdot P_{AEff(i)} \right) \cdot C_{FEA} \cdot SFC_{AE} - \left(\sum_{i=1}^{neff} f_{eff(i)} \cdot P_{eff(i)} \cdot C_{FME} \cdot SFC_{ME} \right)}{f_i \cdot Capacity \cdot V_{ref} \cdot f_w} \quad (1)$$

where

- P_{em}, P_{AE}, P_{PTI} = power of the main, auxiliary and shaft engines
- P_{eff} = main engine power reduction due to technologies
- C = CO₂ emission factor for the main, auxiliary and shaft engines
- SFC = specific fuel consumption of main, auxiliary and shaft engines
- f = correction and adjustment factors
- Capacity = deadweight or container capacity
- V = speed

The benchmark will be progressively reduced in the future compared to a reference value, consequently, decreasing the emission of greenhouse gases. Table 1 represents this progressive reduction of the EEDI for the different vessel types and dimensions (IMO, 2011; Laffineur, 2012). However, the development of the reference values turns out to be quite difficult due to the large spread of EEDI values for different ship types. This is especially the case for small dry cargo short sea ships (Laffineur, 2012).

Table 1. Progressive Reduction of EEDI

Ship type	Size	Phase 0	Phase 1	Phase 2	Phase 3
		1 Jan 2013-31 Dec 2014	1 Jan 2015- 31 Dec 2019	1 Jan 2020 - 31 Dec 2024	1 Jan 2025 onwards
Bulk carrier	20.000 dwt and above	0	10	20	30
	10.000-20.000 dwt	n/a	0-10*	0-20*	0-30*
Gas tanker	10.000 dwt and above	0	10	20	30
	2.000-10.000 dwt	n/a	0-10*	0-20*	0-30*
Tanker	20.000 dwt and above	0	10	20	30
	4.000-20.000 dwt	n/a	0-10*	0-20*	0-30*
Container ship	15.000 dwt and above	0	10	20	30
	10.000-15.000 dwt	n/a	0-10*	0-20*	0-30*
General cargo ship	15.000 dwt and above	0	10	20	30
	3.000-15.000 dwt	n/a	0-10*	0-20*	0-30*
Refrigerated cargo carrier	5.000 dwt and above	0	10	20	30
	3.000-5.000 dwt	n/a	0-10*	0-20*	0-30*

Source: (Laffineur, 2012 ; MEPC 63, 2011), *: Reduction factor depends on vessel size, n/a: no EEDI applies

The SEEMP is an operational measure that helps the shipping company improve the energy efficiency of their operations in existing vessels (IMO, 2010; Laffineur, 2012). The SEEMP shows how energy savings can be made in four steps: planning, implementation, monitoring and self-evaluation. (MEPC 63, 2011).

In the SEEMP, the current performance of the ship has to be determined. Also a plan of improvement must be developed. This improvement can be reached through a large list of possible options (such as speed optimization, weather routing,...) which all should be examined. The energy efficiency of the ship should be monitored in a quantitative way. Here, the EEDI could be used (MEPC 63, 2011).

The MEPC also discusses other possibilities of reducing the greenhouse gas emissions, such as market-based mechanisms. These mechanisms put a price to greenhouse gas emissions, consequently giving economic incentives to the industry to invest in vessels and technologies with low exhaust emissions. The generated revenue can be used to limit climate change (IMO, 2011). These mechanisms could include:

- A levy on vessels that do not meet the EEDI standard.
 - A levy on all greenhouse gas emissions coming from all types of vessels.
 - A global emission trading system.
 - A penalty on trade and development.
 - A rebate mechanism for a market-based instrument for international shipping.
- (IMO, 2010 ; Laffineur, 2012).

3.3 EU White paper

Finally, the recent White paper of the European Commission (European Commission, 2011) states that the European Union wants to diminish its greenhouse gas emissions to limit climate change to 2°C. To reach this goal, the European Union must attain a reduction in greenhouse gas emission levels by 80-95% below 1990 levels by 2050. For the transport sector in particular, the greenhouse gas emissions must be reduced by 20% by 2030 and by 40% by 2050 compared to their level in 2008. The White paper emphasizes that decisions that are taken today will influence future decisions and actions. That is why the implemented measures must be well thought out.

4. Alternative Sustainable Maritime Technologies

This section gives an overview of the different measures that could be implemented to make a vessel more sustainable. In order to categorize the different technical solutions, first the propulsion system of a ship must be understood. This system consists of four main elements: the propulsion plant (engine), the propulsor (propeller), the hull (resistance) and the operation of the ship (the captain). In figure 1, a diagram is given on how four of these main elements are related to each other.

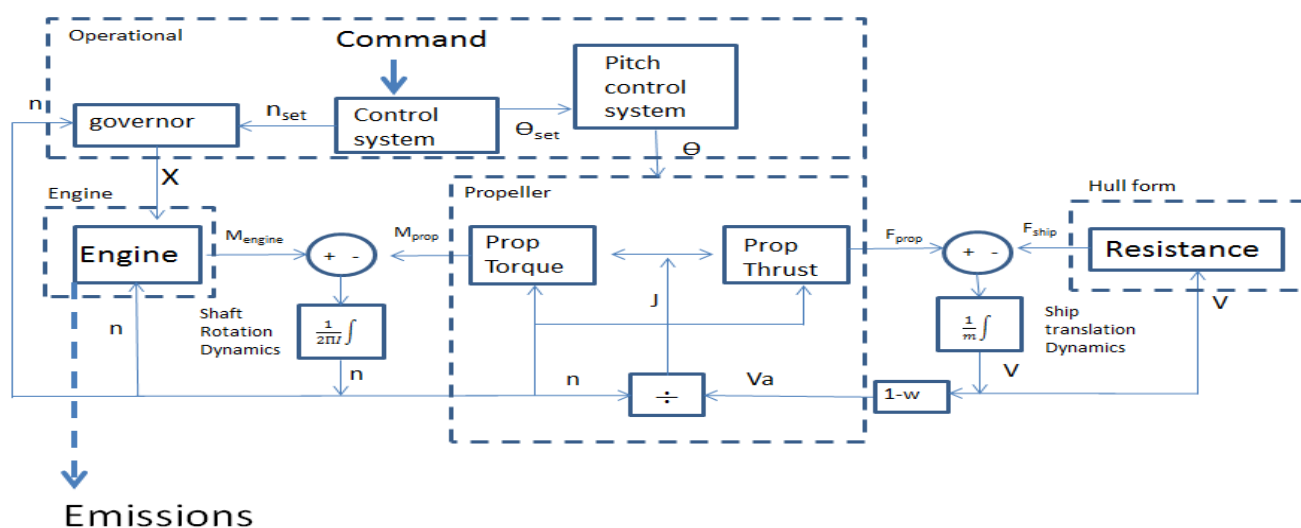


Fig 1. Block Diagram of Propulsion Dynamics

Source: based on Stapersma, 2004

On the left hand side of figure 1, there is the engine. The engine will consume fuel (denoted as X) and generate RPM (revolutions per minute), torque and emissions. The torque generated by the engine will be

transferred to the propeller. On the basis of the difference between the needed propeller torque to sail at a certain speed and the generated torque of the engine, the propeller RPM can be calculated. The engine RPM will be influencing the propeller RPM and it will be used to control the engine (and thus the ship).

In the middle of the figure, the ships' propeller is given. The propeller is in between the engine and the hull of the ship. There are two main components of the propeller namely the torque and the propeller RPM.

On the right hand side, there is the hull form. The hull form will determine, along with the speed of the ship and the draft (which relates to the payload), what the resistance is. In order to overcome this resistance, the propeller must generate thrust. Based on the difference between the propeller thrust and the resistance of the ship the speed of the ship can be calculated. This speed is then influencing the resistance of the ship (there is an iterative relation) and it is influencing the propeller.

On the topside of figure 11, the control system is given (operational part). In this block, the captain can set a certain ship speed. This can be done either by changing the engine's RPM, which can be adjusted by changing the fuel injection of the engine or, when the ship has a controllable pitch propeller, adjusting the pitch of the propeller.

From figure 3, it can be concluded that there are a lot of dynamic links between the different elements of the drive train. This is important to realise when one is discussing the reduction of marine emissions, because reducing marine emissions is not only related to the engine, although it is the engine that is producing these emissions, but it relates to the total system. Fuel consumption (and thus emissions) relates to the complete and dynamic system of engine, propeller, hull form and control systems.

The main objective of this section is to come to a list of potential alternative technologies that could reduce the fuel consumption, therefore reducing the emission of carbon dioxide and other pollutants, or of technologies purely to reduce the level of emissions. These different technologies can be classified into five main classes. All the alternative technologies (and operational changes) and their corresponding classes can be identified in table 2.

Table 2. Overview of the Maritime Technologies and Operational Measures

1. Hull	2. Propulsion	3. Machinery	4. Alternative Energy Sources	5. Operation/ maintenance
Air lubrication (N+R)	Contra-rotating propellers (N+R)	Advanced power management (N+R)	Fuel type: Bio fuel (N+R)	Autopilot adjustment
Bulbous bow (N+R)	Optimization of the propeller blade sections (N+R)	Automation (N+R)	Fuel type: Low sulfur fuel (N+R)	Hull cleaning
Ducktail waterline extension (N+R)	Propeller boss cap with fins (N +R)	Common rail (N+R)	Fuel type: LNG (N+R)	Increasing cargo load factor
Hull surface / Hull coating (H+R)	Propeller nozzle (N+R)	Cooling water pumps, speed control (N+R)	Solar Power (N+R)	Increasing energy awareness
Interceptor trim plates (N+R)	Propeller tip winglets (N+R)	Delta tuning (N+R)	Wind Power: Flettner Rotor (N)	Optimization of trim and ballast
Minimizing resistance of hull openings (N+R)	Propeller-rudder combination (N+R)	Engine derating (N+R)	Wind assisted: Kites (N+R)	Propeller polishing
Efficiency of scale (N)	Rudder resistance (R)	Part load operating optimization (N+R)	Wind Power: Sails (N)	Reducing ballast
Lightweight construction (N)	Constant versus variable speed reduction	Reducing onboard power demand (N+R)		Reducing port time

Optimal propeller hull interaction (N)	Optimization of propeller and hull interaction (N)	Scrubber (N+R)		Reducing speed
Optimization of skeg shape (N)	Propeller efficiency measurement	Selective catalytic reduction (N+R)		Optimizing voyage optimization
Shaft line arrangement (N)	Pulling thruster (N)	Waste Heat Recovery (N)		Weather routing
	Wing thrusters (N)	Diesel-electric machinery (N)		
		Hybrid Auxiliary Power generation (N)		
		Low loss concept for electric network (N)		
		Variable speed electric power (N)		

Source: Crist, (2009) ; MEPC 61, (2010); Wärtsilä, (2009) and Stevens (2012)

The first three classes are based on figure 1 and are measures to adjust the hull of the ship, the propulsor and the installed machinery. The additional class that was added is the class of alternative energy sources (class 4). The class of alternative energy sources is in-between the classes of propulsor and machinery. In this class, the technical solutions such as wind propulsion (sails) and alternative fuel types (low sulphur and LNG) are categorized. The fifth class is the operation (and maintenance) of the ship. This class is not related to different technological solutions but only to the way the ship is being operated.

The technologies are now also classified as newbuilding technologies or retrofitting technologies. The measures followed by (N) are the technologies that can only be built into new ships. (N+R) is used when measures can both be installed in new vessels or that can be retrofitted into existing vessels. The measures without brackets are measures that can be used to reduce the fuel consumption of a vessel by changing one of the parameters in their operational activities. For example, by reducing the speed of a vessel a fuel reduction can be reached (last column).

The list of 55 measures is based on a study of different reports, studies and presentations. Measures that are not yet operational or not widespread are not included into the following table. Therefore, other measures could have been added into the list. For an detailed description of all the different technologies, reference is made to Stevens (2012).

5. Development of a Framework to Link Emission Policy to Maritime Technologies

Now that the policy to reduce the maritime emissions has been explained and the overview of the potential technical solutions was made, it is time to link these two elements. In figure 2, these different links can be seen. The figure is split in two main parts: a ship owner part, who is interested in the fuel cost of his ship, and a policy maker part, who is interested in the emissions part of the ship.

Figure 2 shows that there is no direct link between fuel cost, which is of interest for the ship owner, and the emissions. There is only an indirect link via the fuel consumption. This is a key element in the framework which is developed in figure 2. The ship owner is very much interested in reducing the fuel cost of its vessel. This can be done in two ways, namely by financial or operational means or by reducing the (design) fuel consumption. It can be seen that two different policies are targeting these aspects (SEEMP and EEDI). The policy to implement the (S)ECA's is directly related to the emissions which is not directly related to the fuel costs of the shipowner.

The financial way of reducing the fuel cost is by hedging the fuel price. In this way, it is possible to reduce the fuel cost even without implementing any technical solution. An operational way is to change the route of the vessel (either by voyage optimization or by weather routing). A third operational way to reduce the fuel cost is

to reduce the speed of the vessel. By reducing the speed of a ship also the fuel consumption will be reduced, and as a result, also the emissions. All the operational measures (column 5) mentioned in table 2 can be placed in this part of the diagram.

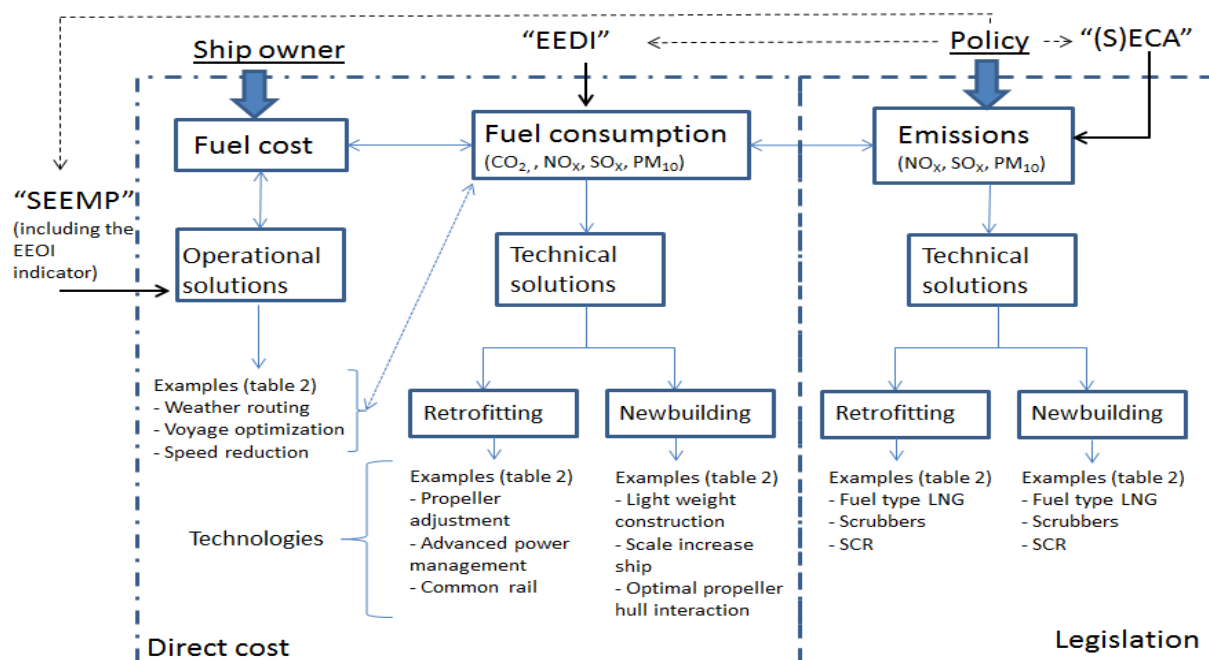


Fig 2. Linking Emission Policy to Maritime Technologies

Source: Own composition

There are also technical ways of reducing the fuel consumption of a ship. This can be split into two different ways, namely adjusting (retrofitting) an existing ship or buying a new ship with the latest technologies. Several possible solutions are given in figure 2. The examples given here come from the first four columns of table 2 without the grey shading. These types of technology are very much in the interest of the ship owner because they can be beneficial by means of a reduced fuel bill.

The right part of figure 2 shows the technical measures that will only reduce the emissions (NO_x, SO_x and PM₁₀) and not the fuel consumption. Examples of these types of technology are scrubbers and using low sulphur fuels. The implementation of these technologies comes at a cost while there is no direct economic benefit for the ship owner. Therefore, the implementation of these technologies is not in the main interest of the ship owner but is rather forced by legislation. It can therefore be expected that if a ship owner is forced to take measures to fulfil new criteria, he will opt for the solutions that are the least costly. In table 2 these technologies are marked with a grey colour. And all these technologies relate to the policy of the introduction of the (S)ECA zones.

The legislation's main interest is in reducing emissions. This can be done by reducing fuel consumption but can also be forced by law. This can be seen at the top side of figure 2, where the different policies are shown. The SECA legislation is an example where the ship owner is forced to think about implementing additional technologies, such as scrubbers, in order to be able to sail to a specific port. The EEDI on the other hand is a type of legislation where the aim is to reduce the emissions by reducing the fuel consumption of the ship. This is a type of legislation which could be of interest to the ship because it is also in its interest that the fuel consumption will be reduced. The technologies which can do that are the unmarked items in table 2. These measures all relate to the SEEMP legislation mentioned in the first part of this paper.

6. Application of the Developed Framework

The framework, which was developed in figure 2, is applied. It will be analysed whether the three mentioned policies of section 3 are stimulating the implementation of the new technologies.

In order to determine the effectiveness of stimulating the implementation of new technologies via the EEDI, first the EEDI has to be examined more in depth. If the EEDI is simplified and the admiralty constantⁱⁱⁱ is inserted into the formula, the EEDI becomes:

$$EEDI = \frac{(C_{CO_2} \cdot sfc - f) \cdot C_{ad} \cdot \Delta^{2/3} \cdot V^2}{dwt} \quad (2)$$

Where C_{ad} is the admiralty constant, Δ the displacement of the ship, DWT the deadweight, C_{CO_2} the CO₂ emission coefficient, sfc the specific fuel consumption, f the reduction factors of green technologies and V the design speed of the ship.

In table 1, an overview was given of the future reduction of the EEDI. In order to do this, the ship owner has several options. It can reduce the fuel consumption by applying the new techniques mentioned in table 2 or it can increase the dwt of the ship (mainly by reducing the lightweight) or it can reduce the speed of the ship. Reducing the EEDI by applying the technologies from table 2 is difficult because the factor “ f ” in formula 2 is unknown or not yet clear for the mentioned technologies^{iv}, while reducing the speed is a much more efficient measure because the EEDI relates to the squared speed of the ship. So, if the effectiveness of the implementation of the new technologies is not clear for the ship owner, the ship owner will be forced to reduce the design speed of the ship. In this respect, the EEDI is not stimulating the implementation of the technologies mentioned in table 2.

With respect to the implementation of the (S)ECA zones in the world, it can be concluded that the pure goal of this policy is to reduce the SO_x emissions in parts of the world (coastal regions). First of all, this will force the ship owner to reduce the emissions in these controlled areas and not outside these areas. It is recognized that the harmful impact of SO_x and PM₁₀ emissions in coastal regions is much higher than on the high seas due to the fact that a lot of people are living in coastal regions. This is thus a measure which is forced upon the ship owner. As a result, he will opt for the easiest (most cost efficient) way to fulfil these criteria. For this type of legislation, we can distinguish among two types of ships: ships that can “escape” the (S)ECA zones (deepsea shipping) and ships that are “trapped” inside the (S)ECA zones (short sea ships, ro/ro ferries, etc.).

For the first group of ships, the most efficient way to deal with the current (S)ECA legislation is to use a bi-fuel system. This means that one uses HFO outside the (S)ECA zones and distillate fuel inside the zone (Greenship, 2012). Also in Yang *et al.* (2012) it was recognized that the most cost-effective way of reducing the SO_x (and PM₁₀) emissions is to use segregated tanks (bi-fuel option).

For the second group of ships (the ones that cannot “escape” the (S)ECA zones), scrubber technology and LNG propulsion are serious alternatives (Greenship, 2012) to fulfil the current day requirements of the (S)ECA-zones besides using low-sulphur fuel.

The introduction of the SEEMP will not contribute to the introduction of new green technologies because this type of legislation only relates to the operation of the ship and not directly to the fuel consumption.

7. Conclusions

Due to the significant increase in attention for the reduction of the marine emission such as CO₂, NO_x, SO_x and PM₁₀, several new legislative actions are taken by the IMO and EU, viz. EEDI and (S)ECA zones. In this paper, different technical solutions are presented to fulfil these new legislation initiatives. Also, a framework was developed to link these new technologies to the legislation.

It was shown that the fuel consumption of a ship is a highly dynamic process which involves the engine, the propeller and the hull of the ship. So, measures to reduce fuel consumption (and thus also emissions) have to take this into account. Just changing or adjusting the engine is not enough!

When the EEDI is applied, it will not stimulate the use of new technologies but it will push the ship designer

into the direction of reducing the design speed (due to the fact that the EEDI relates to squared speed) or to further minimize the light weight of the ship rather than to apply new techniques.

With respect to the (S)ECA zones, it can be concluded that the installation of those zones is by itself very useful. The harmful PM_{10} and SO_x emissions near coastal regions are to be minimized to protect the population from these harmful emissions. However, the implementation of the (S)ECA will not stimulate, in the short run, the implementation of new technologies for ships that will sail in and out of these areas. But it will most likely stimulate the implementation of bi-fuel, hybrid types of propulsion systems which can be switched to (S)ECA mode in the control areas and switched off outside these areas. By using this solution, ship owners can buy some time to further analyse potential solutions to fulfil the necessary requirements of the (S)ECA zones.

The results of the analysis have provided insight into how ship owners might react to the proposed legislation. It can also be used by the policy makers which can see how decisions made at a legislative level will impact the technical aspects of (re)redesigning and operating a ship.

References

- Corbett, J.J. and Koehler, H.W. (2003), Updated emissions from ocean shipping, *Journal of Geophysical Research: Atmospheres* 108(D20).
- Crist, P. (2009), Greenhouse Gas Emissions Reduction Potential from International Shipping, *International Transport Forum*, OECD.
- Cullinane, K. and Bergqvist, R. (2014), Emission control areas and their impact on maritime transport, *Transportation Research Part D: Transport and Environment* (forthcoming).
- DNV (2009), Marpol 73/78 Annex VI Regulations for the Prevention of Air Pollution from Ships, Norway: Det Norske Veritas AS.
- DNV (2012), Mitigating risk: North American emission control area, *Technical e-Newsletter*, May 7, http://www.dnv.com/binaries/DNV_Technical_eNewsletter_North_American_ECA_7May2012_tcm-4516347.pdf.
- Eide, M. S., Endresen, O., Skjong, R., Longva, T. and Alvik, S. (2009), Cost-effectiveness assessment of CO₂ reducing measures in shipping, *Maritime Policy Management* 36 (4): 367- 384.
- European Union (2004, June 25), Directive 2004/26/Ec of The European Parliament and of The Council of 21 April 2004, *Official Journal of the European Union*.
- European Commission (2011), White paper - Roadmap to a Single European Transport Area – Towards a competitive and resource efficient transport system, Brussels.
- European Commission, Emission Reduction Measure, Retrieved 2012, May 22th from Europe Commission: <http://ec.europa.eu/environment/air/transport/pdf/Abatement%20technology.xls>.
- GreenShip (2012), Green ship of the future, vessel emission study: comparison of various abatement technologies to meet emission levels for eca's.
- Harrison, J. (2012), Recent Developments and Continuing Challenges in the Regulation of Greenhouse Gas Emissions from International Shipping, *Edinburgh School of Law Research Paper* 2012:12.
- IMO (2010), Ship Efficiency Measures Could Become Mandatory, *Business & the Environment* 21(12): 8-9.
- IMO (2011 July 15th), Mandatory energy efficiency measures for international shipping adopted at IMO environment meeting, Retrieved 2011, December 12th: www.imo.org/MediaCentre/PressBriefings/Pages/42-mepc-ghg.aspx.
- Jiang, L., Kronbak, J. and Christensen, L. P. (2014), The costs and benefits of sulphur reduction measures: Sulphur scrubbers versus marine gas oil, *Transportation Research Part D: Transport and Environment* (forthcoming).
- Laffineur, L. (2012), Scheepvaartemissies in een Internationale en Europese context: Problemen en oplossingen, Koninklijke Belgische Redersvereniging, Antwerpen.
- Kalli, J., Karvonen, T. and Makkonen, T. (2009), Sulphur content in ships bunker fuel in 2015 – a study on the impacts of the new IMO regulations and transportation costs, *Ministry of Transport and Communications, Publications of the Ministry of Transport and Communications* 31/2009.
- Karim, S. (2010), Implementation of the MARPOL Convention in Developing Countries, *Nordic Journal of International Law* 303-337.

- MAN Diesel A/S - Pedersen, M. F. (2011 September), International: IMO Marine Engine Regulations, Retrieved 2012 18-April from Dieselnet: <http://www.dieselnet.com/standards/inter/imo.php>.
- MEPC 61 (2010), Reduction of GHG emissions from ships: Marginal abatement costs and cost-effectiveness of energy-efficiency measures, IMarEST, London: IMO.
- MEPC 63 (2011), Assessment of IMO Mandated Energy Efficiency Measures for international shipping 62.
- MEPC58/23 Annex 16 (2008), Report of the marine environment protection committee on its fifty-eight session, International Maritime Organization.
- Notteboom, T., Delhay, E. and Vanherle, K. (2010), Analysis of the consequences of low sulphur fuel requirements, ITMMA – Universiteit Antwerpen Transport and Mobility.
- Stapersma, D. (2004), The general propulsion system block diagram: its linear approximation and associated transfer functions, Technical Report KIM-PFS-2004-164, Royal Netherlands Naval College.
- Stevens L. (2012), Sustainable maritime technologies, A closer look of the retrofit market in Flanders, Master thesis Antwerp University.
- Sys, C., Vanellander, T. and Adriaenssens, M. (2012), Worrying clouds? International emission regulations and the consequences for deep sea shipping and European ports, In Maritime transport; 5: Technological, innovation and research / Martinez de Osés, Francesc Xavier, Barcelona 868-887.
- United Nations (1998), Kyoto Protocol, Retrieved 2012 04-April from United Nations Framework Convention on Climate Change: http://unfccc.int/kyoto_protocol/items/2830.php.
- Van Laer, G. (2012, May 9th), Case study Flanders: Retrofitting of sustainable maritime ship technologies (L. Stevens, Interviewer) Vlaams ministerie van welzijn, Brussel, Belgium.
- Wang H. and Lutsey N. (2013), Long-term potential for increased shipping efficiency through the adoption of industry-leading practices, ICCT white paper.
- Yang, Zhang, Caglayan, Jenkinson, Bonsall, Wang, Huang and Yan (2012), Selection of techniques for reducing shipping NOx and SOx emissions, Transportation research part D 17: 478-486.

ⁱ For an overview of the developments: see Harrison (2012).

ⁱⁱ Depending on the outcome of a review, to be concluded in 2018, as to the availability of the required fuel oil, the date may be postponed to January, 1st 2025.

ⁱⁱⁱ $P = C_{ad} \cdot \Delta^{2/3} \cdot V^3$ in which: C_{ad} = admiralty constant [-], Δ = Displacement [tonne], V = Speed [knots] and P = power [kW].

^{iv} Recall also figure 1 where it was shown that the actual fuel consumption is related to the total propulsion system of a ship.

A Duopoly Game for Capacity Expansion in Shipping

Meifeng Luo and Ying Kou

Department of Logistics and Maritime Studies, The Hong Kong Polytechnic University, Hong Kong.

Abstract

The 2008 global financial crisis has created a long-lasting sluggish shipping market with a clear sign of overcapacity. However, huge new orders have been pouring into the market, which further delays the market recovery. To explain such phenomena, a duopoly game-theory model is developed to study the strategic competition of carriers in capacity expansion for given freight rate. We found that capacity expansion is rational at both peak and trough market condition. The benefit of expansion is larger when the competitor also expands, which leads to the Prisoner's Dilemma. A numerical simulation is applied to confirm the analytical results.

Keywords: Capacity expansion, duopoly game, over capacity, Prisoner's Dilemma.

1. Introduction

Since the 2008 global financial crisis, the world shipping market has remained sluggish, and the market freight rate is still showing no sign of recovery. The world layup capacity has reached its record high, and increasingly newer vessels are being demolished. As shown from the index of drybulk market trends from 1996-2014 from Clarkson Shipping Intelligence Networks (Figure 1), the average earnings decreased to an unprecedentedly low level after 2008, while the orderbook volume remained at a very high level, and the fleet capacity kept increasing. The is not only happens to the drybulk sector, but also in the liner market. From January to October, 2013, the total new orders for container vessels amounted to US \$19.2 billion with total capacity of 1.7 million TEU, which is about four times as much as that of the previous year (Clarkson PLC, 2014).

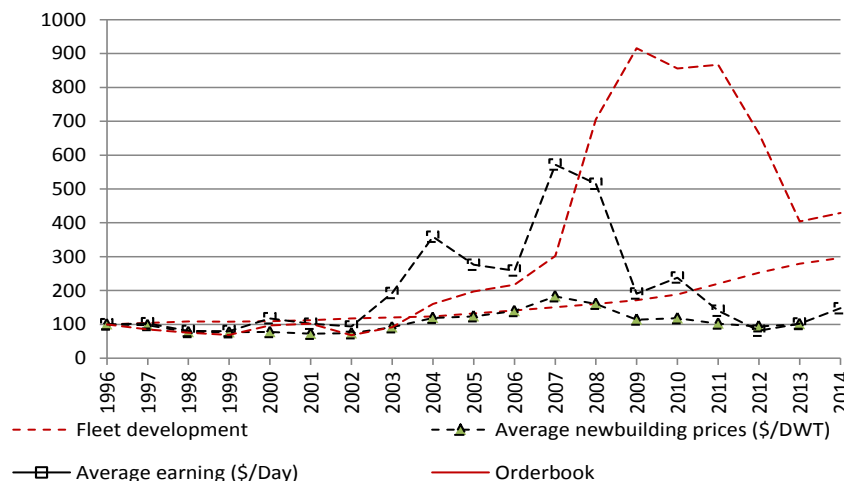


Fig 1. Drybulk market development from 1996 to 2014 (1996=100)

Thus, what are the motivations for these new orders facing an already over-crowded market? Shipping companies are competing in a globalized market where each has very little influence on the market freight rate, and the market share of a company is measured by its carrying capacity, which are durable assets. To outperform its peers and to be successful in the market, the company has to select a best time for ship investment, so that its fleet can grow and its market share can expand. The new orders can be driven by high market demand, as well as by the expansion decision of the others, and by the low building prices when the market freight rate is low. This expansion behavior in the shipping industry is optimal from the perspective of

each individual shipping company, but can result in prolonged overcapacity in the market, which is destructive to the recovery of the market, and in return, reduces the profitability of each company in the market.

A review of the existing literature, as shown in the next section, reveals that little attention has been paid on modeling the strategic ship investment decisions. From the individual company perspective, neglecting the strategic behavior of competitors may result in a wrong estimation on the possible benefit of expansion. Unlike price and quantity competitions, the market share competition in the shipping industry has more significant long-term impacts on the market and the whole industry.

This study develops a game theoretic model to analyze the strategic behavior in ship investment. We assume that two shipping companies compete for market share by capacity expansion, as the market share in shipping is determined by its carrying capacity (Luo et al., 2014). For a given the market freight rate and quantity demanded, the two companies determine whether to expand according to the incremental profit of expansion. For given capacity, each company maximizes its profit by setting an optimal speed within a possible range.

We identified the condition for dominate strategy, and tested the possibility of Prisoner's Dilemma if expansion is a dominating strategy. A comparative static analysis on the dominant strategy was conducted with respect to the bunker price and freight rate. Theoretical results suggest that expansion is possible at both very high freight rate and very low freight rate, regardless the strategy of the competitor. If expansion results in speed decrease, the strategic investment will lead to a Prisoners' Dilemma. A numerical simulation is provided to demonstrate the analytical results.

This study reveals that capacity expansion is a rational decision for the individual shipping company, not just when the market is good, but also at sluggish market. This explains the current heavy new orders in the shipping industry even though the market shows no sign of recovery. As a shipping company, a better strategy is to make a long-term plan recognizing this inherent nature in the shipping market. For the public agency, this can be a chance to upgrade the energy efficiency and cost effectiveness of the world shipping fleet.

After a review of the existing literature in ship investment, we first present the theoretical model and results on the ship investment game. To demonstrate the theoretical results, we also provide the result from numerical simulation, using the current data in bulk shipping as an example. Finally, a summary and conclusion is provided.

2. Literature Review

Ship investment strategy is usually analyzed using ship financing methods or econometric-based methods. For example Bendall (2003), Bendall and Stent (2005) and Dikos (2008) used Real Option Analysis (ROA) to study ship investment, and found that companies value flexibility when making investment decisions. For the econometric-based approach, Alizadeh and Nomikos (2007) compared the ratio of the second-hand ship price and freight rate with its long-run average. If this ratio is larger, it indicates that ship prices are too high, and thus expected to fall. Similarly, Merikas et al. (2008) used price ratio between the second-hand and new-building ship price as a decision-making tool to decide whether to buy old or to order new ships. Fan and Luo (2013) applied a binary logit model and a nested logit model to examine the ship investment and choice decision. They found different capacity expansion behaviors between large companies and smaller ones, as well as preference orders for new orders and second-hand ships, as well as ship size categories.

Another direction of ship investment emphasized the determinants of ship investment. For example, Marlow (1991a; 1991b; 1991c) studied the fiscal and financial ship investment incentives, as well as their effectiveness in the UK, and found that incentives have not affected the size of the UK fleet. Thanopoulou (2002) discussed ship investment from the viewpoints of operational constraints, risk and investment attitudes. She concluded that the lack of constraints in bulk shipping increases its speculative opportunities and enhances its competitiveness.

However, little effort has been made to analyze the strategic ship investment behavior in a competitive environment. Neglecting competitors' strategic response may weaken the competitive position of the shipping

company. On the other hand, recognizing such strategic behavior and anticipating the possible consequences can help both shipping companies to make informed decision.

Game theory is widely applied in analyzing the strategic behavior of market players in transportation research, such as in the airline hub competition by Hansen (1990), liner shipping alliance (Sjostrom, 1989; Pirrong, 1992; Telser, 1996; Abito, 2005; Fusillo, 2003) and port capacity competition (Luo et al., 2012; Ishii et al., 2013). Compared with existing studies, we model the strategic behavior in ship investment in the environment of market share competition, which can have a long lasting effect on the shipping market. Our aim is to point out that it is the inherent nature of market share competition that resulted in the recurring overcapacity in shipping supply, and in return, it will affect the performance of all shipping companies – a stereotype Prisoner Dilemma.

3. The Model

3.1 Basic game model

This section sets up the basic model where shipping companies maximize their respective profits using shipping speed. For simplicity, we assume that there are two shipping companies carrying cargoes between port A and port B with round-trip distance l nautical miles. If the speed is s knots (nautical miles/hour) and the total working time in a year is γ hours, the number of round-trips that a ship can make in a year is $n=\gamma s/l$.

The costs of a ship are assumed to include two parts: voyage cost VC and operating cost OC . The voyage cost mainly consists of fuel cost. From Ronen (1982), fuel consumption per hour can be written as $FC=\lambda s^\alpha$ (α usually equals to 3), where s ($s_{\min} \leq s \leq s_{\max}$) is the actual vessel speed and λ is the fuel efficiency. A larger λ indicates lower energy efficiency. Thus, the total cost per year can be written as $k_i(\gamma VC + OC)$.

To analyze the ship investment decision, we use a binary variable δ_i to describe company i 's decision to order new ships - 0 for 'not order' (N) and 1 for 'order' (Y). Assume that two shipping companies have identical initial number of ships k . If the new orders includes Δk number of ships, the number of ships for company i with investment decision δ_i will be $k+\delta_i\Delta k$, and the total capacity of the two companies is $2k+(\delta_1+\delta_2)\Delta k$. If the total demand for shipping service is Q for every round-trip, shipping companies are price takers and market freight rate is F , the problem facing company i can be written as:

$$\max_s \pi_i(\delta_1, \delta_2) = \frac{F\gamma s(k+\delta_i\Delta k)Q}{l(2k+(\delta_1+\delta_2)\Delta k)} - (k + \delta_i\Delta k)\gamma\lambda P_b s^\alpha - (k + \delta_i\Delta k)OC - \delta_i\Delta k rP \quad (1)$$

s. t. $s_{\min} \leq s \leq s_{\max}$,

where r is the interest rate and P is the new building ship price. The last item is the annualized capital cost for investing Δk number of ships. This profit maximization under unequal constraints can be solved using the Kuhn-Tucker method. The optimal speed can be written as:

$$s^* = \begin{cases} s_{\max} & (s_{\max} < v_{\delta_1\delta_2}) \\ v_{\delta_1\delta_2} & (s_{\min} \leq v_{\delta_1\delta_2} \leq s_{\max}), \\ s_{\min} & (s_{\min} > v_{\delta_1\delta_2}) \end{cases} \quad (2)$$

where $v_{\delta_1\delta_2} = (FQ/[\alpha\lambda P_b(2k + (\delta_1 + \delta_2)\Delta k)])^{\frac{1}{\alpha-1}}$. Clearly, $v_{\delta_1\delta_2}$ follows $v_{11} < v_{10} = v_{01} < v_{00}$, i.e., the more the capacity invested, the lower the speed. Within the range $[s_{\min}, s_{\max}]$, the optimal speed increases with freight rate and average demand per ship, and decreases with energy efficiency, the shipping distance and bunker price. Substituting the s^* into the profit function, the maximum profit function can be written as:

$$\pi_i(\delta_1, \delta_2)^* = \begin{cases} (k + \delta_i\Delta k) \left[\frac{G}{(2k+(\delta_1+\delta_2)\Delta k)^{\frac{\alpha}{\alpha-1}}} - OC \right] - \delta_i\Delta k rP & \text{if } s_{\min} \leq s^* \leq s_{\max} \\ (k + \delta_i\Delta k) \left[\frac{F\gamma Q s_e}{l(2k+(\delta_1+\delta_2)\Delta k)} - \lambda P_b s_e^\alpha - OC \right] - \delta_i\Delta k rP & \text{otherwise} \end{cases} \quad (3)$$

where $G=(\alpha-1)\gamma/(\lambda P_b)^{\frac{1}{\alpha-1}}(FQ/(\alpha l))^{\frac{\alpha}{\alpha-1}}$ and $s_e=s_{\max}$ or s_{\min} .

3.2 Analyzing dominant strategy using normal form game

We first construct the incremental benefit of investment for one company regardless the strategy of the other, i.e., $\Delta\pi_i(\delta_j)=\pi_i^*(1,\delta_j)-\pi_i^*(0,\delta_j)$ [$i,j=(1, 2)$ and $i\neq j$]. Since it depends on the possible speed after investment, we first list the possible changes (Figure 2.), then discuss the incremental benefits for these 5 paths.

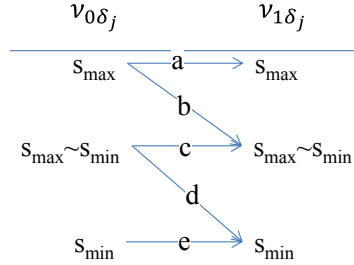


Fig 2. Optimal speed change after ship investment

The extreme case paths a and e

Paths a and e in Figure 2 represent the situation that s^* equals to the boundary speed (s_{\max} or s_{\min}) regardless of the investment decisions by any shipping company. The profit change equals to

$$\Delta\pi_i(\delta_j)^{ext} = \Delta k \left[\frac{F\gamma Q s_e}{2(2k+\Delta k)l} - \gamma \lambda P_b s_e^\alpha - (OC + rP) \right], \quad (3)$$

This incremental profit is independent from δ_j . From this, we can see that in extreme market conditions, the decision of capacity expansion is determined by the freight market, bunker price and ship operation costs. It is irrelevant to the capacity expansion decision of the competitor. If all the ships in the company have to sail at full speed after investment, the demand must be very high, and the response of the competitors should not be a concern. When the speed is running at its minimum, the only reason for expansion is that the bunker price and capital cost are very low so that the incremental revenue can cover the additional costs.

The normal case path c

We define path c in Figure 2 as the normal case where ships sail at normal speed ($s_{\min} \leq v \leq s_{\max}$) after investment. The incremental benefit, $\Delta\pi_i(\delta_j)^c$ can be written as:

$$\Delta\pi_i(\delta_j)^c = G * N(\delta_j) - \Delta k(OC + rP), \quad (4)$$

where $N(\delta_j) = \frac{k+\Delta k}{(2k+(1+\delta_j)\Delta k)^{\frac{\alpha}{\alpha-1}}} - \frac{k}{(2k+\delta_j\Delta k)^{\frac{\alpha}{\alpha-1}}}$. From Appendix A.1, it is clear that $N(1) > N(0)$. Therefore, $\Delta\pi_i(1)^c > \Delta\pi_i(0)^c$, the incremental benefit is larger if the competitor also expands.

The transfer case paths b and d

Paths b and d are the two cases where the speed transfers between the boundary speed and normal speed. Considering the differences between only one expands and both expand capacity, two cases exist for the payoff matrix for each path, which are summarized in Table 1.

Table 1. Payoff matrix for two transfer paths

Path b1: $\delta_i=\delta_j=1, s^*=v_{11}$; otherwise $s^*=s_{\max}$				Path b2: $\delta_i=\delta_j=0, s^*=s_{\max}$; otherwise $s^*=v_{\delta j1}$			
N		Y		N		Y	
N	$\pi_1(0,0,s_{\max}), \pi_2(0,0,s_{\max})$	$\pi_1(0,1,s_{\max}), \pi_2(0,1,s_{\max})$		N	$\pi_1(0,0,s_{\max}), \pi_2(0,0,s_{\max})$	$\pi_1(0,1,v_{01}), \pi_2(0,1,v_{01})$	
Y	$\pi_1(1,0,s_{\max}), \pi_2(1,0,s_{\max})$	$\pi_1(1,1,v_{11}), \pi_2(1,1,v_{11})$		Y	$\pi_1(1,0,v_{10}), \pi_2(1,0,v_{10})$	$\pi_1(1,1,v_{11}), \pi_2(1,1,v_{11})$	
$\Delta\pi_i(0)^{b1}$		$\Delta\pi_i(1)^{b1}$		$\Delta\pi_i(0)^{b2}$		$\Delta\pi_i(1)^{b2}$	
Path d1: $\delta_i=\delta_j=1, s^*=s_{\min}$; otherwise $s^*=v_{0\delta j}$				Path d2: $\delta_i=\delta_j=0, s^*=v_{00}$; otherwise $s^*=s_{\min}$			
N		Y		N		Y	
N	$\pi_1(0,0,v_{00}), \pi_2(0,0,v_{00})$	$\pi_1(0,1,v_{01}), \pi_2(0,1,v_{01})$		N	$\pi_1(0,0,v_{00}), \pi_2(0,0,v_{00})$	$\pi_1(0,1,s_{\min}), \pi_2(0,1,s_{\min})$	
Y	$\pi_1(1,0,v_{10}), \pi_2(1,0,v_{10})$	$\pi_1(1,1,s_{\min}), \pi_2(1,1,s_{\min})$		Y	$\pi_1(1,0,s_{\min}), \pi_2(1,0,s_{\min})$	$\pi_1(1,1,s_{\min}), \pi_2(1,1,s_{\min})$	
$\Delta\pi_i(0)^{d1}$		$\Delta\pi_i(1)^{d1}$		$\Delta\pi_i(0)^{d2}$		$\Delta\pi_i(1)^{d2}$	

The incremental benefits $(\Delta\pi_i(0)^{b1})$ for $b1$ and $\Delta\pi_i(1)^{d2}$ for $d2$ are the same as the extreme case, as the ships remain at the boundary speed after expansion. $\Delta\pi_i(1)^{b2}$ and $\Delta\pi_i(0)^{d1}$ are the same as the normal case because they do not involve boundary speed. For the other cases, the incremental profit of expansion can be written as:

$$\begin{cases} \Delta\pi_i(\delta_j)^b = G * A(\delta_j) - \frac{F\gamma Q S_{\max} k}{l(2k+\delta_j\Delta k)} + k\gamma\lambda P_b S_{\max}^\alpha - \Delta k(OC + rP) \\ \Delta\pi_i(\delta_j)^d = -G * B(\delta_j) + \frac{F\gamma Q S_{\min}(k+\Delta k)}{l(2k+(1+\delta_j)\Delta k)} - (k + \Delta k)\gamma\lambda P_b S_{\min}^\alpha - \Delta k(OC + rP) \end{cases} \quad (5)$$

where $A(\delta_j) = \frac{k+\Delta k}{(2k+(1+\delta_j)\Delta k)^{\frac{\alpha}{\alpha-1}}}$, $B(\delta_j) = \frac{k}{(2k+\delta_j\Delta k)^{\frac{\alpha}{\alpha-1}}}$. Clearly $A(\delta_j) - B(\delta_j) = N(\delta_j)$.

For cases $b1$ and $d2$, it is straight forward that $\Delta\pi_i(0)^{b1} < \Delta\pi_i(1)^{b1}$ and $\Delta\pi_i(0)^{d2} < \Delta\pi_i(1)^{d2}$ from Table 1, because the constrained profit is always less than unconstrained one. For $b2$ and $d1$, by comparing with path c , it is clear that:

$$\Delta\pi_i(1)^{b2} = \Delta\pi_i(1)^c \text{ and } \Delta\pi_i(0)^{b2} > \Delta\pi_i(0)^c \quad (6a)$$

$$\Delta\pi_i(0)^{d1} = \Delta\pi_i(0)^c \text{ and } \Delta\pi_i(1)^{d1} < \Delta\pi_i(1)^c. \quad (6b)$$

Appendix B shows that $\Delta\pi_i(0)^{b2} < \Delta\pi_i(1)^{b2}$ and $\Delta\pi_i(0)^{d1} < \Delta\pi_i(1)^{d1}$ for both cases. Combining the result from the normal case, it is clear that when the shipping speed is decreasing after expansion, the incremental benefit of capacity expansion is larger when the competitor also expands.

From this duopoly game, it is clear that when the players are competing for market share, the individual optimal behavior may lead to overcapacity in the shipping market. Although in a good market, capacity expansion does not lead to overcapacity. When the demand is low, the low ship price can also lead to excessive capacity expansion, which may have significant long-term impacts on the shipping market. In a normal scenario, the strategic capacity expansion will lead to overcapacity because the incremental benefit is larger if both expand.

3.3 Possibility of Prisoners' Dilemma

For symmetric game, if $\pi_1^*(1,0) > \pi_1^*(0,0) > \pi_1^*(1,1) > \pi_1^*(0,1)$, the game is a typical Prisoners' Dilemma. In our model, the extreme case will not fall into this situation because there is no strategic competition. However, it is possible in the other cases when capacity development is optimal, i.e., when $\pi_1^*(1,0) > \pi_1^*(0,0)$ and $\pi_1^*(1,1) > \pi_1^*(0,1)$. In this case, it is only necessary to check whether $\pi_1^*(0,0) > \pi_1^*(1,1)$.

From Eq. 3 and Table 1, the profit difference between no one investing and both investing for normal case c and transfer case b and d can be written as:

$$\pi^c(0,0) - \pi^c(1,1) = \frac{G}{2^{\frac{\alpha}{\alpha-1}}} \left[\frac{1}{k^{\frac{\alpha}{\alpha-1}}} - \frac{1}{(k+\Delta k)^{\frac{\alpha}{\alpha-1}}} \right] + \Delta k(OC + rP) \quad (7a)$$

$$\pi^b(0,0) - \pi^b(1,1) = \frac{F\gamma Q S_{\max}}{2l} - k\gamma\lambda P_b S_{\max}^\alpha - G * A(1) + \Delta k(OC + rP) \quad (7b)$$

$$\pi^d(0,0) - \pi^d(1,1) = G * B(0) - \frac{F\gamma Q S_{\min}}{2l} + (k + \Delta k)\gamma\lambda P_b S_{\min}^\alpha + \Delta k(OC + rP). \quad (7c)$$

It is straight forward to see that $\pi^c(0,0) > \pi^c(1,1)$. Appendix C shows that $\pi^b(0,0) > \pi^b(1,1)$ and $\pi^d(0,0) > \pi^d(1,1)$.

Having explored the possibility of overcapacity in the duopoly market when the players are competing for market share, and the existence of Prisoner Dilemma, we use comparative statics to analyze how the incremental benefit $\Delta\pi_i(\delta_j)$ changes with market factors such as bunker price or freight rate.

3.4 Comparative static analysis

Since it is straight forward to find the impacts of the price of new ships and the mortgage rate, this comparative static analysis is focused on the impact of market parameters including bunker price P_b and freight rate F .

First, differentiate $\Delta\pi_i(\delta_j)$ in three cases *w.r.t.* bunker price P_b :

$$\frac{\partial \Delta \pi_i(\delta_j)^{ext}}{\partial P_b} = -\Delta k \gamma \lambda s_e^{\alpha} < 0 \quad (8a)$$

$$\frac{\partial \Delta \pi_i(\delta_j)^c}{\partial P_b} = G_{P_b} * N(\delta_j) < 0 \quad (8b)$$

$$\frac{\partial \Delta \pi_i(\delta_j)^{trs}}{\partial P_b} = \begin{cases} \frac{\partial \Delta \pi_i(\delta_j)^b}{\partial P_b} = G_{P_b} * A(\delta_j) + k \gamma \lambda s_{\max}^{\alpha} \\ \frac{\partial \Delta \pi_i(\delta_j)^d}{\partial P_b} = -G_{P_b} * B(\delta_j) - (k + \Delta k) \gamma \lambda s_{\min}^{\alpha}, \end{cases} \quad (8c)$$

where $G_{P_b} = \partial G / \partial P_b = -\left(\gamma / \lambda^{\frac{1}{\alpha-1}}\right) (FQ / (\alpha \lambda P_b))^{\frac{\alpha}{\alpha-1}} < 0$ and $N(\delta_j) > 0$ as shown in Appendix A.2. The signs for Eq. 8a and 8b are obvious. Appendix D.1 shows that Eq. 8c is also negative. Therefore, without taking into account that new ships can be more energy efficient, a higher bunker price will increase the voyage cost, which can reduce the incentive for making new order.

Differentiating $\Delta \pi_i(\delta_j)$ w.r.t. the freight rate F :

$$\frac{\partial \Delta \pi_i(\delta_j)^{ext}}{\partial F} = \frac{\gamma Q s_e}{l} \frac{\Delta k}{2(2k + \Delta k)} - \Delta k r P_F \quad (9a)$$

$$\frac{\partial \Delta \pi_i(\delta_j)^c}{\partial F} = G_F * N(\delta_j) - \Delta k r P_F \quad (9b)$$

$$\frac{\partial \Delta \pi_i(\delta_j)^{trs}}{\partial F} = \begin{cases} \frac{\partial \Delta \pi_i(\delta_j)^b}{\partial P_b} = G_F * A(\delta_j) - \frac{\gamma Q}{l} \frac{k s_{\max}}{(2k + \delta_j \Delta k)} - \Delta k r P_F \\ \frac{\partial \Delta \pi_i(\delta_j)^d}{\partial P_b} = -G_F * B(\delta_j) + \frac{\gamma Q}{l} \frac{(k + \Delta k) s_{\min}}{(2k + (1 + \delta_j) \Delta k)} - \Delta k r P_F, \end{cases} \quad (9c)$$

where $G_F = \partial G / \partial F = \gamma (F / (\alpha \lambda P_b))^{\frac{1}{\alpha-1}} (Q / l)^{\frac{\alpha}{\alpha-1}} > 0$ and P_F is the sensitivity of new-building ship price to the freight rate change.

First, in Eq. 9, if we ignore the change of new-building price due to freight rate (i.e., $-\Delta k r P_F = 0$), then $\partial \Delta \pi_i(\delta_j) / \partial F > 0$ for all three cases (The proof for Eq. 9c is shown in Appendix D.2). This implies that if freight rate does affect new-building prices, higher freight rate always motivates making new order.

However, many existing studies found that new-building ship prices are positively correlated with the freight rate (Hawdon, 1978; Haralambides et al., 2004; Luo et al., 2009). For Eq. 9a, if $\gamma Q s_e / (2l(2k + \Delta k)) > r P_F$, the revenue increases faster than the annualized capital cost, then $\partial \Delta \pi_i(\delta_j)^{ext} / \partial F > 0$: a higher freight rate increases the benefit of expansion; otherwise, if ship price decreases faster than the freight rate, then $\partial \Delta \pi_i(\delta_j)^{ext} / \partial F < 0$: a low freight rate increases the benefit of expansion. From this, we can see that the motivation for investing in new ships not only comes from high freight rate, but also when the freight rate is low.

For Eq. 9b, if $F > H \left(\Delta k / N(\delta_j) \right)^{\alpha-1}$ where $H = (\alpha \lambda P_b) (r P_F / \gamma)^{\alpha-1} (l / Q)^{\alpha}$, then $\partial \Delta \pi_i(\delta_j)^c / \partial F > 0$, $\Delta \pi_i(\delta_j)^c$ increases with F . It is better for ordering new ships when the freight rate is high enough. Otherwise, $\frac{\partial \Delta \pi_i(\delta_j)^c}{\partial F} < 0$, $\Delta \pi_i(\delta_j)^c$ increases when F is decreasing.

For Eq. 9c, Appendix D.2 proves that if $\partial \Delta \pi_i(\delta_j)^c / \partial F$ is positive, $\partial \Delta \pi_i(\delta_j)^{trs} / \partial F$ will also be positive. On the other hand, if $F < H (2(2k + \Delta k))^{\alpha-1} (2k + \delta_j \Delta k)$, then $\partial \Delta \pi_i(\delta_j)^{trs} / \partial F < 0$. These results show that expansion is a good strategy at both high and low freight rate.

The comparative static analysis shows that capacity expansion in shipping is a good strategy when the bunker price is low or at both peak and low market. These results explain the high increase in new orders before 2008 when the ship price was high, as well as recently when the average earnings are still very low but the new-

building price is also very low.

4. Numerical Experiments

The numerical analysis will be presented in this section. Each company is assumed to have 10 identical Panamax bulk carriers (60000-80000 dwt). The round-trip distance is $l=20,000$ nm, and days at sea is 250 days (Gratsos et al., 2010), or $\gamma=6000$ hours. Operating cost is 1.8×10^6 \$/year (Stopford, 2009, p.224), and fuel efficiency is $\lambda=0.0012$ (Chang & Chang, 2013). The range of speed is around 12-15 knots (Alizadeh & Nomikos, 2009), and $\pm 15\%$ of the design speed 14.5 knots (Stopford, 2009, p.593), which indicates that speed is around 12.3-16.7 knots. We assume that $s_{\min}=12$ knots and $s_{\max}=17$ knots, and that financing rate is $r=2\%$.

Assume the market is changing from a very good market ($F=\$100/\text{tonne}$ to only $\$10/\text{ton}$), and the quantity demanded for a round trip also decreases from 2.5 to 0.25 million tonnes. We simulate the change in shipping speed for all possible strategy combinations, their profits, as well as their incremental profits with the change of market conditions. Also, we assume that $\Delta k=2$.

Figure 3 is the simulation result for the speed change at different market conditions. It shows that, if the market is really good (on the left side), the three lines overlay with each other, indicating expansion cannot decrease the shipping speed. Also, the speed at when no one invests (v_{00}) is larger than only one invests (v_{01} or v_{10}), which is again larger than both invest (v_{11}). If the market condition is really bad, they will all collapse to the minimum speed.

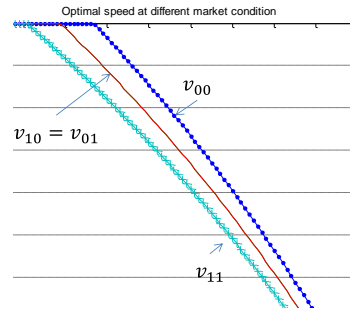


Fig 3. Optimal speed change with the decrease of market freight rate

Second, we also simulate the incremental benefit of capacity expansion for all possible strategies of the competitor, as shown in Figure 4. Firstly, the two lines decrease with the freight rate, indicating the incremental profit decreases when the market becomes worse. Secondly, when the market is really good (on the left side) or really bad (on the right side), the two lines overlap each other. In the middle, $\Delta\pi_i(1)$ is higher than $\Delta\pi_i(0)$, meaning that the incremental profit is higher if the other also invests, which also confirms the theoretical result. If bottom fishing (order when the ship price is very low) is not considered, further decrease in the freight rate can drive the incremental benefit below zero. This indicates possible low orders in a sluggish market.

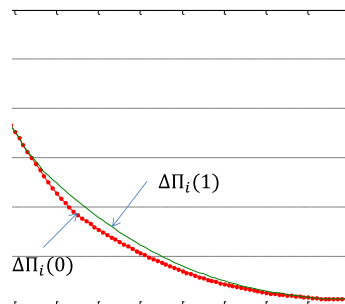


Fig 4. Change of incremental profits with the possible strategies of the competitor

Finally, to check the possibility for Prisoner's Dilemma in capacity expansion, we plot the profit of one player for each possible strategy of the competitor, which is shown in Figure 5. It has four panels. Panel A shows the overall trends with the market condition becoming worse. Panel B, C and D are provided to see the detailed relationship for different ranges of the market condition. In each panel, the lines with dot markers are the profits when the other does not expand ($\pi(1,0)$ and $\pi(0,0)$), and lines with cross markers are the profits when the other expands its capacity ($\pi(1,1)$ and $\pi(0,1)$). The solid line indicates the profit from expansion, and the broken line is the profit from no expansion.

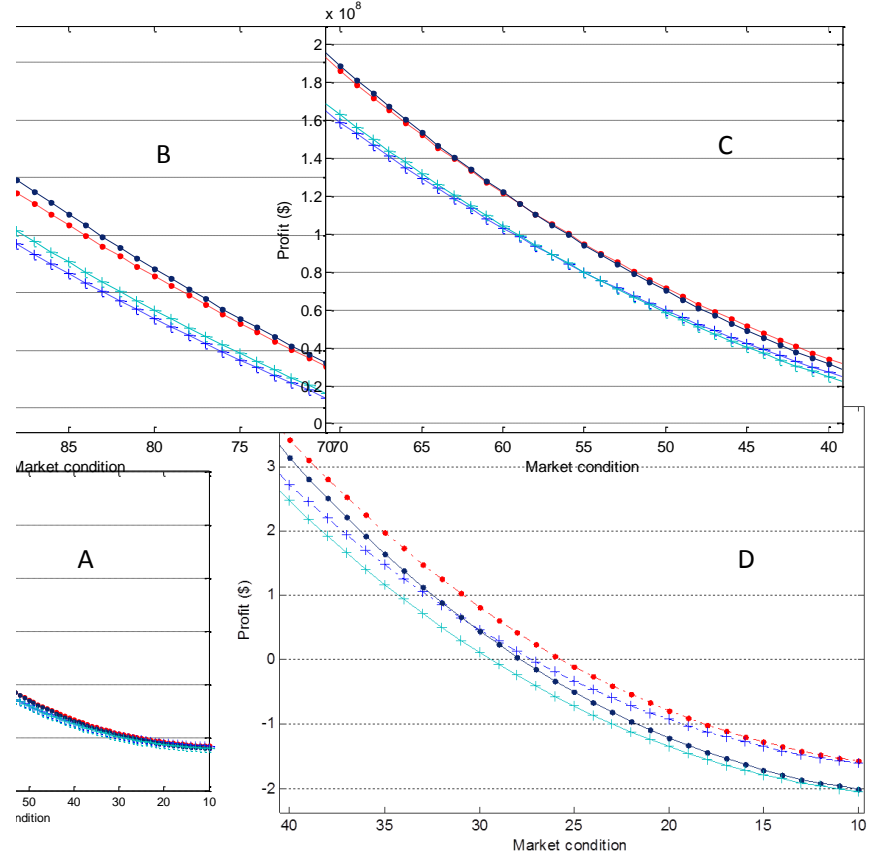


Fig 5. The profit change for the game model when the market slows down

Panel B shows the profit relationship when the market is good. It can be seen that the first group is larger than the second one, indicating that profit is higher when the competitor does not order. However, within each group, the solid line is higher than the broken line, indicating that expansion is a better strategy for whatever strategy the competitor takes. Also, $\pi(0,0)$ is always larger than $\pi(1,1)$.

In panel C, the market freight rate is between 70-40. It shows the incremental benefits of expansion decrease when the market condition becomes worse. However, the red line ($\pi(0,0)$) is always at the top. This indicates as long as the capacity expansion is profitable, Prisoner's Dilemma is persistent.

Panel D shows the situation when the market is at its worse condition. The expansion will result in a negative profit. If any player selects to expand, the other will also follow, as (N,Y) is not a possible equilibrium. In this case, not only will Prisoner's Dilemma occur, but also the excessive capacity will put the industry in a very bad situation.

5. Conclusions

This paper develops a duopoly game theory model to analyze the strategic behavior in ship investment in a competitive environment. We model two shipping companies, under a given market freight rate, that compete for market share by expanding their respective fleet. We analyze the equilibrium strategy in a normal form

game where the payoff of one player for each strategy (invest or not) depends on the strategy of its competitor. For each shipping company, we compare the incremental profit between investing in new ships and not investing for each given strategy of the competitor, and identify the possible Nash equilibriums in the duopoly market. Results show that capacity expansion in shipping can happen in all market situations. However, the investment behavior when the market is at its bottom has the most detrimental effect on the shipping industry. We also find that Prisoner's Dilemma exists whenever the capacity increase is beneficial to the individual company. This reveals the nature of the capacity investment in shipping: even in a duopoly market, the strategic behavior of each individual company in capacity expansion can lead to mutually destructive effects.

A comparative static analysis of the incremental profit was carried out for the changes in bunker price and freight rate. Results suggest that investment more likely occurs at a low bunker price. More importantly, investment is profitable in both a good or bad market. This theoretical result explains the heavy new orders when the freight rate is still at a very low level after the financial crisis. The low new-building price and the market share are the main driving force for such behavior. In addition, the possibility of Prisoner's Dilemma increases with the increase of freight rate.

In summary, this paper is the first attempt in the literature that addresses the strategic behavior in ship investment using a duopoly game theory model. The results can help shipowners understand ship investment behavior, to enable them to make better decisions regarding fleet expansion. Theoretically, it is a rational decision for a shipping company to make new orders even when the freight rate is low. However, such optimal decision at individual level can create over capacity in shipping supply, which may lead to the early retirement of the old or inefficient vessels. From the public point of view, it can help to improve the efficiency of the world shipping fleet, and phase out un-productive ships. For example, it is a good time to put the new ship-building technologies into new ships to replace the old, inefficient ships for fuel and emission reduction. This can help to achieve the goal of reducing CO₂ emission from international shipping.

Acknowledgement

This study is supported by The Hong Kong Polytechnic University Research Grant: A-PL66.

References

- Abito, J.M.M. (2005), *Overtonnaging in liner shipping cooperative agreements: a non-cooperative game theory approach*, Singapore.
- Alizadeh, A.H. and Nomikos, N.K. (2007), Investment time and trading strategies in the sale and purchase market for ships, *Transportation Research Part B* 41(1):126-43.
- Alizadeh, A.H. and Nomikos, N.K. (2009), *Shipping Derivatives and Risk Management*, Palgrave Macmillan.
- Bendall, H. (2003), Investment strategies in market uncertainty, *Maritime Policy and Management* 30(4): 293-303.
- Bendall, H.B. and Stent, A.F. (2005), Ship investment under uncertainty: Valuing a real option on the maximum of several strategies, *Maritime Economics & Logistics* 7(1):19-35.
- Chang, C.-C. and Chang, C.H. (2013), Energy conservation for international dry bulk carriers via vessel speed reduction. *Energy Policy* 59(Aug.): 710-15.
- Clarkson PLC (2014), *Clarkson Shipping Intelligence Network*. [Online] Available at: www.clarkson.net [Accessed 10 February 2014].
- Dikos, G. (2008), Real options econometrics for aggregate tanker investment decisions, *International Journal of Ocean Systems Management* 1(1): 31-44.
- Fan, L. and Luo, M. (2013), Analyzing ship investment behaviour in liner shipping, *Maritime Policy and Management* 40(6): 511-33.
- Fusillo, M. (2003), Excess capacity and entry deterrence: the case of ocean liner shipping markets, *Maritime Economics and Logistics* 5(2): 100-15.
- Gratsos, G.A., Psaraftis, H.N. and Zachariadis, P. (2010), Life-cycle CO₂ emissions of bulk carriers: A comparative study, *International Journal of Maritime Engineering* 152(Part A3):119-34.
- Hansen, M. (1990), Airline competition in a hub-dominated environment: an application of noncooperative

- game theory, *Transportation Research Part B* 24(1): 27-43.
- Haralambides, H.E., Tsolakis, S.D. and Cridland, C. (2004), Econometric modelling of newbuilding and secondhand ship prices, *Research in Transportation Economics* 12(1): 65-105.
- Hawdon, D. (1978), Tanker freight rates in the short and long run, *Applied Economics* 10(3): 203-17.
- Ishii, M., Lee, P.T. W., Tezuka, K. and Chang, Y.T. (2013), A game theoretical analysis of port competition, *Transportation Research Part E* 49(1): 92-106.
- Luo, M., Fan, L. and Liu, L. (2009), An econometric analysis for container shipping market, *Maritime Policy and Management* 36(6): 507-23.
- Luo, , Fan, L. and Wilson, W.W. (2014), Firm growth and market concentration in liner shipping, *Journal of Transport Economics and Policy* 48(1):171-87.
- Luo, M., Liu, L. and Gao, F. (2012), Post-entry container port capacity expansion, *Transportation Research Part B* 46(1): 120-38.
- Marlow, P.B. (1991a), Shipping and investment incentives: a trilogy Part 1, Investment inventives for industry, *Maritime Policy & Management* 18(2):123-38.
- Marlow, P.B. (1991b), Shipping and investment incentives: a trilogy Part 2, Investment inventives for shipping, *Maritime Policy & Management* 18(3): 201-16.
- Marlow, P.B. (1991c), Shipping and investment incentives: a trilogy Part 3, The effectiveness of investment incentives for shipping - the UK experience 1950-1987, *Maritime Policy and Management* 18(4): 283-311.
- Merikas, A.G., Merika, A.A. and Koutroubousis, G. (2008), Modelling the investment decision of the entrepreneur in the tanker sector: choosing between a second-hand vessel and a newly built one, *Maritime Policy & Management* 35(5): 433-47.
- Pirrong, S.C. (1992), An application of core theory to the analysis of ocean shipping market, *Journal of Law and Economics* 35(1): 89-131.
- Ronen, D. (1982), The effect of oil price on the optimal speed of ships, *The Journal of the Operational Research Society* 33(11): 1035-40.
- Sjostrom, W. (1989), Collusion in Ocean Shipping: a test of monopoly and empty core models, *Journal of Political Economy* 97(5): 1160-79.
- Stopford, M. (2009), *Maritime Economics* (3rd edition), USA Routledge.
- Telser, L.G. (1996), Competition and the core, *Journal of Political Economy* 104(1): 85-107.
- Thanopoulou, H. (2002), Investing in ships: an essay on constraints, risk and attitudes, In Grammenos, C. *The Handbook of Maritime Economics and Business*, London LLP.

Appendix A. Properties of the term $N(\delta_j)$

A.1 Comparison between $N(1)$ and $N(0)$

In order to compare $N(1)$ and $N(0)$, we establish a difference between them:

$$N(1) - N(0) = \frac{k+\Delta k}{(2k+2\Delta k)^{\frac{\alpha}{\alpha-1}}} - \frac{2k+\Delta k}{(2k+\Delta k)^{\frac{\alpha}{\alpha-1}}} + \frac{k}{(2k)^{\frac{\alpha}{\alpha-1}}}. \quad (\text{A.1. 1})$$

Eq. A.1.1 equals to when $\alpha=3$:

$$\frac{1}{2} \left[\left(\frac{1}{\sqrt{2k}} - \frac{1}{\sqrt{2k+\Delta k}} \right) - \left(\frac{1}{\sqrt{2k+\Delta k}} - \frac{1}{\sqrt{2k+2\Delta k}} \right) \right]. \quad (\text{A.1. 2})$$

Let $f(x) = \frac{1}{\sqrt{x}} = x^{-0.5}$ and substitute $f(x)$ into Eq. A.1.2:

$$\frac{1}{2} [(f(2k) - f(2k + \Delta k)) - (f(2k + \Delta k) - f(2k + 2\Delta k))]. \quad (\text{A.1. 3})$$

Since $f(x) < 0$ and $f''(x) > 0$, it is straight forward to see that $f(2k+\Delta k) < f(2k)$, $f(2k+2\Delta k) < f(2k+\Delta k)$, and $f(2k) - f(2k+\Delta k) > f(2k+\Delta k) - f(2k+2\Delta k)$. Therefore, $N(1) > N(0)$.

A.2 The sign of $N(\delta_j)$

The expression of $N(\delta_j)$ is from Eq. 5. First, we assume that $k > \Delta k > 0$, i.e., new orders are less than the existing fleet size, and they are both positive. Second, we use $\alpha=3$ in this discussion.

To discuss whether $N(\delta_j) > 0$, it equivalent to discuss whether $(k + \Delta k)/k - [(2k + (1 + \delta_j)\Delta k)/(2k + \delta_j\Delta k)] > 0$, or $1 + \Delta k/k > 1 + \Delta k/2k + \delta_j\Delta k/1.5$.

The Left-Hand Side (LHS) is the increasing proportion in investor's own capacity k , while the Right-Hand Side (RHS) is the proportional increase in the total market capacity $2k + \delta_j\Delta k$.

Let $m = \Delta k/(2k + \delta_j\Delta k)$ and expand the RHS using a Taylor series approximation:

$$(1 + m)^{1.5} \approx 1 + 1.5m + \frac{1}{2} 1.5 * 0.5 * m^2 - \frac{1}{6} 1.5 * 0.5 * 0.5 * m^3 - \dots \quad (\text{A.2. 1})$$

Since the terms that have the negative sign only reduce the value of the RHS of Eq. A.2.1 and terms that have the positive sign are very small, it is sufficient to check if:

$$\frac{\Delta k}{k} > 1.5m + \frac{1}{4} 1.5m^2. \quad (\text{A.2. 2})$$

Now, because $\Delta k/k$ is at least twice as much as m , substitute m in the RHS of Eq. A.2.2 with $\Delta k/(2k)$:

$$1.5 \frac{\Delta k}{2k} + \frac{1}{4} 1.5 \left(\frac{\Delta k}{2k} \right)^2 = 1.5 \frac{\Delta k}{2k} \left(1 + \frac{\Delta k}{8k} \right). \quad (\text{A.2. 3})$$

From Eq. A.2.3, as long as $\Delta k < \frac{8}{3}k$, i.e., the expansion capacity is not larger 2.66 times of its original capacity, the LHS is always larger than the RHS. In other words, the $N(\delta_j) > 0$.

Appendix B. Relationship between $\Delta\pi_i(0)$ and $\Delta\pi_i(1)$ for case $b2$ and $d1$

We construct a reference value $X=\pi_i(1,0,v_{10})-\pi_i(0,0,v_{10})$ for path $b2$ and $Y=\pi_i(1,1,v_{01})-\pi_i(0,1,v_{01})$ for path $d1$.

The second term in X , $\pi_i(0,0,v_{10})$, and the first term in Y , $\pi_i(1,1,v_{01})$, can be obtained by substituting the value v_{10} into $\pi_i(0,0)$ and v_{01} into $\pi_i(1,1)$ in Eq. 1. $\pi_i(0,0,v_{10})$ and $\pi_i(1,1,v_{01})$ equal to:

$$\pi_i(0,0,v_{10}) = G \frac{2(\alpha-1)k+\alpha\Delta k}{\alpha} - kOC \quad (\text{B. 1.a})$$

$$\pi_i(1,1,v_{01}) = G \frac{2(\alpha-1)k+(\alpha-2)\Delta k}{\alpha} - (k+\Delta k)OC - \Delta k rP. \quad (\text{B. 1.b})$$

Substituting $\pi_i(1,0,v_{10})$ and $\pi_i(0,1,v_{01})$ from Eq. 3 and $\pi_i(1,1,v_{01})$ and $\pi_i(0,0,v_{10})$ from Eq. B.1 into X and Y , we can get:

$$X = G \frac{(\alpha-2)\Delta k}{2(\alpha-1)(2k+\Delta k)^{\alpha-1}} - \Delta k(OC + rP) \quad (\text{B. 2.a})$$

$$Y = G \frac{(\alpha-2)\Delta k}{2(\alpha-1)(2k+\Delta k)^{\alpha-1}} - \Delta k(OC + rP). \quad (\text{B. 2.b})$$

The differences between $\Delta\pi_i(1)^{b2}$ and X and between $\Delta\pi_i(0)^{d1}$ and Y equal to:

$$\Delta\pi_i(1)^{b2} - X = G * \left[\frac{k+\Delta k}{(2k+2\Delta k)^{\alpha-1}} - \frac{k+\frac{(\alpha-2)\Delta k}{2(\alpha-1)}}{(2k+\Delta k)^{\alpha-1}} \right] \quad (\text{B. 3.a})$$

$$\Delta\pi_i(0)^{d1} - Y = G * \left[\frac{k+\frac{\alpha}{(2\alpha-2)\Delta k}}{(2k+\Delta k)^{\alpha-1}} - \frac{k}{(2k)^{\alpha-1}} \right]. \quad (\text{B. 3.b})$$

When $\alpha=3$, the difference between the square of these two terms for Eq. B.3.a and Eq. B.3.b can be re-written as:

$$\left(1 + \frac{\frac{3}{4}\Delta k}{k+\frac{1}{4}\Delta k}\right)^2 - \left(1 + \frac{\Delta k}{2k+\Delta k}\right)^3 = \frac{8(k+\Delta k)^2\Delta k^2(3k+\Delta k)}{(4k+\Delta k)^2(2k+\Delta k)^3} > 0 \quad (\text{B. 4.a})$$

$$\left(1 + \frac{3\Delta k}{4k}\right)^2 - \left(1 + \frac{\Delta k}{2k}\right)^3 = -\frac{\Delta k^2(3k+2\Delta k)}{16k^3} < 0. \quad (\text{B. 4.b})$$

Therefore, Eq. B.3.a>0, and Eq. B.3.b<0. Then, we have the following relationship:

$$\Delta\pi_i(1)^{b2} > X \quad (\text{B. 5.a})$$

$$\Delta\pi_i(0)^{d1} < Y. \quad (\text{B. 5.b})$$

As $s_{\max} > v_{10}$ for path $b2$ and $v_{11} < s_{\min}$ for path $d1$, we have:

$$\pi_i(0,0,s_{\max}) > \pi_i(0,0,v_{10}) \quad (\text{B. 6.a})$$

$$\pi_i(1,1,v_{11}) > \pi_i(1,1,s_{\min}). \quad (\text{B. 6.b})$$

Subtracting Eq. B.6.a from $\pi_i(1,0,v_{10})$, and subtract $\pi_i(0,1,v_{01})$ from Eq. B.6.b, we get:

$$\pi_i(1,0,v_{10}) - \pi_i(0,0,s_{\max}) < \pi_i(1,0,v_{10}) - \pi_i(0,0,v_{10}) \quad (\text{B. 7.a})$$

$$\pi_i(1,1,v_{11}) - \pi_i(0,1,v_{01}) > \pi_i(1,1,s_{\min}) - \pi_i(0,1,v_{01}). \quad (\text{B. 7.b})$$

Eq. C.7 is equivalent to:

$$\Delta\pi_i(0)^{b2} < X \quad (\text{B. 8.a})$$

$$Y > \Delta\pi_i(1)^{d1}. \quad (\text{B. 8.b})$$

From Eqs. B.5 and B.8, $\Delta\pi_i(0)^{b2} < X < \Delta\pi_i(1)^{b2}$ and $\Delta\pi_i(0)^{d1} < Y < \Delta\pi_i(1)^{d1}$, showing that $\Delta\pi_i(0)^{b2} < \Delta\pi_i(1)^{b2}$ and $\Delta\pi_i(0)^{d1} < \Delta\pi_i(1)^{d1}$ in both cases.

Appendix C. Prisoners' Dilemma (transfer case)

For the transfer case, we know the ranges for s_{\max} and s_{\min} should satisfy:

$$\begin{cases} \left(\frac{FQ}{\alpha \lambda P_b (2k + (1 + \delta_j) \Delta k)} \right)^{\frac{1}{\alpha-1}} < s_{\max} < \left(\frac{FQ}{\alpha \lambda P_b (2k + \delta_j \Delta k)} \right)^{\frac{1}{\alpha-1}} \\ \left(\frac{FQ}{\alpha \lambda P_b (2k + (1 + \delta_j) \Delta k)} \right)^{\frac{1}{\alpha-1}} < s_{\min} < \left(\frac{FQ}{\alpha \lambda P_b (2k + \delta_j \Delta k)} \right)^{\frac{1}{\alpha-1}} \end{cases} \quad (C. 1)$$

as expanding the capacity of company i would lead to speed reduction to or from the boundary speed. From Eq. C.1, we can get:

$$\frac{F\gamma Q}{2l} s_{\max} > \frac{\alpha G}{2\alpha-2} \frac{1}{(2k + (1 + \delta_j) \Delta k)^{\frac{1}{\alpha-1}}} \quad \text{and} \quad -k\gamma \lambda P_b s_{\max}^\alpha > -\frac{G}{\alpha-1} \frac{k}{(2k + \delta_j \Delta k)^{\frac{\alpha}{\alpha-1}}} \quad (C. 2.a)$$

$$-\frac{F\gamma Q s_{\min}}{2l} > -\frac{\alpha G}{2\alpha-2} \frac{1}{(2k + \delta_j \Delta k)^{\frac{1}{\alpha-1}}} \quad \text{and} \quad (k + \Delta k) \gamma \lambda P_b s_{\min}^\alpha > \frac{G}{\alpha-1} \frac{k + \Delta k}{(2k + (1 + \delta_j) \Delta k)^{\frac{\alpha}{\alpha-1}}} \quad (C. 2.b)$$

Substituting Eqs. C.2.a and C.2.b into Eq. 7b and 7c respectively, we have:

$$\pi^b(0, 0) - \pi^b(1, 1) > \frac{G}{\alpha-1} \left(\frac{1.5}{(2k + (1 + \delta_j) \Delta k)^{\frac{1}{\alpha-1}}} - \frac{k}{(2k + \delta_j \Delta k)^{\frac{\alpha}{\alpha-1}}} - \frac{1}{(2k + 2\Delta k)^{\frac{1}{\alpha-1}}} \right) + \Delta k(OC + rP) \quad (C. 3.a)$$

$$\pi^d(0, 0) - \pi^d(1, 1) > \frac{G}{\alpha-1} \left(\frac{1}{(2k)^{\frac{1}{\alpha-1}}} - \frac{1.5}{(2k + \delta_j \Delta k)^{\frac{1}{\alpha-1}}} + \frac{k + \Delta k}{(2k + (1 + \delta_j) \Delta k)^{\frac{\alpha}{\alpha-1}}} \right) + \Delta k(OC + rP). \quad (C. 3.b)$$

The RHS of Eq. C.3.a can be written as:

$$\begin{cases} \frac{G}{\alpha-1} N(1) + \Delta k(OC + rP) > 0 & \text{when } \delta_j = 1 \\ \frac{G}{\alpha-1} * J + \Delta k(OC + rP) & \text{when } \delta_j = 0, \end{cases} \quad (C. 4)$$

$$\text{where } J = \frac{1.5}{(2k + \Delta k)^{\frac{1}{\alpha-1}}} - \frac{1}{(2k + 2\Delta k)^{\frac{1}{\alpha-1}}} - \frac{0.5}{(2k)^{\frac{1}{\alpha-1}}}.$$

Differentiate J w.r.t. k , we can get:

$$\frac{\partial J}{\partial k} = \frac{1}{2} \left[\frac{1}{(2k)^{1.5}} - \frac{1}{(2k + \Delta k)^{1.5}} \right] - \left[\frac{1}{(2k + \Delta k)^{1.5}} - \frac{1}{(2k + 2\Delta k)^{1.5}} \right] > 0. \quad (C. 5)$$

Eq. C.5 indicates that, with the increase of k , J will increase. If $k = \Delta k$, it is straight forward to see that $J > 0$. Then it is clear that $J > 0$ for $k > \Delta k$.

Thus, the RHS of Eq. C.3.a is larger than 0, i.e. $\pi^b(0,0) - \pi^b(1,1) > 0$.

Similar, the RHS of Eq. C.3.b equals to:

$$\begin{cases} \frac{G}{\alpha-1} \left[N(1) - N(0) + \frac{1}{2} \left(\frac{1}{(2k)^{\frac{1}{\alpha-1}}} - \frac{1}{(2k + \Delta k)^{\frac{1}{\alpha-1}}} \right) \right] + \Delta k(OC + rP) > 0 & \text{when } \delta_j = 1 \\ \frac{G}{\alpha-1} * N(0) + \Delta k(OC + rP) > 0 & \text{when } \delta_j = 0. \end{cases} \quad (C. 6)$$

Since $N(1) > N(0)$ from Appendix A.1, the RHS of Eq. C.3.b is positive, then $\pi^d(0,0) - \pi^d(1,1) > 0$.

Appendix D. Comparative static analysis of $\Delta\pi_i(\delta_j)$

D.1 Comparative static analysis w.r.t. P_b

Eq. 8c is for the transfer case, from the RHS of the first equation and LHS of the second equation in Eq. C.1, we have:

$$\begin{cases} k\gamma\lambda s_{\max}^\alpha < -G_{P_b} * B(\delta_j) \\ -(k + \Delta k)\gamma\lambda s_{\min}^\alpha < G_{P_b} * A(\delta_j), \end{cases} \quad (\text{D.1. 1})$$

where $G_{P_b} = -\left(\gamma/\lambda^{\frac{1}{\alpha-1}}\right)(FQ/(\alpha l P_b))^{\frac{\alpha}{\alpha-1}}$.

Substitute Eq. D.1.1 into Eq. 8c:

$$\frac{\partial \Delta\pi_i(\delta_j)^{trs}}{\partial P_b} = \begin{cases} \frac{\partial \Delta\pi_i(\delta_j)^b}{\partial P_b} < G_{P_b} * N(\delta_j) \\ \frac{\partial \Delta\pi_i(\delta_j)^d}{\partial P_b} < G_{P_b} * N(\delta_j). \end{cases} \quad (\text{D.1. 2})$$

Since $G_{P_b} < 0$ and $N(\delta_j) > 0$, then $\partial \Delta\pi_i(\delta_j)^{trs} / \partial P_b < 0$.

D.2 Comparative static analysis w.r.t. F

From Eq. C.1, we have the following inequality:

$$\begin{cases} -G_F * B(\delta_j) < -\frac{\gamma Q k}{l(2k + \delta_j \Delta k)} s_{\max} < -\frac{G_F k}{(2k + \delta_j \Delta k)(2k + (1 + \delta_j) \Delta k)^{\frac{1}{\alpha-1}}} \\ G_F * A(\delta_j) < \frac{\gamma Q (k + \Delta k)}{l(2k + (1 + \delta_j) \Delta k)} s_{\min} < \frac{G_F (k + \Delta k)}{(2k + (1 + \delta_j) \Delta k)(2k + (1 + \delta_j) \Delta k)^{\frac{1}{\alpha-1}}}. \end{cases} \quad (\text{D.2. 1})$$

Substitute the LHS of Eq. D.2.1 into Eq. 9c:

$$\frac{\partial \Delta\pi_i(\delta_j)^{trs}}{\partial F} = \begin{cases} \frac{\partial \Delta\pi_i(\delta_j)^b}{\partial F} > G_F * N(\delta_j) - \Delta k r P_F = \frac{\partial \Delta\pi(\delta_j)^c}{\partial F} \\ \frac{\partial \Delta\pi_i(\delta_j)^d}{\partial F} > G_F * N(\delta_j) - \Delta k r P_F = \frac{\partial \Delta\pi(\delta_j)^c}{\partial F} \end{cases}, \quad (\text{D.2. 2})$$

where $G_F = \partial G / \partial F = \gamma(F/(\alpha l P_b))^{\frac{1}{\alpha-1}}(Q/l)^{\frac{\alpha}{\alpha-1}} > 0$. This proves that if $\partial \Delta\pi_i(\delta_j)^c / \partial F$ is positive, $\partial \Delta\pi_i(\delta_j)^{trs} / \partial F$ will also be positive.

Substituting the RHS of Eq. D.2.1 into Eq. 9c, we have:

$$\frac{\partial \Delta\pi_i(\delta_j)^{trs}}{\partial F} = \begin{cases} \frac{\partial \Delta\pi_i(\delta_j)^b}{\partial F} < \frac{\Delta k G_F}{2(2k + \Delta k)} \frac{1}{(2k + (1 + \delta_j) \Delta k)^{\frac{1}{\alpha-1}}} - \Delta k r P_F \\ \frac{\partial \Delta\pi_i(\delta_j)^d}{\partial F} < \frac{\Delta k G_F}{2(2k + \Delta k)} \frac{1}{(2k + \delta_j \Delta k)^{\frac{1}{\alpha-1}}} - \Delta k r P_F \end{cases}. \quad (\text{D.2. 3})$$

Eq. D.2.3 shows that if $\frac{\Delta k G_F}{2(2k + \Delta k)} \frac{1}{(2k + (1 + \delta_j) \Delta k)^{\frac{1}{\alpha-1}}} - \Delta k r P_F < 0$, $\frac{\partial \Delta\pi_i(\delta_j)^b}{\partial F} < 0$; if $\frac{\Delta k G_F}{2(2k + \Delta k)} \frac{1}{(2k + \delta_j \Delta k)^{\frac{1}{\alpha-1}}} - \Delta k r P_F < 0$, $\frac{\partial \Delta\pi_i(\delta_j)^d}{\partial F} < 0$. Since $\frac{1}{(2k + (1 + \delta_j) \Delta k)^{\frac{1}{\alpha-1}}} \leq \frac{1}{(2k + \delta_j \Delta k)^{\frac{1}{\alpha-1}}}$, when $\frac{\partial \Delta\pi_i(\delta_j)^d}{\partial F} < 0$, it must be true

that $\frac{\partial \Delta\pi_i(\delta_j)^b}{\partial F} < 0$. Therefore, the condition for $\partial \Delta\pi_i(\delta_j)^{trs} / \partial F < 0$ is:

$$F < H(2(2k + \Delta k))^{\alpha-1}(2k + \delta_j \Delta k), \quad (\text{D.2. 4})$$

where $H = (\alpha l P_b)(r P_F / \gamma)^{\alpha-1}(l/Q)^\alpha$.

Port Investments on Coastal and Marine Disasters Prevention: An Economic and Policy Investigation

Yi-bin Xiao¹, Xiaowen Fu², Adolf K.Y. Ng^{3*} and Anming Zhang⁴

¹School of Mathematical Sciences, University of Electronic Science and Technology of China.

Email: xiaoyb9999@uestc.edu.cn

²Institute of Transport and Logistics Studies, University of Sydney, Australia.

E-mail: xiaowen.fu@sydney.edu.au

³Department of Supply Chain Management, I.H. Asper School of Business, University of Manitoba, Canada.

E-mail: adolf.ng@umanitoba.ca

⁴Sauder School of Business, University of British Columbia, Canada. Email: anming.zhang@sauder.ubc.ca

**Corresponding author*

Abstract

Located along shorelines, ports are highly vulnerable to coastal and marine natural disasters. Damage caused by disasters can be prevented or alleviated if sufficient investments are made in a timely manner. However, despite a wide range of investment options and well-developed engineering expertise, port investment on disaster prevention remains a challenging task involving great complexities. So far, there has been little definite government policy or guidance either. This study develops an integrated economic model for the analysis of disaster prevention investments at a “landlord” port. It simultaneously considers the uncertainty of disaster occurrence and associated return of prevention investments, the information accumulation and related investment timing, and the spillovers (externalities) of investment among stakeholders. Analytical results suggest that the timing of port investments depends on the probability of disasters. Immediate investment is optimal for disasters with high probability, whereas investment should be postponed if such a probability is very low. Optimal timing for cases of intermediate probability can’t be determined as it is influenced by other factors such as discount rate, information accumulation and efficiency of investments. Positive externalities between a port and its tenants lead to under-investment, which can be corrected by coordination between stakeholders. However, since there are risks of over-investment due to uncertainty, government intervention is only optimal with a good understanding of disaster probability distribution. Our study also demonstrates the importance of scientific research, which brings significant economic value in operation planning and investment decisions.

Highlights:

- It constructs an economic model of port investments in coastal and marine natural disaster prevention, focusing on the “landlord” port
- It develops an integrated model that incorporates the uncertainty of disaster occurrence and associated value of disaster prevention investments, the information accumulation over time and related investment timing, and the spillovers (externalities) of investment among stakeholders

Contributions:

- It identifies conditions under which government should make all decisions related to investment timing and amount
- It demonstrates the value of a better understanding of natural disasters, since the choices of optimal corporate strategy and government policy are all dependent on the true probability distribution of disasters.
- It demonstrates the importance of scientific research in bringing significant economic and strategic values to operation, planning and investment decisions

1. Introduction

Over the past decade coastal and marine natural disasters have led to substantial social and economic damages around the world, as exemplified by the impacts of hurricanes Katrina (in 2005) and Sandy (in 2012) to the North American coastline, the humanitarian disasters caused by tsunamis in the Indian Ocean countries (in 2004) and Japan (in 2011), and the devastating damages caused by typhoon Haiyan (in 2013) to the Philippines. Scientific studies on climate change suggest that there is an increasing risk of natural disasters (e.g., Keohane and Victor, 2010; Min et al. 2011; Pall et al. 2011) in the near future, which may trigger substantial social, economic and political instability (Zhang et al. 2007). For instance, Schaeffer et al. (2012) warn that by 2100, the sea level may be 75-80 cm higher than today's level. Located along shorelines, seaports (hereinafter called 'ports') are highly vulnerable to coastal and marine natural disasters. With more than 80% of globally traded goods being carried by maritime transportation (Ng and Liu, 2014), natural disasters may impose severe damages to the global economy, as well as unprepared ports.

Nowadays, the development of effective measures in preventing or alleviating such risks is not a choice but a necessity. There is certainly no shortage of research investigating this topic, but often dominated by either greenhouse gas (GHG) emission measurement/control due to ship and port operations (e.g., Eide et al., 2011; Berechman and Tseng, 2012), or the impacts and consequences if such disasters are going to take place, such as the risks posed by climate change (e.g., Sanchez-Arcilla et al., 1996; Jevrejeva et al., 2012) and the vulnerability of coastal areas (e.g., El-Raey, 1997; McGinnis and McGinnis, 2011), while investigations on the measures are comparatively scarce. In this case, one should note that damage caused by coastal and marine natural disasters can be prevented or alleviated if sufficient investments are made in a timely manner. Possible investments may include building storm-surge barriers and promoting beach nourishments, raising the height of roads (causeways), the improvements of groins, dykes, levees and seawalls, improvements to a port's storm water system, and better potable and wastewater emergency response and maintenance for more common and more extensive coastal flooding in vulnerable areas. Some of these investments can be quite costly and time-consuming. For example, after the 1953 North Sea Flood, the Netherlands started the Delta Works to protect a large area of land around the Rhine-Meuse-Scheldt delta. The works were made up of dams, sluices, locks, dykes, levees and storm surge barriers. The project was declared finished in 1997. Nevertheless, in 2008 the Delta Works Commission made 12 recommendations to the Dutch Cabinet, and called for an additional investment of 100 billion Euros over the next 100 years due to increased risks associated with climate change and sea level rise. In 1978, the construction of the Saint Petersburg Flood Prevention Facility Complex was initiated, aiming to protect the city from storm surges. This project was completed in 2011 costing US\$3.85 billion.ⁱ The huge costs and lengthy durations call for careful planning and evaluation of these projects, so that investments can be made in a timely and efficient manner. Finally, there are also studies investigating the construction of coastal defenses through marine eco-systems (e.g., Tobey et al., 2010).

Despite the wide range of investment options and extensive engineering knowledge, port investments on coastal and marine disaster prevention remain a challenging decision involving great complexities. A major challenge is the uncertainty of the exact value brought by those projects. In most cases, such investments will only render benefits in the case of disasters and provide little value otherwise. Such an uncertainty has led to somewhat arbitrary decisions in practice with mixed results. Largely due to the strong will of its mayor Kotaku Wamura the Japanese city of Fudai started building a huge sea wall and floodgates in 1972. The project took 12 years to finish and was widely regarded as a waste of £20 million - until it saved more than 3,000 local residents in the 2011 tsunami.ⁱⁱ In the US, port facilities at Gulfport, Mississippi, were severely damaged by hurricane Katrina in 2005. Soon afterwards, US\$570 million from the Federal Community Development and Block Grant was allocated to help in Gulfport's restoration. Ironically, only one day after hurricane Sandy hit New York City, the port announced that it would not raise its West Pier by 25 feet as recommended. The stated reason was that building up that high would delay the port's ability to welcome new port tenants; rather the focus should be shifted from disaster recovery to better serving current tenants, attracting new business and creating additional jobs.ⁱⁱⁱ All the above cases illustrated a major deficiency in research so far, namely the strong emphasis on the 'technical' side of the problem. Indeed, despite repeated calls for more research in strategic planning and investments from scholars and practitioners, including defining clear roles and responsibilities for both public and private port stakeholders (National Research Council of the USA, 2010; UNCTAD, 2012), this area of research is still seriously scarce.

Another challenge is related to the allocation of investment responsibilities. Many ports are operated under the “landlord port” model. However, the responsibilities for investing disaster prevention are usually not clearly (if at all) specified in concession agreements. The responsibilities of investments among the port stakeholders in paying the (substantial) investment bills are usually not clearly defined, not helped by the substantial uncertainties associated with the likelihood and severity of the occurrence of such disasters (notably with the impacts of climate change) (Ng et al., 2013). Unsurprisingly, this often leads to finger pointing between a port authority and its tenants (e.g., terminal operators, owners of other businesses on port land such as warehouse keepers, logistics service providers, owners of commercial facilities such as hotels, car parks and shipyards). In many cases, there is also no clear government policy guidance on this issue either. As a result, investments are often postponed or delayed as both sides (the port authority and tenants) may wish to free ride the other side’s investments. It should be noted, however, that delay of investment is not necessarily bad *per se*. It is well known that in the presence of uncertainty, it might be better to postpone irreversible investments until better information is available than to make decisions right away (Dixit and Pindyck, 1994). Thus, there may be an optimal timing for environmental investments and policies (Arrow and Fisher, 1974; Henry, 1974). In short, port investment is a complex decision (Xiao et al., 2012), especially in the prevention or alleviation of coastal and marine natural disasters. It involves multiple issues such as the uncertainty of disaster and thus value of projects, investment responsibility allocation and efforts coordination among stakeholders, and the choice of investment timing. There has been no clear policy or operational guidance on important questions such as who should pay for such investments, when and how much should be invested, whether government intervention is needed and how government should intervene.

It has been well recognized that the issues of uncertainty, optimal timing and externalities need to be considered for environmental policies and investments. However, few previous studies have considered these issues in an integrated model, and it is unclear whether findings from them can be applied directly to ports. Take the study on the mitigation of climate change as an example. The Stern Review (Stern, 2007) recognizes great uncertainty and calls for early action on CO₂ emission control because “delaying action now means more drastic emissions reductions over the coming decades”. In addition, early actions provide the option to switch to a lower emissions path if this turns out to be desirable later, but late abatement would introduce higher risks of climate impacts. On the other hand, Gollier (2006), Nordhaus (2007) and Weitzman (2007), among others, criticized the Stern Review for its use of extremely low discount rate, thus that payoffs in the distant future have a large present value. Kolstad (1996), Fisher and Narain (2003), Pindyck (2000, 2002) concluded that it is optimal to wait or to reduce the amount of investments in the early stage, since GHG build-up is sufficiently slow, and the investment irreversibility effect is much larger than the GHG irreversibility effect. In this regard, Pindyck (2007) concluded that the optimal timing is model-specific: if catastrophic impacts are not considered, then waiting is a better choice; otherwise, early investments may be preferred. Indeed, one main issue affecting the choice of investment timing in these investigations is stock externality, as CO₂ or other forms of pollution accumulates or decays over time. The severity of climate change is determined by the stock of emissions, and thus reduced investment today may be compensated by larger investments in the future. Such a feature is clearly not present, or critical, in the analysis of coastal and marine natural disasters. Another major difference between emission/pollution control and disaster prevention is the pay-off of investments. Measures on emission will certainly reduce stock and thus probability of climate change, whereas investments against disasters offer no benefits if nothing happened. Finally, the models on climate change usually consider current consumption (or production) and emission simultaneously, since more consumption leads to more emissions. Such an assumption may not be valid for port disaster investments, as a disaster-resilient port does not have to reduce its production or traffic volume. Shippers, shipping carriers or freight forwarders may perceive reduced risks of operation after the investments, leading to an increase in traffic going through the port.

The externalities and free ride problem have also been well recognized in the environment-protection literature, and the recommended solutions are usually coordinated actions among all parties, which may be facilitated by formal agreements or market-based mechanisms (e.g., Pearce, 1991; Sebenius, 1991; Hoel, 1997; Cooper, 1998; Carraro and Siniscalco, 1998; Cantore et al., 2009). For studies on ports, Homsombat et al. (2013) showed analytically that it is important for ports to coordinate their pollution control efforts. More generally, Lam et al. (2013) argued that it is important for all stakeholders to be involved in port governance, and Basso et al. (2014) examined regional cooperation in accessibility investments in the context of port

competition. Indeed, extensive effort has been made to coordinate international efforts against climate change (e.g., the Kyoto Protocol, the United Nations Framework Convention on Climate Change (UNFCCC) negotiation process). Using a non-cooperative game, Hoel (1990) illustrated that if one country reduces its emission unilaterally when other countries' policy is solely determined by their self-interests, the outcome of international negotiations may be affected, which could lead to higher total emissions. Yuen and Zhang (2012) have obtained similar results in the context of airline emissions. Although there are studies questioning the feasibility and sustainability of coordination agreements (Carraro and Siniscalco, 1993; Barrett, 1994), or arguing the Pareto optimal outcome may be achieved without formal coordination under ideal conditions such as competitive markets for labor and products (Hoel, 1997), no studies so far have dismissed the benefits of coordinated efforts. The intuition is similar to the provision of public good, where government intervention is preferred. Few studies have investigated the effects of externalities in disaster-prevention investments. Depoorter (2006) argued that investments in prevention by one government actor confer positive externalities upon other government actors by reducing the overall chance of being held responsible. However, *ex post* disaster relief involves negative externalities when action by one agency makes other agencies look worse. In addition, the results of prevention investments are uncertain and less tangible than expenditures in *ex post* relief. Sending in troops, personnel, and food and medical supplies is highly visible and attracts better media coverage compared to successful disaster prevention efforts. As a result, there is under-investment in disaster-prevention investments, whereas state and local governments compete with each other in disaster relief efforts. Depoorter (2006)'s study is however purely descriptive, and investment timing and scale are not examined. Therefore, the effects of externalities on port disasters prevention investment remain to be examined together with uncertainty and optimal timing. As to be discussed in later sections, this will lead to significantly different results, when coordination among stakeholders may lead to worse outcomes.

Understanding such, by focusing on "landlord" ports, this study constructs an economic model of port investments in preventing or alleviating the risks/impacts posed by coastal and marine natural disasters. In recent decades, many ports had experienced a wave of neoliberal reforms towards the "landlord" model characterized by corporatization and privatization in port planning and management, while in most cases, the public sector maintained its presence in terms of regulations and the provision of public goods (Wang et al., 2004; Ng and Pallis, 2010). This transformation made the port community more complex than ever (Martin and Thomas, 2001), and thus we believe that "landlord" ports are the most appropriate choice in fulfilling the objectives of this study.

In terms of objectives, first, we aim to offer managerial and policy insights on issues related to disaster prevention investments including investment timing and scale, government regulation and intervention, and sharing of investment responsibilities among stakeholders, including their appropriate roles and responsibilities. Our second objective is to develop an integrated model that incorporates the uncertainty of disaster and associated value of disaster prevention investments, the information accumulation over time and related investment timing, and the spillovers (externalities) of investment among stakeholders. This integrated approach differs from previous studies and as shown in following sections, considering all these factors simultaneously is very important and could lead to very different results compared to previous studies. Our analytical results suggest that the timing of port investments depends on the probability of disasters. Immediate investment is optimal for disasters with high probability, whereas investment should be postponed if such a probability is very low. Optimal timing for cases of intermediate probability cannot be determined as it is influenced by other factors such as discount rate, information accumulation and efficiency of investments. Positive externalities between a port and its tenants lead to under-investment, which can be corrected by coordination between stakeholders. However, since there are risks of over-investment due to uncertainty, government intervention is only optimal with a good understanding of disaster probability distribution. That is, unlike in previous studies where coordinated actions are always optimal, coordination may not be preferred and there are cases where port stakeholders should make their own decisions. This pioneer study demonstrates the importance of scientific research in bringing significant economic and strategic values to operation, planning and investment decisions. After this introductory section, the economic model is introduced in Section 2. Sections 3 and 4 solve equilibrium results in various cases, which are benchmarked in Section 5. Section 6 summarizes and concludes our analysis.

2. The Economic Model

We consider the behavior of a port authority (or a port owner/manager) and a port tenant (who may represent such stakeholders as terminal operators, owners of other businesses on port land or owners of commercial facilities) over two periods. Both the port authority (hereafter “port”) and the tenant (hereafter “tenant”) obtain financial returns from the operations of the port. In particular, the (current price) returns of the port and the tenant in a period are, respectively, R_p and R_t . In each period, there is a chance of occurrence of coastal and marine natural disasters, and the associated probability is presented as a random variable x . The occurrence of a disaster will lead to a financial damage of Dx to the port and the tenant respectively, where D is a constant reflecting the maximum possible financial loss caused. An implied assumption of this specification is that damage is proportional to the probability of disaster x , thus that if the probability of disaster is higher, so will be the damage caused.^{iv}

At the beginning of either period 1 or period 2, the port and the tenant may invest I_p and I_t respectively on disaster prevention facilities. Such an investment brings no benefit to the port and the tenant in the case of no disaster. If there is a disaster, it reduces the damage to the port by $\theta I_p + \alpha I_t$ and the damage to the tenant by $\theta I_t + \alpha I_p$, where $\theta > \alpha > 0$ and $\theta > 1$. These specifications imply that both the port and the tenant can benefit from their own investment as well as the other side’s investment. Condition $\theta > 1$ requires that a unit investment by the port (tenant) will lead to a higher damage reduction, whereas $\theta > \alpha > 0$ implies that the benefit arising from one’s own investment is larger than that made by the other side. Therefore, the actual damages to the port and the tenant are $\text{Max}\{0, Dx - (\theta I_p + \alpha I_t)\}$ and $\text{Max}\{0, Dx - (\theta I_t + \alpha I_p)\}$, respectively. Such a specification allows for overinvestment. That is, when $Dx < \theta I_p + \alpha I_t$ or $Dx < \theta I_t + \alpha I_p$, investment brings no extra benefit other than reducing disaster damage to zero, and prevention investment offers no value if there were no disasters.^v

The true probability distribution of x is represented with a uniform distribution in the range of $[\underline{x}, \bar{x}]$, where $0 \leq \underline{x} < \bar{x} \leq 1$. However, in period 1, such information is not known, and thus the perceived distribution is a uniform distribution in $[0, 1]$. In period 2, there is a better understanding of coastal and marine natural disasters, and thus the true distribution of x is known to both the port and tenant. Such a specification reflects the fact that early estimates of uncertainty associated with environmental issues are often based on subjective analysis such as survey and expert opinions (see, for example, estimations of probability and confidence intervals on climate change by Nordhaus 1994, Roughgarden and Schneider 1999), whereas overtime probability can be better estimated with historical data and scientific knowledge.^{vi}

Let the time discount factor to be k ($0 < k < 1$), and denote a firm’s perceived expected profit as π_i ($i = p, t$), and the actual expected payoff as π_i . The objective of both the port and the tenant is to maximize their individual expected profits by choosing investment timing (i.e., “early” in period 1 vs. “late” in period 2) and investment amount (i.e. I_p and I_t). Such a decision process over two periods is represented in Figure 1, where investment can be made either at the beginning of period 1 or period 2, but not both.^{vii}

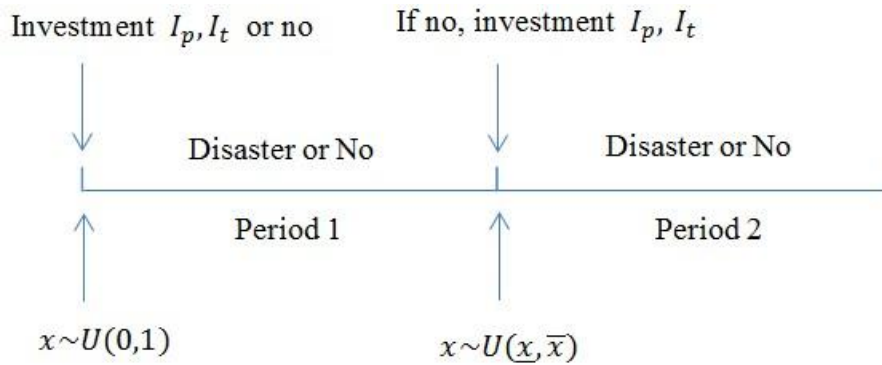


Figure 1. Basic Model Structure ($0 \leq \underline{x} < \bar{x} \leq 1$)

The following cases are defined and considered based on the identity of decision-makers for investment amount and on investment timing:

Case 1. Investment in period 1 and individual decision-making: In such a case, the port and the tenant make their investment decisions based on subjective distribution of x .

Case 2. Investment in period 2 and individual decision-making: In such a case, the port and the tenant make decisions based on the observed true distribution of x in period 2.

Case 3. Investment in period 1 and coordinated investment: In this case, the port and tenant's investment scales are mandated by the government, who decides I_p and I_t for the total benefits of the port industry. It may also be interpreted as coordinated decision-making by the port and the tenant to maximize their joint benefits.

Case 4. Investment in period 2 and coordinated investment.

By comparing the results in Cases 1 to 4, we could identify the effects of government intervention/coordination and investment timing. The optimal government policy and corporate strategies can be identified by comparing the profits of the port industry across different cases.

Disaster-prevention investments are likely to impose a significant positive externality to the society, and thus, government subsidy or direct investments may be justified. Such a positive externality is not explicitly considered in our model thus that we could focus on the business decision process and corporate strategies for port industry. Such an externality and government subsidy, if explicitly modelled, will complicate the interpretation of modelling results and prevent clear intuition to be obtained. For example, if the positive externality is sufficiently large, then it will always be optimal for the government to mandate early investment with subsidy. This would “overwhelm” the effects of other issues we would like to examine such as timing and information accumulation over time. In addition, the possibility of receiving government subsidy in the future could distort firms' incentives and decisions, since they may postpone or reduce necessary investments. Therefore, in this study, we aim to focus on the analysis of corporate strategy and industrial policy based on the port industry's well-being only. One may interpret the conclusions obtained to be “self-sustained” since external financial support or subsidy is not needed. Also, it implies that the investment quantity and optimal timing obtained in our study are the “lower bound” of practical decisions, since if such a positive externality to social welfare is considered more investments shall be made at an earlier stage than what would be obtained from our model.

In the following sections we first solve market equilibriums in each case, thus that the optimal government policy and corporate strategies can be identified by comparing market outcomes across different cases.

3. Analysis with Individual Decision-making

In this section, we will analyze the Case 1 and Case 2, when the port and tenant make individual investment decision without coordination.

3.1. Case 1

Case 1 refers to the scenario of early investment in period 1. The true distribution of x is not known to the port and tenant. Decisions can only be made based on the perceived distribution of x , which is uniform in $[0, 1]$. Therefore the objective functions are specified as follows, where port and tenant choose their respective investments to maximize the perceived expected profits, and 1 in subscript $\{i, 1\}$ ($i = p, t$) denotes Case 1.

$$(1.1) \text{MAX}_{I_p} \pi_{\{p,1\}} = (1+k) \left[R_p - \int_0^1 \text{Max}\{0, Dx - (\theta I_p + \alpha I_t)\} dx \right] - I_p$$

$$(1.2) \text{MAX}_{I_t} \pi_{\{t,1\}} = (1+k) \left[R_t - \int_0^1 \text{Max}\{0, Dx - (\theta I_t + \alpha I_p)\} dx \right] - I_t$$

To obtain the optimal investments for the port and the tenant, we first simplify the objective functions by considering the integrals. For ease of notation, define $RD_p = \theta I_p + \alpha I_t$ and $RD_t = \theta I_t + \alpha I_p$. For $i = \{p, t\}$, one has

$$(2) \quad \int_0^1 \text{Max}\{0, Dx - RD_i\} dx = \begin{cases} \int_{RD_i/D}^1 Dx - RD_i dx, & RD_i \leq D \\ 0, & RD_i > D \end{cases}$$

$$= \begin{cases} \frac{1}{2D} (D - RD_i)^2, & RD_i \leq D \\ 0, & RD_i > D \end{cases}.$$

Because it is not optimal for the port and the tenant to invest more than the damage of disaster such that either $RD_p = \theta I_p + \alpha I_t > D$ or $RD_t = \theta I_t + \alpha I_p > D$, the objective functions for the port and the tenant can be simplified as follows:

$$(3.1) \quad \text{MAX}_{I_p} \pi_{\{p,1\}} = (1+k)[R_p - \frac{1}{2D}(D - RD_p)^2] - I_p$$

$$s.t. \quad RD_p = \theta I_p + \alpha I_t \leq D$$

$$(3.2) \quad \text{MAX}_{I_t} \pi_{\{t,1\}} = (1+k)[R_t - \frac{1}{2D}(D - RD_t)^2] - I_t$$

$$s.t. \quad RD_t = \theta I_t + \alpha I_p \leq D$$

By ignoring the constraints in (3.1) and (3.2) and specifying the corresponding first-order conditions for the port and tenant, we can get the best response functions as follows:

$$(4) \quad \begin{cases} \frac{\partial \pi_{\{p,1\}}}{\partial I_p} = \frac{\theta(1+k)}{D}(D - RD_p) - 1 = 0 \\ \frac{\partial \pi_{\{t,1\}}}{\partial I_t} = \frac{\theta(1+k)}{D}(D - RD_t) - 1 = 0, \end{cases}$$

which jointly yield

$$(5) \quad \tilde{I}_{\{p,1\}} = \tilde{I}_{\{t,1\}} = \frac{D}{\alpha + \theta} \left(1 - \frac{1}{\theta(1+k)}\right).$$

For an easy distinction of two types of solutions, in this paper, the optimal capacity investments that maximize perceived expected profit are denoted with tilt (e.g., $\tilde{I}_{\{p,i\}}$ for Case i), whereas the optimal capacity investments that maximize the true expected profits are denoted with star (e.g., $I_{\{p,i\}}^*$ for Case i). Substituting $\tilde{I}_{\{p,1\}}$ and $\tilde{I}_{\{t,1\}}$ in the constraints in (3.1) and (3.2), one has $\theta \tilde{I}_{\{p,1\}} + \alpha \tilde{I}_{\{t,1\}} = \theta \tilde{I}_{\{t,1\}} + \alpha \tilde{I}_{\{p,1\}} = D \left(1 - \frac{1}{\theta(1+k)}\right) < D$, which implies that $\tilde{I}_{\{p,1\}}$ and $\tilde{I}_{\{t,1\}}$ are the optimal investments for the port and the tenant in Case 1. It can be shown that

$$(6) \quad \frac{\partial \tilde{I}_{\{p,1\}}}{\partial k} = \frac{\partial \tilde{I}_{\{t,1\}}}{\partial k} > 0, \quad \frac{\partial \tilde{I}_{\{p,1\}}}{\partial \alpha} = \frac{\partial \tilde{I}_{\{t,1\}}}{\partial \alpha} < 0.$$

The signs of $\frac{\partial \tilde{I}_{\{p,1\}}}{\partial \theta}$ and $\frac{\partial \tilde{I}_{\{t,1\}}}{\partial \theta}$ however cannot be determined, where

$$(7) \quad \frac{\partial \tilde{I}_{\{p,1\}}}{\partial \theta} = \frac{\partial \tilde{I}_{\{t,1\}}}{\partial \theta} = \frac{D}{(1+k)(\alpha + \theta)^2 \theta^2} (\alpha + 2\theta - (1+k)\theta^2).$$

The interpretation of equation (6) is clear: a larger discount factor k leads to more investments by the port and the tenant. Moreover, when α is bigger both the port and the tenant can benefit more from their partner's investment. This would reduce the incentive for own investments. However, knowing the tenant (port) will

reduce its investment also promotes the port (tenant) to increase its own investment as a compensatory measure (it can be shown that $\frac{\partial \tilde{I}_{\{i,1\}}}{\partial \tilde{I}_{\{j,1\}}} < 0$ for $i, j = p, t$). The primary (first type of, “free riding”) effect dominates the secondary (second type of, compensatory) effect, and thus, the port and the tenant will reduce their own investment if they could benefit more from their partner’s investment, thus that $\frac{\partial \tilde{I}_{\{p,1\}}}{\partial \alpha} = \frac{\partial \tilde{I}_{\{t,1\}}}{\partial \alpha} < 0$.

On the other hand, the effect of θ is less straightforward, as it depends on the sign of $\alpha + 2\theta - (1+k)\theta^2$. By solving the inequality it can be obtained that $\alpha + 2\theta - (1+k)\theta^2 > 0$ when $\alpha < \frac{1}{1+k}(1 + \sqrt{1 + \alpha(1+k)})$, whereas $\alpha + 2\theta - (1+k)\theta^2 < 0$ when $\alpha > \frac{1}{1+k}(1 + \sqrt{1 + \alpha(1+k)})$. In addition, since $\alpha + 2\theta - (1+k)\theta^2 < \theta + 2\theta - \theta^2 = \theta(3 - \theta)$, we also have $\frac{\partial \tilde{I}_{\{p,1\}}}{\partial \theta} < 0$ if the absolute value of θ is large (e.g., when $3 < \theta$). The intuition for $\frac{\partial \tilde{I}_{\{p,1\}}}{\partial \theta} > 0$ is clear: as the investment on disaster prevention becomes more effective, both the port and tenant will invest more. The result of $\frac{\partial \tilde{I}_{\{p,1\}}}{\partial \theta} < 0$ when θ is very large seems counter-intuitive at the first sight. This is because investments bring no extra benefits other than reducing the damage of possible disasters, thus that the optimal investments by the port and the tenant will decrease when θ gets sufficiently large, and there will be no over-investment.

These results probably explain why very large investments against coastal and marine disasters are not frequently observed. A port, be it the tenant or government agencies, having an interest will only commit large investments if it has a large stake in global-warming (i.e., large Dx), cannot free ride others (i.e., small α), has a vision for the future (i.e., large k), and when the investment is effective but not too effective (large but not too large θ).

With the optimal investments solved, the perceived expected profits for the port and the tenant can be obtained as follows:

$$(8.1) \quad \tilde{\pi}_{\{p,1\}} = (1+k)[R_p - \frac{D}{2\theta^2(1+k)^2}] - \frac{D}{\alpha+\theta} \left(1 - \frac{1}{\theta(1+k)}\right)$$

$$(8.2) \quad \tilde{\pi}_{\{t,1\}} = (1+k)[R_t - \frac{D}{2\theta^2(1+k)^2}] - \frac{D}{\alpha+\theta} \left(1 - \frac{1}{\theta(1+k)}\right).$$

Since the true probability distribution of x is $U(\underline{x}, \bar{x})$, the actual expected payoffs for the port and the tenant can be specified as

$$(9.1) \quad \tilde{\Pi}_{\{p,1\}} = (1+k)[R_p - \int_{\underline{x}}^{\bar{x}} \text{Max}\{0, Dx - (\theta \tilde{I}_{\{p,1\}} + \alpha \tilde{I}_{\{t,1\}})\} \frac{1}{\bar{x}-\underline{x}} dx] - \tilde{I}_{\{p,1\}}$$

$$(9.2) \quad \tilde{\Pi}_{\{t,1\}} = (1+k)[R_t - \int_{\underline{x}}^{\bar{x}} \text{Max}\{0, Dx - (\theta \tilde{I}_{\{t,1\}} + \alpha \tilde{I}_{\{p,1\}})\} \frac{1}{\bar{x}-\underline{x}} dx] - \tilde{I}_{\{t,1\}},$$

which can be obtained as in (10), where $i = \{p, t\}$.

$$(10) \quad \tilde{\Pi}_{\{i,1\}} = \begin{cases} (1+k) \left[R_i - D \left(\frac{\bar{x}+\underline{x}}{2} - \left(1 - \frac{1}{\theta(1+k)}\right) \right) \right] - \tilde{I}_{\{i,1\}}, & \text{if } 1 - \frac{1}{\theta(1+k)} \leq \underline{x} \\ (1+k) \left[R_i - \frac{D}{2(\bar{x}-\underline{x})} \left(\bar{x} - \left(1 - \frac{1}{\theta(1+k)}\right) \right)^2 \right] - \tilde{I}_{\{i,1\}}, & \text{if } \underline{x} < 1 - \frac{1}{\theta(1+k)} < \bar{x} \\ (1+k)R_i - \tilde{I}_{\{i,1\}}, & \text{if } 1 - \frac{1}{\theta(1+k)} \geq \bar{x} \end{cases}$$

3.2. Case 2

In Case 2 investments are made in period 2, when the true distribution of x , i.e. $U(\underline{x}, \bar{x})$, is known to the port

and the tenant. The objective functions of the port and the tenant are thus specified as follows:

$$(11.1) \text{MAX}_{I_p} \Pi_{\{p,2\}} = \left[R_p - \int_{\underline{x}}^{\bar{x}} Dx \frac{1}{\bar{x}-x} dx \right] + k \left[(R_p - I_p) - \int_{\underline{x}}^{\bar{x}} \text{Max}\{0, Dx - RD_p\} \frac{1}{\bar{x}-x} dx \right]$$

$$(11.2) \text{MAX}_{I_t} \Pi_{\{t,2\}} = \left[R_t - \int_{\underline{x}}^{\bar{x}} Dx \frac{1}{\bar{x}-x} dx \right] + k \left[(R_t - I_t) - \int_{\underline{x}}^{\bar{x}} \text{Max}\{0, Dx - RD_t\} \frac{1}{\bar{x}-x} dx \right]$$

For $i = \{p, t\}$, it can be shown that

$$(12) \int_{\underline{x}}^{\bar{x}} \text{Max}\{0, Dx - RD_i\} \frac{1}{\bar{x}-x} dx = \begin{cases} \int_{\underline{x}}^{\bar{x}} [Dx - RD_i] \frac{1}{\bar{x}-x} dx, & \text{if } RD_i \leq D\underline{x} \\ \int_{RD_i/D}^{\bar{x}} [Dx - RD_i] \frac{1}{\bar{x}-x} dx, & \text{if } D\underline{x} < RD_i < D\bar{x} \\ 0, & \text{if } RD_i \geq D\bar{x}, \end{cases}$$

which implies that

$$(13) \frac{\partial \Pi_{\{i,2\}}}{\partial I_i} = \begin{cases} k(\theta - 1), & \text{if } RD_i \leq D\underline{x} \\ k \left[\frac{\theta}{D(\bar{x}-\underline{x})} (D\bar{x} - RD_i) - 1 \right], & \text{if } D\underline{x} < RD_i < D\bar{x} \\ -k, & \text{if } RD_i \geq D\bar{x}. \end{cases}$$

Utilizing the first-order conditions $\frac{\partial \Pi_{\{i,2\}}}{\partial I_i} = 0, i = \{p, t\}$, and the requirement $\theta > 1$, the optimal investments for the port and the tenant can be obtained as in (14). The profits of the port and the tenant can be calculated accordingly but not reported to save space.

$$(14) I_{\{p,2\}}^* = I_{\{t,2\}}^* = \frac{D}{\theta + \alpha} \left(\bar{x} - \frac{1}{\theta} (\bar{x} - \underline{x}) \right)$$

In this case, it is straightforward to show that $\frac{\partial I_{\{p,2\}}^*}{\partial \alpha} = \frac{\partial I_{\{t,2\}}^*}{\partial \alpha} < 0$. However, the sign of $\frac{\partial I_{\{p,2\}}^*}{\partial \theta}$ and $\frac{\partial I_{\{t,2\}}^*}{\partial \theta}$ are not clear, since $\frac{\partial I_{\{p,2\}}^*}{\partial \theta} = \frac{\partial I_{\{t,2\}}^*}{\partial \theta} = \frac{D}{(\alpha + \theta)^2 \theta^2} ((\alpha + 2\theta)(\bar{x} - \underline{x}) - \theta^2 \bar{x})$. The interpretation and intuition of these comparative statics are similar to those in Case 1.

Comparing the optimal investments in Cases 1 and 2, one has

$$(15) \tilde{I}_{\{i,1\}} - I_{\{i,2\}}^* = \frac{D}{(\alpha + \theta)\theta} \left(\bar{x} - \underline{x} - \left(\frac{1}{1+k} - \theta(1 - \bar{x}) \right) \right), \text{ where } i = \{t, p\}.$$

Since $\frac{D}{(\alpha + \theta)\theta} > 0$, the sign of (15) depends on whether $\bar{x} - \underline{x} > \frac{1}{1+k} - \theta(1 - \bar{x})$. That is, the relative size of the two investments depends on the position and length of the interval $[\underline{x}, \bar{x}]$, as reflected by \bar{x} and $\bar{x} - \underline{x}$ respectively, and parameters θ and k . Two extreme scenarios deserve attention. In the first extreme scenario, the port and the tenant will invest less in period 2 than in period 1 if the length of the interval $[\underline{x}, \bar{x}]$ is large enough such that $\bar{x} - \underline{x} > \frac{1}{1+k}$. This corresponds to the outcome in which there is little information gain from waiting, that is, the interval $[\underline{x}, \bar{x}]$ didn't shrink much from $[0, 1]$. Another extreme scenario is that the interval $[\underline{x}, \bar{x}]$ is so narrow that $\bar{x} - \underline{x} \approx 0$, and $\bar{x} < 1 - \frac{1}{\theta(1+k)}$. This corresponds to the outcome in which there is a lot of information gains but the risk of natural disaster turns out to be very low.

We summarize the results on optimal investment for the port and the tenant without coordination in the following proposition.

Proposition 1. For the port and the tenant, which make their investment decisions independently without coordination,

- (1) both early investment in period 1 and late investment in period 2 decrease in α , whereas early investment increases in the time discount factor k and late investment is independent with k ;
- (2) both early investment and late investment increase in θ when θ is not too large while decrease in θ when θ is too large since investments bring no extra benefits other than reducing the damage of possible disasters; and
- (3) whether the scale of late investment should be increased or decreased than the early investment depends on many parameters, e.g., θ, k, α , etc.

4. Investment with Coordination

In order to evaluate the effects of government involvements (i.e., whether government should decide the investment responsibility of port and tenant), Case 3 and Case 4 are solved as follows.

4.1. Case 3

In Case 3, investment is made in period 1, and I_p and I_t are coordinated in order to maximize the expected total profits of the port and the tenant based on the perceived probability. The objective function is specified as

$$(16) \quad MAX_{I_p, I_t} \pi_3 = \pi_{\{p,1\}} + \pi_{\{t,1\}} = (1+k) \left[R_p + R_t - \int_0^1 \text{Max}\{0, Dx - (\theta I_p + \alpha I_t)\} dx - \int_0^1 \text{Max}\{0, Dx - (\theta I_t + \alpha I_p)\} dx \right] - (I_p + I_t).$$

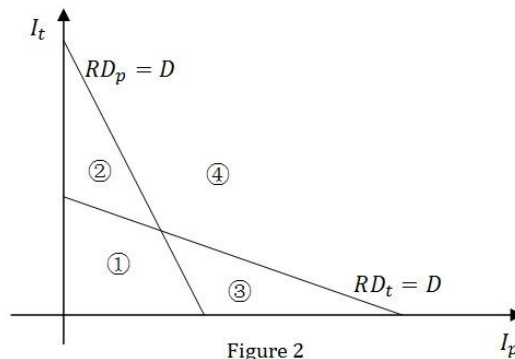
It can be shown that for $i = \{p, t\}$, one has

$$(17) \quad \int_0^1 \text{Max}\{0, Dx - RD_i\} dx = \begin{cases} \int_{RD_i/D}^1 Dx - RD_i dx, & RD_i \leq D \\ 0, & RD_i > D \end{cases}$$

Thus that the objective function of the government can be rewritten as

$$(18) \quad MAX_{I_p, I_t} \pi_3 = \begin{cases} (1+k) \left[R_p + R_t - \frac{1}{2D} \left((D - RD_p)^2 + (D - RD_t)^2 \right) \right] - (I_p + I_t), & (I_p, I_t) \in \\ (1+k) \left[R_p + R_t - \frac{1}{2D} (D - RD_p)^2 \right] - (I_p + I_t), & (I_p, I_t) \in \\ (1+k) \left[R_p + R_t - \frac{1}{2D} (D - RD_t)^2 \right] - (I_p + I_t), & (I_p, I_t) \in \\ (1+k)(R_p + R_t) - (I_p + I_t), & (I_p, I_t) \in \end{cases},$$

where the investment decision areas ①-④ are represented in Figure 2.



Solving the first-order conditions $\frac{\partial \pi_3}{\partial I_i} = 0, i = \{p, t\}$, the optimal solutions can be obtained as

$$(19) \quad \tilde{I}_{\{p,3\}} = \tilde{I}_{\{t,3\}} = \frac{D}{\alpha + \theta} \left(1 - \frac{1}{(\theta + \alpha)(1+k)} \right).$$

The perceived expected profits for the port and the tenant can be calculated correspondingly as

$$(20) \quad \tilde{\pi}_{\{i,3\}} = (1+k) \left[R_i - \frac{1}{2D} (D - \tilde{RD}_{\{i,3\}})^2 \right] - \tilde{I}_{\{i,3\}},$$

where $i = \{p, t\}$, $\tilde{RD}_{\{p,3\}} = \theta \tilde{I}_{\{p,3\}} + \alpha \tilde{I}_{\{t,3\}}$ and $\tilde{RD}_{\{t,3\}} = \theta \tilde{I}_{\{t,3\}} + \alpha \tilde{I}_{\{p,3\}}$. Since the true probability distribution of x is $U(\underline{x}, \bar{x})$ rather than $U(0,1)$, the actual expected payoffs for the port and the tenant is $\tilde{\Pi}_{\{i,3\}} = (1+k) \left[R_i - \int_{\underline{x}}^{\bar{x}} \text{Max}\{0, Dx - \tilde{RD}_{\{i,3\}}\} \frac{1}{\bar{x} - \underline{x}} dx \right] - \tilde{I}_{\{i,3\}}$, which can be specified as follows:

$$(21) \quad \tilde{\Pi}_{\{i,3\}} = \begin{cases} (1+k) \left[R_i - D \left(\frac{\bar{x} + \underline{x}}{2} - \left(1 - \frac{1}{(\theta + \alpha)(1+k)} \right) \right) \right] - \tilde{I}_{\{i,3\}}, & \text{if } 1 - \frac{1}{(\theta + \alpha)(1+k)} \leq \underline{x} \\ (1+k) \left[R_i - \frac{D}{2(\bar{x} - \underline{x})} \left(\bar{x} - \left(1 - \frac{1}{(\theta + \alpha)(1+k)} \right) \right)^2 \right] - \tilde{I}_{\{i,3\}}, & \text{if } \underline{x} < 1 - \frac{1}{(\theta + \alpha)(1+k)} < \bar{x} \\ (1+k) R_i - \tilde{I}_{\{i,3\}}, & \text{if } 1 - \frac{1}{(\theta + \alpha)(1+k)} \geq \bar{x}, \end{cases}$$

It is easy to show that $\frac{\partial \tilde{I}_{\{p,3\}}}{\partial k} = \frac{\partial \tilde{I}_{\{t,3\}}}{\partial k} > 0$, but the signs of other comparative statics are not straightforward, where

$$(22) \quad \frac{\partial \tilde{I}_{\{p,3\}}}{\partial \alpha} = \frac{\partial \tilde{I}_{\{t,3\}}}{\partial \alpha} = \frac{\partial \tilde{I}_{\{p,3\}}}{\partial \theta} = \frac{\partial \tilde{I}_{\{t,3\}}}{\partial \theta} = \frac{\partial \tilde{I}_{\{p,3\}}}{\partial (\alpha + \theta)} = \frac{\partial \tilde{I}_{\{t,3\}}}{\partial (\alpha + \theta)} = \frac{D}{(\alpha + \theta)^3} \left(\frac{2}{1+k} - (\alpha + \theta) \right).$$

Intuitively, in Case 3 the government aims to maximize the sum of the subjectively perceived expected profits of the port and the tenant by choosing optimal I_p and I_t jointly. The benefit derived from unit investment is $\alpha + \theta$, and there will be no free riding problem in choosing optimal capacity. Therefore, if $\alpha + \theta$ is very large optimal investment may be reduced to avoid over-investment.

4.2 Case 4

In Case 4, investments are postponed to the second period when the true distribution of x is known. Investments I_p and I_t are jointly chosen to maximize the sum of the actual expected profits of the port and the tenant. Thus, the objective function is specified as

$$(23) \quad \text{MAX}_{I_p, I_t} \Pi_4 = \Pi_{\{p,2\}} + \Pi_{\{t,2\}} = \left[R_p - \int_{\underline{x}}^{\bar{x}} Dx \frac{1}{\bar{x} - \underline{x}} dx \right] + \left[R_t - \int_{\underline{x}}^{\bar{x}} Dx \frac{1}{\bar{x} - \underline{x}} dx \right] + k \left[R_p - I_p - \int_{\underline{x}}^{\bar{x}} \text{Max}\{0, Dx - (\theta I_p + \alpha I_t)\} \frac{1}{\bar{x} - \underline{x}} dx + R_t - I_t - \int_{\underline{x}}^{\bar{x}} \text{Max}\{0, Dx - (\theta I_t + \alpha I_p)\} \frac{1}{\bar{x} - \underline{x}} dx \right].$$

As shown in appendix, solving the problem (23) yields the optimal capacity investments for the port and the tenant as follows:

$$(24) \quad I_{\{p,4\}}^* = I_{\{t,4\}}^* = \frac{D}{\alpha + \theta} \left(\bar{x} - \frac{1}{\alpha + \theta} (\bar{x} - \underline{x}) \right).$$

Similarly, the sign of the comparative statics in (25) cannot be determined. The interpretation and intuition are similar to the cases already solved.

$$(25) \quad \frac{\partial I_{\{p,4\}}^*}{\partial \alpha} = \frac{\partial I_{\{t,4\}}^*}{\partial \alpha} = \frac{\partial I_{\{p,4\}}^*}{\partial \theta} = \frac{\partial I_{\{t,4\}}^*}{\partial \theta} = \frac{\partial I_{\{p,4\}}^*}{\partial (\alpha + \theta)} = \frac{\partial I_{\{t,4\}}^*}{\partial (\alpha + \theta)} = \frac{D}{(\alpha + \theta)^3} (2(\bar{x} - \underline{x}) - \bar{x}(\alpha + \theta))$$

Comparing the optimal investments in Cases 3 and 4 yields

$$(26) \tilde{I}_{\{i,3\}} - I_{\{i,4\}}^* = \frac{D}{(\alpha+\theta)^2} \left(\bar{x} - \underline{x} - \left(\frac{1}{1+k} - (\alpha + \theta)(1 - \bar{x}) \right) \right),$$

where $i = \{t, p\}$, we have the similar comparison results of the optimal investments for the port and the tenant between Case 3 and Case 4 as that between Case 1 and Case 2.

We summarize the results on optimal coordinated investment for the port and the tenant in the following proposition.

Proposition 2. For the port and the tenant, whose investment decisions are coordinated by the government,

- (1) early coordinated investment in period 1 increases in the time discount factor k while late coordinated investment in period 2 is independent with k ;
- (2) the parameter θ and α have same effects on optimal coordinated investment. More specifically, both early coordinated investment and late coordinated investment increase in θ and α when $\alpha + \theta$ is not too large while decrease in θ and α when $\alpha + \theta$ is too large since investments bring no extra benefits other than reducing the damage of possible disasters; and
- (3) whether the scale of late coordinated investment should be increased or decreased than the early coordinated investment depends on many parameters, e.g., θ, k, α , etc.

Moreover, comparing the optimal investments by different decision-makers in same period (period 1 or period 2), one has

$$(27.1) \tilde{I}_{\{i,1\}} - \tilde{I}_{\{i,3\}} = \frac{D}{(\alpha+\theta)(1+k)} \left(\frac{1}{\alpha+\theta} - \frac{1}{\theta} \right) < 0$$

$$(27.2) I_{\{i,2\}}^* - I_{\{i,4\}}^* = \frac{D(\bar{x}-\underline{x})}{(\alpha+\theta)} \left(\frac{1}{\alpha+\theta} - \frac{1}{\theta} \right) < 0,$$

where $i = \{t, p\}$. Therefore, we further have the following proposition on the optimal investment for the port and the tenant.

Proposition 3. For the port and the tenant, the optimal coordinated investment (including early investment in period 1 and late investment in period 2) decided by the government is always larger than the investment decided by themselves.

5. Effects of Investment Timing and Coordination

In order to identify the best corporate strategy and government policy, in this section, we compare the market outcomes across the four cases studied above. We will first examine the effects of investment timing. Then we will examine the effects of government intervention on investment amount.

5.1. Invest earlier or wait?

In this subsection, we will examine the effects of investment timing by comparing Case 1 vs. Case 2 and Case 3 vs. Case 4.

Comparison between Case 1 and Case 2

In these two cases, the port and the tenant decide their optimal investments respectively. The main difference is that in Case 2 the true probability of x is known, whereas in Case 1 decisions can only be made upon perceived probability. Therefore, comparison between these two cases will allow us to evaluate the cost and

benefits associated with early investment. On the one hand, an early investment in period 1 allows a longer time for investment to pay off. On the other hand, a late investment in period 2 allows optimal capacity to be invested based on a better understanding of the risks associated with natural disasters, thus that there will be no efficiency loss associated with over-investments or sub-investments.

To identify whether early or late investment is a better choice for the port and tenant, one need to compare the actual expected profit in the two cases. As reported in Equation (10), the actual expected profits for the port and the tenant in Case 1 are piecewise functions. Comparison results suggest that if $1 - \frac{1}{\theta(1+k)} \leq \underline{x}$, the actual expected profits of the port and the tenant in Case 1 are always larger than those in Case 2. However, if $\bar{x} \leq \min\left\{\frac{1}{4\theta+k}, \frac{k}{(k+1)(k+2)}\right\}$, then the actual expected profits of the port and the tenant in Case 2 are always larger than those in Case 1. Otherwise the relative size of the expected profits in the two cases depends on parameters θ, α, k and \underline{x}, \bar{x} . Intuitively, when $1 - \frac{1}{\theta(1+k)} \leq \underline{x}$, the natural disaster happens with high probability in each period, and thus the benefits associated with early investment outweigh possible information gains by waiting till the second period. Therefore, it is always better to make early investment. However, if the probability of the natural disaster in each period is very low (i.e. $\bar{x} \leq \min\left\{\frac{1}{4\theta+k}, \frac{k}{(k+1)(k+2)}\right\}$), the benefits associated with longer pay-off time cannot offset the negative effects associated with sub-optimal investments. It is better to postpone investment to period 2 in order to get a better understanding of the risk associated with natural disasters. Otherwise if the probability of natural disaster is neither too high nor too low, the optimal timing will depend on many factors which determine the relative size of the benefits associated with information gains against the benefits associated with longer payoff time.

Comparison between Case 3 and Case 4

In these two cases, the government decides the investment for the port and the tenant. In Case 3, the government makes investment decision in period 1 by his perceived probability distribution of x while, in Case 4, the government makes investment decision in period 2 after the true probability distribution of x is known.

By comparing the actual expected profit in the two cases, similar conclusions as in Case 1 vs. Case 2 can be obtained. More specifically, if $1 - \frac{1}{(\theta+\alpha)(1+k)} \leq \underline{x}$, for both the port and the tenant, the actual expected profits in Case 3 are always larger than that in Case 4. However, if $\bar{x} \leq \min\left\{\frac{1}{4\theta+k}, \frac{1+2k}{2(k+1)(k+2)}, \frac{1}{k} - \frac{2}{k(1+k)\theta}\right\}$, the converse conclusion holds, i.e., the actual expected profits of the port and the tenant in Case 4 are always larger than that in Case 3. Otherwise the relative size of the actual expected profits for the port and the tenant in the two cases depends on parameters θ, α, k and \underline{x}, \bar{x} . Also, the intuition here is similar to Case 1 vs. Case 2.

The comparison results and relative conditions for the effects of investment timing are summarized in the following table.

	Period 1		Period 2	Conditions
Investment by port and tenant	EP of Case 1	>	EP of Case 2	$\underline{x} \geq 1 - \frac{1}{\theta(1+k)}$
		<		$\bar{x} \leq \min\left\{\frac{1}{4\theta+k}, \frac{k}{(k+1)(k+2)}\right\}$
Investment by government	EP of Case 3	>	EP of Case 4	$\underline{x} \geq 1 - \frac{1}{(\theta+\alpha)(1+k)}$
		<		$\bar{x} \leq \min\left\{\frac{1}{4\theta+k}, \frac{1+2k}{2(k+1)(k+2)}, \frac{1}{k} - \frac{2}{k(1+k)\theta}\right\}$

Table 1. Profit comparison between earlier and later investment (EP=Expected profit)

5.2. Is coordination always better?

After the study of investment timing, we proceed to examine the effects of government intervention on investment amount. As derived above, when decisions are made by the port and the tenant (instead of the government) their optimal investments, no matter in period 1 or period 2, decrease in \bar{x} . That is, the port and the tenant will invest less if they could benefit more from their partner's investment. Intuitively, if the decision is made by the government, such a free ride problem can be avoided. However, whether this will benefit the industry is not self-evident. This issue is investigated by comparing Case 1 vs. Case 3 and Case 2 vs. Case 4.

Comparison between Case 1 and Case 3

In both cases, investments are made in period 1 based on perceived probability distribution of x . In Case 1 investment decision is made by the port and the tenant. However, in Case 3 investments are coordinated, which overcomes the free riding problem as evidenced by (27.1).

However, since the actual expected profits are piecewise functions (i.e. eq. (10) and eq. (20) respectively), actual profits are dependent on the true distribution of x . There is no general conclusion on profit comparisons. Still, two extreme cases are worth to be noted. When $\underline{x} \geq 1 - \frac{1}{(\theta + \alpha)(1 + k)}$, it can be concluded that $\tilde{\Pi}_{\{i,1\}} \leq \tilde{\Pi}_{\{i,3\}}, i = \{t, p\}$, that is, if there is a high chance of disasters, the port and the tenant will be better off if their investments are coordinated or mandated by government. However, if $\bar{x} \leq 1 - \frac{1}{\theta(1 + k)}$, then $\tilde{\Pi}_{\{i,1\}} \geq \tilde{\Pi}_{\{i,3\}}, i = \{t, p\}$, that is, when disaster is not likely to occur, the port and the tenant will be worse off if investments are coordinated. The intuition is clear: although coordination overcomes the free riding problem thus leads to larger investment, coordinated investments are not based on better knowledge of the disaster, and thus, may lead to over-investment when the risk of natural disaster is actually low. Therefore, government intervention or coordination on investments may either improve or reduce the port industry's well-being.

Comparison between Case 2 and Case 4

In both cases, investments are decided in period 2 based on the actual probability distribution of x . In Case 2 investment decisions are made by the port and tenant, whereas in Case 4 the government imposes/coordinates investments. As expected, government coordination leads to higher capacity and expected profit. The intuition is that with the same knowledge of the probability of natural disasters, government intervention eliminates the free riding problem and thus leads to optimal investment, as shown in (27.2) and (28).

$$(28) \Pi_{\{i,2\}}^* < \Pi_{\{i,4\}}^*, \text{ where } i = \{t, p\}.$$

We summarize the comparison results and the conditions needed for the effects of government intervention in the following table.

	Investment by port and tenant		Investment by government	Conditions
Period 1	EP of Case 1	$>$	EP of Case 3	$\bar{x} \leq 1 - \frac{1}{\theta(1 + k)}$
		$<$		$\underline{x} \geq 1 - \frac{1}{(\theta + \alpha)(1 + k)}$
Period 2	EP of Case 2	$<$	EP of Case 4	No condition required

Table 2. Profit comparison between coordinated and individual investment (EP=Expected profit)

The comparison results in Tables 1 and 2 suggest that if there is a high risk of disaster then both the port and the tenant will be better off if the government requires early investment and coordinates/mandates investment

amounts for the port and the tenant. That is, when $\underline{x} \geq 1 - \frac{1}{(\theta+\alpha)(1+k)}$, we have $\Pi_{\{i,2\}}^* < \tilde{\Pi}_{\{i,1\}} \leq \tilde{\Pi}_{\{i,3\}}$ and $\Pi_{\{i,4\}}^* < \tilde{\Pi}_{\{i,3\}}, i = \{t, p\}$. Otherwise if the risk of disaster is very low, the best outcome to both the port and the tenant is achieved if investment is postponed to period 2 and coordinated by the government. In our model, when $\bar{x} \leq \min\left\{\frac{1}{4\theta+k}, \frac{k}{(k+1)(k+2)}, \frac{1}{k} - \frac{2}{k(k+1)\theta}, 1 - \frac{1}{\theta(k+1)}\right\}$ it can be shown that $\tilde{\Pi}_{\{i,1\}} < \Pi_{\{i,2\}}^* < \Pi_{\{i,4\}}^*$ and $\tilde{\Pi}_{\{i,1\}} < \tilde{\Pi}_{\{i,3\}} < \Pi_{\{i,4\}}^*, i = \{t, p\}$. The intuition is that if there is a low risk of disaster then investment should be postponed, thus that optimal decision can be made based on better knowledge of the risk. In addition, when such information is available in period 2, it is always better to let the government to coordinate investments which would overcome the free riding problem.

It should be emphasized that coordination of investments, either by the port industry itself or imposed by government is not always a good solution. Numerical simulations confirmed that when the probability of disaster is neither too high nor too low, letting the port and the tenant choose their own investments in period 1 can be the best solution. This is a new finding in the literature. The intuition is that the coordinated investment is always higher than the independent choices by the port and the tenant due to the removal of free ride problem. However, without knowing the true risk associated with the disaster in period 1, there is a possibility of over-investment. Such a result manifests the importance to consider all the important factors, such as uncertainty, investment timing and externality in an integrated model.

We end this section with the following proposition which summarizes the optimal decisions of investment for the port and the tenant.

Proposition 4. With the information uncertainty of natural disaster, early coordinated investment and late coordinated investment are the optimal investment for the port and the tenant when the risk of disaster is very high and very low respectively. However, coordination of investments is not always a good solution. Early investment by the port and the tenant may be a good solution when the probability of disaster is neither too high nor too low.

6. Concluding Remarks

Ports are of critical importance to international trade and the global economy. With the rapid development of port-focal logistics (Ng and Liu, 2014) and multimodal transport systems, more and more activities are carried out on port's land by stakeholders such as terminal operators, warehouse keeper and logistics operators, and more logistics parks, office buildings, hotels and other infrastructures are built within or proximate to ports. If ports and their tenants fail to secure sufficient investments in preventing or alleviating disasters, major damage and financial loss could happen to the port community and the whole society.

Due to climate change and global warming, there have been significant increases in the frequency and magnitude of coastal and marine natural disasters. However, so far, only a handful of major disaster-preventing investments have been committed or carried out. Numerous factors could have been blamed for: since such investments could benefit both ports and their tenants, both sides have an incentive to free ride. In addition, there is yet to be a good understanding of the risks and consequences of coastal and marine natural disasters. As a consequence, even if ports could obtain financial support from governments, they may prefer to use them on other more prioritized areas (e.g., business expansion) instead of disaster-prevention facilities. Although governments might coordinate or mandate investments for ports and tenants, they do not necessarily have better knowledge than the port industry. Therefore, it is unclear what the optimal policy is, and to what extent government should intervene in decisions such as investment timing and scale.

Hence, this study constructs an integrated model with which the decision-making processes of port, tenant and regulator can be characterized. The investigation results suggest that there are tradeoffs for making early investments: an early investment allows a longer time for investment to payoffs, while postponing investment allows stakeholders to get a better understanding of the risk associated with disasters, thus that there will be no (or minimal) over-investments or sub-investments. Without government's coordination, the port and the tenant will reduce their own investments if they could benefit more from the other side's investment, while

government's coordination will increase the investment amount due to the removal of free riding problem. However, this does not necessarily lead to better outcomes overall because, as mentioned earlier, governments usually have no better information about natural and marine disaster risks than the port community. There are times when government's coordination or intervention could lead to even more severe over-investments. In such cases, whether the government should decide the timing and amount of investments remains an open question subject to further research.

Having say so, this study does identify conditions under which government should make all decisions related to investment timing and amount. In particular, if there is a high risk of disaster then the government should require early investment and mandate the investment amounts for the port and the tenant. Otherwise if the risk of disaster is very low, the best outcome will be achieved if investments are postponed to a later stage with coordination. Other than identifying the conditions for full government intervention, a major finding is that both the port and the tenant can be better off by letting the government play more important roles. Most studies have justified government regulation and subsidy because of the existence of negative externalities (e.g., pollution) to the society or welfare. This is different from the scenario considered in this study, where only profits of the port community are considered.

Another major contribution of our study is the demonstration of the value of a better understanding of natural disasters, since the choices of optimal corporate strategy and government policy are all dependent on the true probability distribution of disasters. Therefore, government supports to scientific research of natural disasters are of both operational value and economic significance. Research fund and subsidy on relevant R&D efforts will not only benefit the global community in terms of saving lives and protecting the environment, but will also bring about substantial economic returns, and thus should be strongly encouraged. Also, our modelling results explain why major investments against in preventing or alleviating natural disasters (including climate change) have not been frequently observed: as analytical shown in our model, a port or a tenant will only commit large investments if it has a large economic stake, cannot free ride others, has a vision for the future, and when the investment is (but not too) effective. Investment against natural disasters is a very complex decision involving numerous determinants, and it is important to develop an integrated model taking into account of the important factors which may interact with each other. Further research is urgently required to further validate our analysis in this paper, notably the collection of relevant reliable time-series data which is serious lacking at the moment. This pioneer study provides the ideal platform for us to do so.

Acknowledgments

Adolf K.Y. Ng is funded by the University of Manitoba's University Research Grant Program (URGP) (project no: 42227) for this study.

References

- Arrow, K.J. and Fisher, A.C. (1974), Environmental preservation, uncertainty, and irreversibility, *Quarterly Journal of Economics* 88 (1): 312–319.
- Barrett, S. (1994), Self-enforcing international environmental agreements, *Oxford Economic Papers* 46: 878–894.
- Berechman, J. and Tseng, P.H. (2012), Estimating the environmental costs of port related emissions: the case of Kaohsiung, *Transportation Research Part D: Transport and the Environment* 17: 35–38.
- Basso, L.J., Wan, Y. and Zhang, A. (2014), Seaport competition, regional cooperation and strategic investment in accessibility, Working paper, Sauder School of Business, University of British Columbia.
- Cantore N., Peskett L. and te Velde D.W. (2009), Climate negotiations and development - How can low-income countries gain from a Climate Negotiation Framework Agreement?, *Overseas Development Institute Working Paper* 312.
- Carraro, C. and Siniscalco, D. (1993), Strategies for the international protection of the environment, *Journal of Public Economics* 52: 309–328.
- Carraro, C. and Siniscalco, D. (1998), International environmental agreements: incentives and political economy, *European Economic Review* 42: 561–572.
- Cooper R.N. (1998), Toward a real global warming treaty, *Foreign Affairs* 77(2): 66–79.

- Depoorter, B. (2006), Horizontal political externalities: the supply and demand of disaster management, *Duke Law Journal* 56(1):101-125.
- Dixit, A.K. and Pindyck, R.S. (1994), *Investment Under Uncertainty*, Princeton, NJ: Princeton University Press.
- Eide, M.S., Longva, T., Hoffman, P., Endresen, O. and Dalsoren, S.B. (2011), Future cost scenarios for reduction of ship CO₂ emissions, *Maritime Policy & Management* 38(1): 11-37.
- El-Raey, M. (1997), Vulnerability assessment of the coastal zone of the Nile delta of Egypt, to the impacts of sea level rise, *Ocean and Coastal Management* 37(1): 29-40.
- Fisher, A.C. (2001), Uncertainty, irreversibility and the timing of climate policy, Paper presented to PEW Center for Global Climate Change, October 10–12.
- Fisher, A.C. and Narain, U. (2003), Global warming, endogenous risk, and irreversibility, *Environmental and Resource Economics* 25: 395–416.
- Gollier, C. (2006), An evaluation of stern's report on the economics of climate change, IDEI working paper no. 464, University of Toulouse.
- Henry, C. (1974), Investment decisions under uncertainty: the irreversibility effect, *American Economic Review* 64: 1066-1012.
- Hoel, M. (1991), Global environmental problems: the effects of unilateral actions taken by one country, *Journal of Environmental Economics and Management* 20: 55–70.
- Hoel, M. (1997), Coordination of environmental policy for transboundary environmental problems, *Journal of Public Economics* 66: 199–224.
- Homsombat W., Yip, T.L., Yang, H. and Fu, X. (2013), Regional cooperation and management of port pollution, *Maritime Policy & Management* 40(5): 451-466.
- Jevrejeva, S., Moore, J.C. and Grinsted, A. (2012), Sea level projections to AD2500 with a new generation of climate change scenarios, *Global and Planetary Change* 81: 14-20.
- Keohane, R.O. and Victor, D.G. (2010), The regime complex for climate change, Discussion paper, The Harvard Project on International Climate Agreements, Cambridge, MA 2010-33.
- Kolstad, C.D. (1996), Learning and stock effects in environmental regulation: the case of greenhouse gas emissions, *Journal of Environmental Economics and Management* 31:1–18.
- Kunreuther, H. (1996), Mitigating disaster losses through insurance. *Journal of Risk and Uncertainty* 12: 171-187.
- Lam J.S.L., Ng, A.K.Y. and Fu, X. (2013), Stakeholder management for establishing sustainable regional port governance, *Research in Transportation Business and Management* 8: 30-38.
- Martin, J. and Thomas, B.J. (2001), The container terminal community, *Maritime Policy & Management* 28(3): 279-292.
- McGinnis, M.V. and McGinnis, C.E. (2011), Adapting to climate impacts in California: the importance of civic science in local coastal planning, *Coastal Management* 39: 225-241.
- Min, S., Zhang X., Zwiers F. and Hegerl, G. (2011), Human contribution to more-intense precipitation extremes, *Nature* 470: 378-381.
- National Research Council of the USA (2010), *Advancing the Science of Climate Change*, National Academies Press, Washington, DC.
- Ng, A.K.Y., Becker, A. and Fischer, M. (2013), A theoretical discussion on climate change, port adaptation strategies and institutions, *Proceedings of the Canadian Transportation Research Forum*, Halifax, NS, Canada, 10-11 June.
- Ng, A.K.Y. and Liu, J.J. (2014), *Port-Focal Logistics and Global Supply Chains*, Palgrave Macmillan, New York.
- Ng, A.K.Y. and Pallis, A.A. (2010), Port governance reforms in diversified institutional frameworks: generic solutions, implementation asymmetries, *Environment and Planning A* 42(9): 2147-2167.
- Nordhaus, W.D., 1994. Expert opinion on climate change. *American Scientist* 82, 45–51.
- Nordhaus, W.D. (2007), A Review of the Stern Review on the Economics of Climate Change, *Journal of Economic Literature* 45: 686-702.
- Pall P., Aina T., Stone D., Stott P., Nozawa T., Hilberts A., Lohmann D. and Allen M. (2011), Anthropogenic greenhouse gas contribution to flood risk in England and Wales in autumn 2000, *Nature* 470: 382-385.
- Pearce, D. (1991), The role of carbon taxes in adjusting to global warming, *The Economic Journal* 101 (407): 938-948.

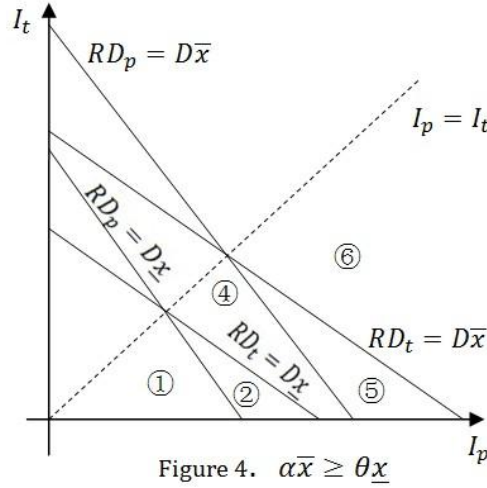
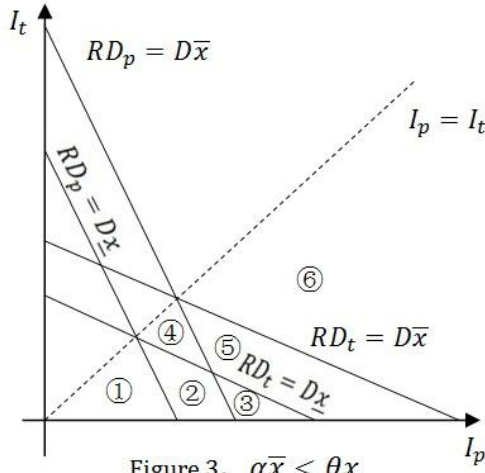
- Pindyck, R.S. (2000), Irreversibilities and the timing of environmental policy, *Resource and Energy Economics* 22: 233-59.
- Pindyck, R.S. (2002), Optimal timing problems in environmental economics, *Journal of Economic Dynamics and Control* 26: 1677-1997.
- Pindyck, R.S. (2007), Uncertainty in environmental economics, *Review of Environmental Economics and Policy* 1(1): 45-65.
- Roughgarden, T. and Schneider, S.H. (1999), Climate change policy: quantifying uncertainties for damages and optimal carbon taxes, *Energy Policy* 27: 415-29.
- Sanchez-Arcilla, A., Jimenez, J.A., Stive, M.J.F., Ibanez, C., Pratt, N., Day Jr., J.W. and Capobianco, M. (1996), Impacts of sea-level rise on the Ebro Delta: a first approach. *Ocean and Coastal Management* 30(2-3): 197-216.
- Schaeffer, M., Hare, W., Rahmstorf, S. and Vermeerm, M. (2012), Long-term sea-level rise implied by 1.5 °C and 2 °C warming levels, *Nature Climate Change* 2: 867-870.
- Sebenius, J. (1991), Designing negotiations toward a new regime: the case of global warming, *International Security* 15 (4): 110-148.
- Stern, N. (2007), *The Economics of Climate Change: The Stern Review*, Cambridge.
- Tobey, J., Rubinoff, P., Robadue Jr., D., Ricci, G., Volk, R., Furlow, J. and Anderson, G. (2010), Practicing coastal adaptation to climate change: lessons from integrated coastal management, *Coastal Management* 38: 317-335.
- UNCTAD (2012), *Ad Hoc Expert Meeting on Climate Change Impacts and Adaptation: A Challenge for Global Ports*: Geneva, Palais des Nations, 29-30 September 2011: Main Outcomes and Summary of Discussions, UNCTAD, Geneva, Switzerland.
- Wang, J.J., Ng, A.K.Y. and Olivier, D. (2004), Port governance in China: a review of policies in an era of internationalising port management practices, *Transport Policy* 11(3): 237-250.
- Weitzman, M.L. (2007), A review of the stern review on the economics of climate change, *Journal of Economic Literature* 45: 703-724.
- Xiao, Y., Fu, X. and Zhang, A. (2013), Demand uncertainty and airport capacity choice, *Transportation Research Part B: Methodological* 57: 91-104.
- Xiao, Y., Ng, A.K.Y., Yang, G. and Fu, X. (2012), An analysis of the dynamics of ownership, capacity investments and pricing structure of ports, *Transport Reviews* 32(5): 629-652.
- Yuen, A. and Zhang, A. (2011), Unilateral regulation and greenhouse gas emissions: The case of the airline industry, *Transportation Research, Part D: Transport and Environment* 16: 540-546.
- Zhang, D.D., Brecke, P., Lee, H.F., He, Y. and Zhang, J. (2007), Global climate change, war and population collapse during the recent human history, *Proceedings of the National Academy of Sciences of the United States of America* 104(49): 19214-19219.

Appendix: Optimal investment with coordination in period 2

In order to get the optimal investment solution by solving the problem (23), we consider the two scenarios of $I_p \geq I_t$ and $I_p < I_t$.

Scenario One: $I_p \geq I_t$

In this scenario, $I_p \geq I_t$ implies that $RD_p \geq RD_t$. The objective function in (23) can be specified for the following six sub-cases based on the ranges of I_p and I_t as defined in Figure 3 and Figure 4.



Sub-case I: If $RD_p \leq D\underline{x}$, i.e., $(I_p, I_t) \in$ in Figure 3 or Figure 4, objective function (23) can be simplified as

$$(A.1) \quad \text{MAX}_{I_p, I_t} \pi_4 = \left[R_p - \int_{\underline{x}}^{\bar{x}} D\underline{x} \frac{1}{\bar{x}-\underline{x}} dx \right] + \left[R_t - \int_{\underline{x}}^{\bar{x}} D\underline{x} \frac{1}{\bar{x}-\underline{x}} dx \right] + k \left[R_p - I_p - \int_{\underline{x}}^{\bar{x}} D\underline{x} - (\theta I_p + \alpha I_t) \frac{1}{\bar{x}-\underline{x}} dx + R_t - I_t - \int_{\underline{x}}^{\bar{x}} (\theta I_t + \alpha I_p) \frac{1}{\bar{x}-\underline{x}} dx \right] = k [R_p - I_p + RD_p + R_t - I_t + RD_t - D(\bar{x} + \underline{x})].$$

Sub-case II: If $RD_t \leq D\underline{x}$ and $D\underline{x} < RD_p < D\bar{x}$, i.e., $(I_p, I_t) \in$ in Figure 3 or Figure 4, objective function (23) can be simplified as

$$(A.2) \quad \text{MAX}_{I_p, I_t} \pi_4 = \left[R_p - \int_{\underline{x}}^{\bar{x}} D\underline{x} \frac{1}{\bar{x}-\underline{x}} dx \right] + \left[R_t - \int_{\underline{x}}^{\bar{x}} D\underline{x} \frac{1}{\bar{x}-\underline{x}} dx \right] + k \left[R_p - I_p - \int_{RD_p/D}^{\bar{x}} D\underline{x} - (\theta I_p + \alpha I_t) \frac{1}{\bar{x}-\underline{x}} dx + R_t - I_t - \int_{\underline{x}}^{\bar{x}} (\theta I_t + \alpha I_p) \frac{1}{\bar{x}-\underline{x}} dx \right] = k \left[R_p - I_p - \frac{(D\bar{x} - RD_p)^2}{2D(\bar{x} - \underline{x})} + R_t - I_t - \frac{D(\bar{x} + \underline{x})}{2} + RD_t \right].$$

Sub-case III: If $RD_t \leq D\underline{x}$ and $RD_p \geq D\bar{x}$, i.e., $(I_p, I_t) \in$ in Figure 3 when $\alpha\bar{x} < \theta\underline{x}$, but as depicted in Figure 4, there is no feasible (I_p, I_t) when $\alpha\bar{x} \geq \theta\underline{x}$, then objective function (23) can be simplified as

$$(A.3) \quad \text{MAX}_{I_p, I_t} \pi_4 = \left[R_p - \int_{\underline{x}}^{\bar{x}} D\underline{x} \frac{1}{\bar{x}-\underline{x}} dx \right] + \left[R_t - \int_{\underline{x}}^{\bar{x}} D\underline{x} \frac{1}{\bar{x}-\underline{x}} dx \right] + k \left[R_p - I_p + R_t - I_t - \int_{\underline{x}}^{\bar{x}} (\theta I_t + \alpha I_p) \frac{1}{\bar{x}-\underline{x}} dx \right] = k \left[R_p - I_p + R_t - I_t - \frac{D(\bar{x} + \underline{x})}{2} + RD_t \right].$$

Sub-case IV: If $RD_t > D\underline{x}$ and $RD_p < D\bar{x}$, i.e., $(I_p, I_t) \in$ in Figure 3 or Figure 4, objective function (23) can be simplified as

$$(A.4) \quad MAX_{I_p, I_t} \pi_4 = \left[R_p - \int_{\underline{x}}^{\bar{x}} D x \frac{1}{\bar{x} - \underline{x}} dx \right] + \left[R_t - \int_{\underline{x}}^{\bar{x}} D x \frac{1}{\bar{x} - \underline{x}} dx \right] + k \left[R_p - I_p - \int_{RD_p/D}^{\bar{x}} D x - (\theta I_p + \alpha I_t) \frac{1}{\bar{x} - \underline{x}} dx + R_t - I_t - \int_{RD_t/D}^{\bar{x}} (\theta I_t + \alpha I_p) \frac{1}{\bar{x} - \underline{x}} dx \right] = k \left[R_p - I_p - \frac{(D\bar{x} - RD_p)^2}{2D(\bar{x} - \underline{x})} + R_t - I_t - \frac{(D\bar{x} - RD_t)^2}{2D(\bar{x} - \underline{x})} \right].$$

Sub-case V: If $D\underline{x} < RD_t < D\bar{x}$ and $RD_p \geq D\bar{x}$, i.e., $(I_p, I_t) \in$ in Figure 3 or Figure 4, objective function (23) can be simplified as

$$(A.5) \quad MAX_{I_p, I_t} \pi_4 = \left[R_p - \int_{\underline{x}}^{\bar{x}} D x \frac{1}{\bar{x} - \underline{x}} dx \right] + \left[R_t - \int_{\underline{x}}^{\bar{x}} D x \frac{1}{\bar{x} - \underline{x}} dx \right] + k \left[R_p - I_p + R_t - I_t - \int_{RD_t/D}^{\bar{x}} (\theta I_t + \alpha I_p) \frac{1}{\bar{x} - \underline{x}} dx \right] = k \left[R_p - I_p + R_t - I_t - \frac{(D\bar{x} - RD_t)^2}{2D(\bar{x} - \underline{x})} \right].$$

Sub-case VI: If $RD_t \geq D\bar{x}$, i.e., $(I_p, I_t) \in$ in Figure 3 or Figure 4, objective function (23) can be simplified as

$$(A.6) \quad MAX_{I_p, I_t} \pi_4 = \left[R_p - \int_{\underline{x}}^{\bar{x}} D x \frac{1}{\bar{x} - \underline{x}} dx \right] + \left[R_t - \int_{\underline{x}}^{\bar{x}} D x \frac{1}{\bar{x} - \underline{x}} dx \right] + k [R_p - I_p + R_t - I_t].$$

Scenario Two: $I_p < I_t$

In this scenario, condition $I_p < I_t$ implies that $RD_p < RD_t$. The objective function in (23) can be specified for another six sub-cases based on the ranges of I_p and I_t as in Scenario one, derivation details of which are not reported here.

Now, by applying the first-order conditions $\frac{\partial \pi_4}{\partial I_i} = 0, i = \{p, t\}$ to different cases in the above two scenarios, the optimal capacity investments can be obtained as follows:

$$(A.7) \quad I_{\{p,4\}}^* = I_{\{t,4\}}^* = \frac{D}{\alpha + \theta} \left(\bar{x} - \frac{1}{\alpha + \theta} (\bar{x} - \underline{x}) \right)$$

Thus, the actual expected payoffs across two periods for the port and the tenant can be obtained accordingly.

ⁱ "Russia completes Soviet-era dam in St Petersburg", Reuters report, Aug 13, 2011.

ⁱⁱ "The Japanese mayor who was laughed at for building a huge sea wall - until his village was left almost untouched by tsunami", MailOnline, 14 May 2011.

ⁱⁱⁱ Information retrieved at <http://www.portofthefuture.com/>, a website created for distribution of information related to the rebuilt efforts by the Mississippi State Port Authority at Gulfport. It appeared that the decision of reducing the pier elevation was mostly based on business considerations instead of scientific research. One port commissioner stated that "I personally feel that if we get our elevation up to somewhere around 15 feet that's going to mean something to somebody that is bringing cargo to our port to be exported. I personally feel that if we get it up to 15 feet we'll be in good shape", another commissioner was quoted that "That's based on 15 being something our contractor told us he could reach in a relative quick period of time. 12 or 14 being what some of our tenants said was comfortable for them". <http://www.portofthefuture.com/news-headlines/port-authority-nixes-25-feet-elevation-for-gulfport/>.

^{iv} For example, Min et al. (2011) and Pall et al. (2011) pointed out that GHG emissions might increase the occurrence or the strength of weather related natural disasters.

^v In a way the specification used here is similar to insurance, where insurance is purchased *ex ante* whereas compensation is delivered *ex post* in the case of a loss. Indeed, studies such as Kuneruther (1996) argued that disaster might be mitigated through insurance. However, insurance involves two opposing parties (i.e. insurer vs. insured), a scenario different from the "horizontal" externality considered in our analysis. In addition, insurance arrangements often involve information asymmetry and monitoring efforts for insured party's damage prevention efforts. For example, Kuneruther (1996) proposed disaster insurance coupled with well-enforced building code (i.e. disaster prevention investment from the insured). This would be a very different setting compared to our model.

^{vi} For example, the United Nations International Strategy for Disaster Reduction (UNISDR) has helped building disaster loss databases in more than 60 countries (www.desinventar.net), and has jointly launched initiatives with the Indian Ocean Commission to "provide governments with a new, more robust methodology that will enable them to calculate the nature and extent of future risks with much more accuracy, particularly those related to weather and climate hazards." - the Indian Ocean Commission, "New Methods to protect our people and our economy against disaster risk and climate change".

^{vii} In practice, certain port facilities may be enlarged with additional investments. In fact, such flexibility may be obtained with additional investments or the arrangements of real options. Extended study with such a possibility may bring new insights on this important issue.

Impact of Government Policies on FDI in Indian Port Sector

Girish Gujar¹, Hong Yan¹, Rachna Gangwar² and Mukul Jain³

¹Department of Logistics and Maritime Studies, The Hong Kong Polytechnic University, Hong Kong.

²Institute of Management Technology, Ghaziabad.

³Rail Vikas Nigam Limited, New Delhi.

Abstract

All developing countries are keen to attract foreign direct investment (FDI). Large FDI inflows are an affirmation of the liberal economic policies that the country is implementing as well as a confirmation of the economic health of that particular country. According to the World Bank, since 1990s, India has emerged as one of the attractive destinations for FDI globally, particularly in the infrastructure sector. However this does not indicate that all infrastructure development projects are equally successful in attracting FDI neither are all sectors open for foreign investments for a variety of reasons. Having said this, Indian port sector is an exception and has been able to attract a reasonable amount of FDI in the past decade. However, it is far from adequate as the sector is not considered to be attractive enough when compared to the port sector in other countries, notably China and Australia, due to the market distortions caused by the heavy presence of government owned and operated ports and allied infrastructure. The dominance of public sector and the 'service' oriented business model of Indian ports create conflicts of interest and unfair competition. This paper analyzes the impact of such unfair competition on the port sector as a whole and how it influences the flow of FDI by using a modified Solow model. The results reveal that the total factor productivity of the sector might be adversely affected due to the heavy market presence of the government thus causing the FDI inflows into this sector to slow down further. The paper concludes by making certain recommendations to resolve the conundrum.

Keywords: Market distortion, unfair competition, FDI, Ports, Solow model and India.

1. Introduction

FDI plays an important role in the economic development of emerging economies. Various papers have been dealing with measuring the impact of FDI on economic growth (Borensztein, De Gregorio & Lee, 1998; Alfaro, Chanda, Kalemli-Ozcan and Sayek, 2004; Bengoa and Sanchez Robles, 2003). A clear rising trend of FDI inflows during the last decades has been observed most of it being directed towards developing countries. The logic behind inviting FDI was that it would trigger productivity gains by sharing technology, managerial skills or facilitating market access. It is debatable whether the increasing share of FDI in emerging countries can crowd out local incentives to set up similar investments (Singh, K., 2005) or whether domestic investment (both public and private) act as an entry barrier for FDI.

Borensztein (1998) stressed in his paper that the success of FDI to a great extent also leads to improvement of human resources by way of skills, knowledge and managerial ability. Thus, FDI seems to be an important vehicle when it comes to the transfer of knowledge. Bengoa and Sanchez-Robles (2003) emphasize the relevance of economic freedom and macro-economic stability in the process of economic expansion. Their empirical model analyzes the interaction between economic freedom, FDI and economic growth based on a sample of Latin American countries for the time span of 30 years. They concluded that economic freedom is an important determinant for FDI inflows. Intuitively, this makes sense as easier access to markets enables foreign investors to make crucial investments e.g. in communication, transport networks and allied infrastructure.

In the early nineties, due to several policy related reasons, India was left with no option but to adopt an economic reform program aimed at transforming its inward looking economy into a market driven one based

on export-led growth and opening of certain sectors either fully or partially to FDI. Since then its economic performance has improved markedly. Some of the key indicators showing India's economic performance after economic reform are given in Table 1. The country's external trade, currently in excess of 900 million tons of cargo (exports and imports), is projected to double by the year 2020. This confronts the port sector, already operating beyond capacity, with the challenge to sustain this growth in a seamless, cost effective and efficient way. Undoubtedly, this pre condition to future economic development will require significant efforts towards further port modernization and coordinated port development.

Table 1. India's Key Economic Indicators

	2008-09	2009-10	2010-11
GNP (bln. IRP)	157,377.78	180,290.84	190,028.8
Average Exchange Rate (IRP/USD)	45.99	47.42	45.68
GNP (bln. USD)	3422	3802	4160
GNP Growth (IRP basis, %)	22.27	14.56	5.40
GNP Growth (USD basis, %)	7.04	11.10	9.42
Population (millions)	1154	1170	1186
Income per Capita (USD)	40,605	46,492	54,527
Wholesale Price Inflation (%)	8.0	3.6	9.4
External Debt (% of GNI)	18.73	18.21	16.9
Reserves (bln. USD, excluding gold)	252	279.1	297.3
Foreign Investment (mil. USD)	43.41	35.60	24.16

Source: Economic Survey, 2011; World

2. Indian Port Sector

India's coastline of approximately 7500kms enfolds 12 major and 187 minor ports. Of these, Kolkata, Paradip, Vishakhapatnam, Chennai, Tuticorin, Cochin, New Mangalore, Mormugoa, Mumbai, JNPT and Kandla are categorized as major ports accounting for over 60% of the country's total port traffic. Six of them are located in the west coast of India, handling trade mainly with Europe, America, Africa and the Middle East and 6 are east coast ports, involved in trade with mainly Asia and the Pacific. Table 2 gives the information on throughput, growth and market share of major ports in 2010-11. Major ports fall under the direct jurisdiction of the Ministry of Shipping and are governed by the Major Ports Trust Act 1908 (MPTA) and the Indian Ports Act 1963. Port Trusts are administered by a Board of Trustees of wide representation comprising members from government, labor and industry.

Additional 187 non-major ports are governed by the Indian ports Act (IPA) of 1908 and come under the jurisdiction of the different State governments. The cargo turnover from non-major ports account for approximately 40% of total seaborne trade. This mainly consists of fertilizers, fertilizer raw materials, food grains, salt, building materials, iron ores and other ores.

All major ports handle significant volumes of liquid cargo, with the predominance of Mumbai and Kandla which together handle more than half of the country's POL trade, currently at 315 million tons (2011). Other important ports for liquid cargo operations are Kolkatta/Haldia (12.8%), Chennai (11.5%) and Cochin (11%). The majority of POL and other liquid bulk is carried by Indian ships (54%) mainly due to the government's cargo guarantees in favor of national shipping.

Table 2. Throughput of Major Ports

Port	2009-2010 (x1000 tons)	2010-2011 (x1000 tons)	Growth (%)	Market Share in 2010-11 (%)
Kolkata/ Haldia	46,423	47,432	2.2	8.3
Paradip	57,011	56,030	-1.7	9.8
Visakhapatnam	65,501	68,041	3.9	11.9
Ennore	10,703	11,009	2.9	1.9
Chennai	61,057	61,460	0.7	10.8
Tuticorin	23,787	25,727	8.2	4.5
Cochin	17,429	17,873	2.5	3.1
New Mangalore	35,528	31,550	-11.2	5.5
Mormugao	48,847	50,022	2.4	8.8
Mumbai	54,541	54,585	0.1	9.6
JNPT	60,763	64,299	5.8	11.3
Kandla	79,500	81,880	3.0	14.4
TOTAL	561,090	569,908	1.6	100.0

Source: Indian Ports Association, Operation Details 2011

Table 3. Throughput by Type of Cargo (2010-2011)

Port	Liquid Cargo (x1000 tons)	Dry Bulk (x1000 tons)	Container		Other cargo (x1000 tons)	Total (x1000tons)
			(x1000 tons)	(x1000 TEUs)		
Kolkata/ Haldia	10,532	14,768	9,055	526	13,190	47,545
Paradip	12,846	37,768	61	4	5,355	56,930
Visakhapatnam	19,267	34,891	2,572	145	11,311	68,041
Ennore	509	9,769	-	-	731	11,009
Chennai	13,991	5,107	29,422	1,524	12,940	61,460
Tuticorin	742	7,314	8,168	468	9,502	25,727
Cochin	12,101	469	4,419	312	884	17,873
New Mangalore	21,551	7,388	568	40	2,043	31,550
Mormugao	938	47,433	182	18	1,469	50,022
Mumbai	33,229	4,363	653	72	16,341	54,586
JNPT	5,035	-	56,426	4,270	2,848	64,309
Kandla	48,427	10,508	2,568	160	20,359	81,880
TOTAL	179,168	179,778	114,113	7,539	96,973	570,032

Source: Indian Ports Association, Operation Details 2011

Dry bulk cargo movements consist mainly of iron ore, coal and fertilizers. Iron ore is India's major export 142 million tons in 2011 bought by Japan, South Korea, China and the EU. Coal the main input of electricity generation, is both imported and exported in large quantities and it is the major product shipped under cabotage arrangements. Haldia, Paradip, Vishakhapatnam, and Mormugoa are the principal dry bulk ports handling both commodities.

Container cargo handled by major ports was 7.5 million TEUs in 2011. JNPT, the largest container port in India, handles more than 50% of the total containerized cargo from major ports, followed by Chennai which handles around 20%. With new terminals planned at JNPT, Mumbai, Chennai, Ennore, and New Mangalore, the container volumes are bound to grow.

Table 3 gives the details of liquid, dry bulk and containerized cargo handled from major ports in 2010-11.

2.1 Need for FDI

Currently, most Indian ports are characterized by obsolete and poorly maintained equipment, hierarchical and bureaucratic management structures, and excessive labor and, in general, an institutional framework that is considerably in variance with the government's overall economic objectives. Government of India has yet to earmark the required resources critical to port development. Greater participation of the private sector (both domestic and foreign) is thus sought together with the accompanying institutional reforms, but in the altered poor global economic circumstances it is doubtful whether the private sector will rise up to the occasion. The government also needs to clearly define the parameters of port restructuring in a way that makes port investment in India an attractive business alternative to both national and international capital. However at present the government continues to dominate the port sector by way of ownership, archaic labor laws and as a tariff and competition regulator, thus distorting the markets and providing unfair competition.

The 10th five year plan working group has estimated the traffic through major ports to grow to 1 billion tons by the year 2020. This would still leave a capacity shortage of 400 million tons that will have to be created through projects in the present 12th five year plan. The plan envisages USD 100 billion worth of projects in the port sector in the next five years. It thus becomes evident that, mainly due to lack of capital resources and other pressing national priorities, the government of India has ignored port development for long. As a result Indian ports are currently faced with severe capacity limitations, leading to long turnaround times of ships poor port performance. This situation has discouraged bigger main line vessels from calling at Indian ports resulting in the Indian exporters resorting to expensive transshipment at Singapore or Dubai and subsequent loss of competitive advantage.

2.2 Policy Environment for Investors

To attract foreign investors in port sector, the government has permitted 100% FDI through automatic route. Automatic route implies that it does not require any prior approval from the government or Reserve Bank of India. 100% income tax exemption to investors for a period of 10 years is also provided. Joint venture formations between a major port and a foreign port, between major port and minor port(s) without tender, as well as between major port and company(ies) following tender route are permitted by the Government. The measure is aimed at facilitating port trusts to attract new technology, introduce better managerial process, expedite implementation of schemes, foster strategic alliance with minor ports for creation of optimal port infrastructure and enhance confidence of private sector in funding ports.

In terms of revenue streams for operators, the tariff that the port operators can charge is regulated by the Tariff Authority for Major Ports (TAMP). However, TAMP has jurisdiction only on major ports, creating unhealthy competition between major and non-major ports. Investors would be apprehensive of investing in terminals at major ports due to TAMP regulation which would have to compete with a nearby non-major port such as Kanda (major port) and Mundra (non-major port) which are just 60 km apart. TAMP initially adopted a cost plus approach with a maximum permissible rate of return of 20% on equity employed. It has now been changed to a reference tariff for each service or category of service along with the performance standards to TAMP. The reference tariff has been linked to inflation and will remain the maximum fixed tariff at the

concerned major port trust. Its primary function is the protection of the customer from any monopolistic pricing of the Major Port Trusts and the private operators located therein. This was particularly necessary as tariff is considered most vulnerable to creation of market monopolies and predatory pricing. As a result TAMP was set up which formulated guidelines developed through a consensual process involving all stakeholders. The guidelines were modified subsequently in response to new issues which emerged over the times.

When TAMP was formed in 1997, non-major ports collectively handled less than 10 % of port traffic. In 2012-13 they handled 42 % of total traffic indicating a shift in traffic to non-regulated operators. The emerging trends in this market in India suggest intense competition between the major and non-major ports that is expected to deepen and broaden further with the induction of greater FDI and entry of more international players. The public-private partnership model has created a highly competitive port services market where market forces themselves are expected to play the role of an effective regulator. In such a scenario subjecting the major ports to the regulatory control of the TAMP and allowing the non-major ports the freedom to fix and revise their tariff structure appears to be unfair. Hence Ministry of Shipping has issued new Guidelines in July 2013 those impart greater autonomy to the Major Ports in determination of tariff in conformity with the international practice. However it should be noted that tariff setting is a minor, though crucial, aspect of port competition.

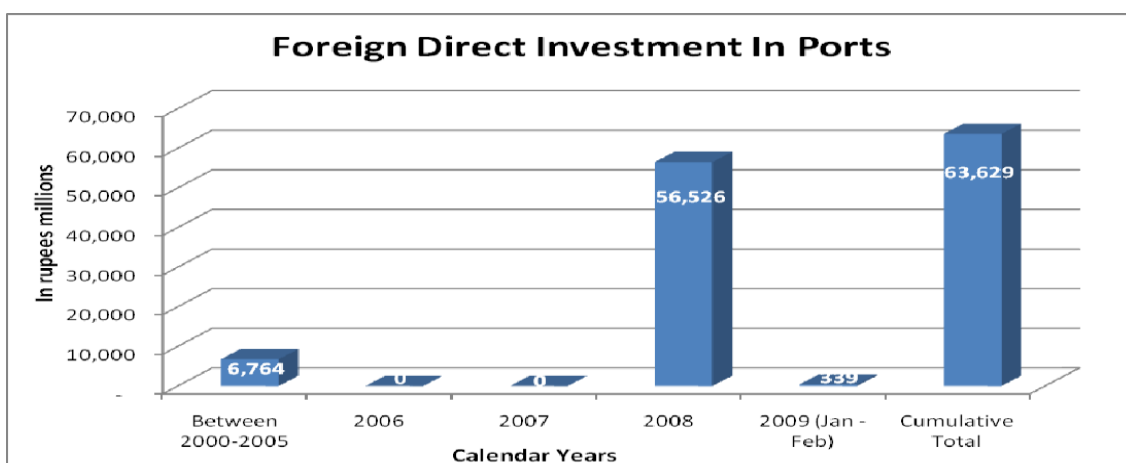
Tariff was also considered to be an important element of the privatization process where the key bid criteria for awarding a terminal contract to a private port operator was the royalty per TEU that the private terminal operator had to pay to the port. In addition the operator also had to assure a minimum annual throughput.

On gaining experiences from several privatization projects, the criteria in subsequent bids was altered to minimum revenue share rather than royalty per TEU as there was some confusion regarding the methodology of computation of royalty which left the operator with no incentive to pay more than the minimum guaranteed sum. Under the new guidelines, the TAs insisted that the terminals use a cost based approach, computed by taking into consideration the total capital and operating costs and a minimum allowable return on equity capital deployed for the designed terminal capacity.

2.3 FDI in Port Infrastructure

Driven by India's export import growth of over 20% per annum, the Ministry of Shipping is aggressively trying to pursue port development in India. The government, in order to facilitate FDI, in certain aspects of port development, has permitted 100% FDI. Various areas of port functioning, such as leasing out existing assets of the port, construction/ creation of additional assets, construction of cargo handling berths, container terminals and warehousing facilities, installation of cargo handling equipments, construction of dry docks and ship-repair facilities, leasing of floating crafts, pilotage and captive facilities for port based industries, etc have been opened to private participation including multinational companies. Accordingly, 100% FDI has been allowed to supplement domestic capital, technology and skills, for accelerated economic growth.

The ports sector has received US\$ 1635 million during the period 2000-2013. But as can be seen from the figure below, it has all but dried up since the financial tsunami in 2008 when there was a gush of investments as a result of quantitative easing and easing of norms by the government. Till March 2009, there were six approved port projects which were to be developed in collaboration with foreign terminal operators. These included terminals Container Terminal project at Jawaharlal Nehru Port developed on BOT basis by Maersk A/S and CONCOR and International Container Transshipment Terminal at Cochin Port developed on BOT basis by M/s Dubai Ports International (DPI).



Source: Department of Industrial Policy and Promotion

The World Bank has projected that the future economic growth in India would be in the manufacturing sector and the subsequent international trade would lead to rapid growth in the port throughput. In order to exploit the opportunity, various foreign institutional investors such as Standard Chartered Bank and General Insurance Corporation have invested in several ports and terminals in India. In addition global port operators such as DP World (DPW), Port of Singapore Authority (PSA) and APM Terminals (Maersk) have also leased terminals at JNPT, Chennai, Kochi and Vizagapatam.

The major port operators of today such as APM Terminals, DPW, PSA, HWL and PoR have cast their net far and wide in search of revenue and profits. In their earlier manifestation they viewed the shipping lines as their prime customers. Subsequently they shifted their gaze to the big shippers, consignees and freight forwarders. In the next phase they started providing value added services such as warehousing, inventory control and rail transportation.

2.4 FDI in Port Connectivity

Port connectivity has a major role to play in development of ports. Currently the hinterland traffic in India is almost entirely carried by Rail (30%) or Road (65%) with an insignificant quantity being ferried by inland waterways and coastal shipping. Pipelines are used to transport some amount of liquid petroleum products. The present port traffic mode share and optimal share is shown in table 4 below. Currently road transport is the most popular mode as it is cost effective, especially over shorter distances and also accords flexibility. However poor quality of roads results in higher costs, both in terms of time as well as money. On the other hand the railways are cost and time efficient, especially over longer distances. However the railways face severe capacity constraints particularly on the Delhi-Mumbai sector where capacity utilization is in excess of 130% resulting in delays and congestion at the ports. The government has planned to construct two Dedicated Freight Corridors (DFCs) to provide additional track capacity but that would be completed only after 2017 or later.

Table 4. Port Traffic Mode Share (% of Tons Handled)

Present Mode	Share % 2012	Optimal Mode Share %
Railways	24	34
Roads	36	22
Pipeline	30	44
Other including inland	10	-

Source: World Bank Report 2007

During the British rule the Indian Railways (IR) were assigned the task to provide rail connectivity to the ports. There was a PPP element to this policy, with the government providing free land and a guaranteed rate

of interest, thus minimizing the operational risk. Since independence in 1947, all railway projects were solely developed and managed by Ministry of Railways (MoR).

With the opening of Indian economy since 1990s, port sector was also opened for private investments. Considerable private sector investment was directed into the development of new green field ports, as well as into expansion and modernization of older major ports. IR by then had already constructed rail connectivity to various major ports; thus the old ports were spared the cost of providing the rail connectivity.

Subsequently in 2008, the Government of India, with a view to upgrade the port sector, stipulated that every major port must be connected by a double railway line and four lane highway. For the IR, the port connectivity had low priority. As the government lacked the finances for achieving these goals, the ports were required to provide the finance for this enhanced last mile connectivity, both by road and rail. At present, road connectivity projects are implemented through Joint Ventures (JVs) where Major Ports and National Highway Authority of India (NHAI) contribute up to 30 % each of the cost of the projects. In contrast, the rail infrastructure remains a government monopoly.

Major Ports suffer from obsolete, inadequate and poor infrastructure including the poor and inadequate connectivity. On the other hand, the green field ports have no option but to fund the green-field rail connectivity projects all by them. As per the policy for attracting private investment in rail connectivity projects, the real options for the ports are:

- a) Build a private line on privately acquired non-railway land and connect the same to the railway's network. This is termed as the Non-Government Railway Model (NGR)
- b) To form a JV with IR or one of its subsidiary companies. The JV would then lease back the land acquired by IR with the funds provided by the JV and then construct the rail line and maintain it with the funds provided by the JV once again.

At present 7 ports connectivity projects have been or are being implemented via the JV model. On the other hand Adani Port in Gujarat, which is one of the largest privately owned ports in India, initiated the concept of private investment in rail port connectivity that evolved as NGR model in due course. Adani Port constructed the rail line on land acquired by them. They also maintain the line at their own cost.

As a result of this arrangement, the capital cost of the private port projects increases. As the rail/road connectivity is vital to the port, incurring the additional cost is inescapable, even though connectivity costs deter fresh investments in port sector and would ultimately be counterproductive for the national economy. If the private port waits for the Indian Railway to provide the connectivity, as it had done for the older ports, inadequate resources would delay the new lines by several years, if not several decades. By investing their own funds, the private port developers can expedite the connectivity and use the port facilities. Without a proper rail line, the port cannot be optimally used.

A major hurdle in providing connectivity is land acquisition. The process of land acquisition is slow, uncertain and prone to litigation. Port developers are therefore keen on forming JVs with IR (or with one of the companies promoted by IR) for developing the rail corridor to the port. (This is because IR, as a government entity, could compulsorily acquire public land and also has expertise in constructing railway lines.) It is easier for a JV with IR as a partner to acquire land and obtain approvals from IR and other government agencies in constructing the line, compared to the developer doing the same on his own. Furthermore, due to the involvement of IR the risk perception of such projects in the eyes of the lenders improves to a certain extent. However the price that a private investor has to pay for entering into such joint ventures is by way of bureaucratic and procedural hurdles that are inevitable in partnering any government organization and varies from project to project. This aspect causes certain amount of ambiguity. On the other hand the NGR model will find its takers wherever land is available or the developer is confident of acquiring land without the assistance of the heavy hand of the state.

The government has passed a new act in 2013 governing the land acquisition process wherein the process has become even more tortuous and expensive. As per the new act, the consent of 80% of the land losers is

required when a company for a private company wants to acquire land for a public purpose, whereas this percentage is reduced to 70% in case of a JV with government. Thus formation of a JV with government (or its companies) so that JV acquires land instead of the port developer will provide only marginal ease under the new Land Acquisition Act of 2013.

Since 2002 100% FDI is allowed in the ports sector in India. In October 2013, the MoR has also, for the first time, decided to invite FDI in railway infrastructure projects, including for port connectivity projects. A 74% FDI ceiling is proposed for such projects under the JV model. FDI in rail connectivity projects is expected to help the government attract FDI in the port sector as well as encourage the international players to invest in allied infrastructure projects such as dedicated freight corridors, logistic parks etc. However, given the terms and conditions stipulated by the government for investing in such projects in addition to the added uncertainty caused by the new land acquisition law, the port sector may not be able to attract the targeted FDI in next few years.

3. Theoretical Framework

The Solow–Swan growth model is a popular model used for forecasting long-run economic growth. It does so by looking at different factors such as productivity, capital ingress (both domestic and foreign), population growth, labor output, technological progress etc. Subsequently labor was also added as a factor of production. In this paper we modify the model by substituting capital accumulation with FDI and population with port traffic. In Solow's model, new capital (FDI) is considered to be more valuable than old capital (domestic) because it is commonly believed that FDI also stimulates technological progress and hence it would be more productive. According to the model the steady state level of output can also be affected by policy measures such as tax cuts or subsidies (overt and covert) but not the long run rate of growth. The rate of growth would be essentially affected by capital ingress and the rate of technological progress i.e. the speed at which old, obsolete and inefficient port equipment is replaced. Thus the key assumption of this model is that capital is subject to diminishing rates of return in a closed system considering all other things being equal.

In this paper the model discussed here captures not only the direct, but also the indirect effect of unfair competition/market distortion on economic growth. Borensztein et al. (1998) concluded that FDI contributes more to economic growth than domestic investment only when there is a certain threshold of market freedom. Considering this fact we arrive at two conclusions; first, a higher level of market distortion due to unfair competition lowers market freedom and second, this reduction in market freedom reduces the possibility for FDI to effectively contribute to the domestic economic growth. As a matter of fact it may even hamper economic growth. Based on the Solow model, an extension is developed in this section that analyzes the impact of unfair competition on the FDI flows into the port sector of the country.

The basic Solow model can be used to explain the growth path of global ports in different countries and why certain ports experience a higher growth rate than others at a given time. This is subject to the underlying assumptions that the capital input rate, technological progress and traffic growth are exogenous and the port production function(Y) has a Cobb-Douglas form with three inputs: capital(K)technology (A)and labor(L). This can be written at time t as follows:

$$Y(t) = F[K(t), A(t)L(t)]$$

$$Y(t) = K(t)^\alpha A(t)L(t)^{1-\alpha}, \text{ where } 0 < \alpha < 1$$

This production function displays positive and strictly diminishing returns of the marginal product of labor and capital. Assuming that $L(0)$ and $A(0)$ be respectively the initial number of workers and level of the technology we partially differentiate the log of each variable with respect to time to model the dynamics of the growth rates

$$L(t) = L(0)e^{nt}$$

$$A(t) = A(0)e^{gt}$$

The evolution for capital, human capital and the technology is described by the following equations:

$$\begin{aligned}\dot{k}(t) &= s_k f(k(t), h(t), g(t)) - (n + g + \delta_k)k(t) \\ \dot{h}(t) &= s_h f(k(t), h(t), g(t)) - (n + g + \delta_h)h(t) \\ \dot{g}(t) &= s_g f(k(t), h(t), g(t)) - (n + g + \delta_g)g(t)\end{aligned}$$

A steady state occurs when the endogenous determined variables in the model grow at a constant rate, which occurs when (K) , (A) and (L) are equal to zero, thus when the actual investment equals the break even investment. The intensive form of the production function after taking the natural logarithms results in the following equation

$$\begin{aligned}\ln y(t) = \ln A_0 + g t - \left[\left(\frac{\alpha + \beta + \gamma}{1 - \alpha - \beta - \gamma} \right) \ln(n + g + \delta) \right] + \left(\frac{\alpha}{1 - \alpha - \beta - \gamma} \right) \ln s_k + \left(\frac{\beta}{1 - \alpha - \beta - \gamma} \right) \ln s_h \\ + \left(\frac{\gamma}{1 - \alpha - \beta - \gamma} \right) \ln s_g\end{aligned}$$

From this equation it could be concluded that the output per capita is positively affected by the initial level of technology and its growth rate and by the investment rates of capital and public sector.

Following Farida and Ahmadi-Esfahani (2007) a direct measure of unfair competition can be added to the extended Solow model by making the labor-augmenting variable a function of such competition. Such competition can also be defined as a function of government expenditures. A more general adjustment would be accounting for the negative externality imposed by technological progress. The main conclusion stays the same however: unfair competition not only influences FDI inflows but total factor productivity.

$$\begin{aligned}\ln y(t) = \ln A_0 + g t - \left[\left(\frac{\alpha + \beta + \gamma}{1 - \alpha - \beta - \gamma} \right) \ln(n + g + \delta) \right] + \left(\frac{\alpha}{1 - \alpha - \beta - \gamma} \right) \ln s_k + \left(\frac{\beta}{1 - \alpha - \beta - \gamma} \right) \ln s_h \\ + \left(\frac{\gamma}{1 - \alpha - \beta - \gamma} \right) \ln s_g + n\theta\end{aligned}$$

In the Solow growth model, influences from outside the domestic market, like FDI, are not determined within the model. If the home country opens up to trade, there will be a capital boost due to FDI. In the above equation it is captured by S_k . Because the ratio of the productivity of capital to the effectiveness of labor is assumed to be positive, the capital inflow results in a shift upwards of the actual investment curve. This generates a temporarily higher growth until a new steady state level is reached. The FDI inflow thus has a permanent level-effect, but only a temporarily growth effect. However if the ratio is negative due to low productivity or faster depreciation of port assets and slower capital ingress the inadequate FDI inflows will not lead to a sustainable steady state level. Thus it will not have a permanent level effect which is one of the reasons why the sector remains unattractive to the foreign investors.

4. Conclusions

In the coming years the government proposes to invest US\$ 20 Billion in the port sector of which 60% has been earmarked for non-major ports and the rest for major ports. It plans to use most of the funds for capacity expansion by way of construction of berths, terminals, rail connectivity and jetties. It expects the private sector to provide bulk of the funds while it will provide some budgetary support mostly by way of tax holidays etc.

Though favorable industry conditions exist at the moment, it is commonly believed that potential investors are faced with numerous challenges which present a downside risk and managing project execution risks in addition to the pressure on raising cheap and adequate and assuring attractive returns would be necessary. The balance sheets of such companies could also come under stress in the event of delays in project execution, cost overruns and insufficient cash flows. In such circumstances the private sector ability to raise and service debt at cheap interest rates for long gestation periods could be severely tested.

The main losers in the bargain are the Indian exporters and importers as poor port productivity raises transport costs of exports and imports. High cost of imports also adversely affects the domestic producers who use imported raw materials and equipment in their production processes thus rendering them uncompetitive in the global markets.

Realization of this fact would allow India to be in a position to offer foreign investors terms of privatization at least as attractive as they could secure in alternative investments outside the country, while herself would benefit from the knock-on multiplicative impacts of foreign investment. Price control is also exercised by many nations of Western Europe and North America not through government regulations but through promotion of fair but intense port competition that does not allow rent seeking behavior or collusion amongst the ports nor formation of cartels. Investment planning is also carefully exercised to avoid wastage of resources.

While, owing to their “trust status”, the public sector ports do not pay taxes to the government yet they do receive budgetary support which allows them to unfairly compete with the private sector ports. This is exploitation by the public sector ports of their market dominant position. This aspect distorts the market totally and yet the sector has managed to attract FDI which reveals the actual potential the sector possesses. This untapped potential can only be realized if and only if the unfair competition provided by the government itself is done away with and market forces are set free.

FDI is known to have a positive influence on a country's growth rate. Following the Solow growth model a positive coefficient for FDI is hence desirable. Like any research this investigation about the effect of unfair competition on growth in the port sector through the channel of FDI has its limitations. Firstly, the impact of market distortions on the growth is not entirely observable and therefore hard to measure. An objective measure of unfair competition would be reliable when it captures the frequency and the depth of market distortions only when it is comparable over time and among countries. As such further research in greater depth needs to be carried out by future researchers.

References

- Alfaro, L., Chanda, A., Kalemli-Ozcan, S. and Sayek, S (2004), FDI and economic growth: the role of local financial markets, *Journal of International Economics* 64: 89-112.
- Associated Chambers of Commerce and Industry in India (2010), *Port Privatization*, New Delhi.
- Bengoa, M. and Sanchez-Robles, B. (2003), Foreign direct investment, economic freedom and growth: new evidence from Latin America, *European Journal of Political Economy* 19: 529-545.
- Borensztein, E., de Gregorio, J. and Lee, J.W. (1998), How does foreign direct investment affect Confederation of Indian Industry (CII) Ports and Roads – Investment Opportunities and Financing Avenues, Conference Proceedings, New Delhi, 11-12 March 1997.
- Confederation of Indian Industry (2008), *Port Development in India – Effective Participation of the Private Sector*. Report, New Delhi.
- Drewry Shipping Consultants (2007), *Drewry India: The Emerging Economic and Industrial Power; the Potential Impact of World Shipping and Trade*, London.
- Farida, M. and Ahmadi-Esfahani, F. (2007), Modeling corruption in a Cobb-Douglas production function <http://ageconsearch.umn.edu/handle/10400>.
- Gopalan, S. (2008), Current and Envisaged Port and Shipping Development in India, 29th PIANC Congress, The Hague, September 2008.
- Government of India (2008), Ministry of Surface Transport Guidelines to be Followed by Major Port Trusts for Private Sector Participation in the Major Ports, New Delhi.
- Government of India (2010), Ministry of Surface Transport Privatization, New Delhi.
- Indian Ports Association (2007), *Major Ports of India 1995-96*. New Delhi.
- Mankiw, G., Romer, D. and Weil D. (1992), A contribution to the empirics of economic growth.
- Singh, K. (2005), *Foreign Direct Investment in India: A Critical Analysis of FDI from 1991-2005*, Centre for Civil Society, New Delhi.
- World Bank (2012), *World Development Indicators*, www.data.worldbank.org/data-catalog/world-development-indicators.

Vessel Collision Frequency Estimation in Archipelagic Waters

Yajun Li^{1,2}, Junmin Mou^{1,3}, Xi Chen¹ and Guozhu Hao¹

¹Navigation School, Wuhan University of Technology, Wuhan, Hubei Province, China.

²Hubei Inland Shipping Technology Key Laboratory, Wuhan University of Technology, Wuhan, China.

³Key Laboratory of High Performance Ship Technology (Wuhan University of Technology), Ministry of Education Wuhan, Hubei Province, China.

Abstract

The Islands in the vicinity of intense ship traffic yields complex maneuvering situations for ships and pose a potential collision hazard. This paper presents a new approach for the probability of vessels colliding estimation on the basis of maritime accidents analysis and ship collision parameters calculating. First a Fault Tree Analysis (FTA) model is introduced to estimate the probability of failing to avoid a collision (the causation probability) based on accident statistics and ship traffic flows. Then a ship domain theory was applied to calculate the number of collision candidates on basis of Automatic Identification System (AIS) data. Finally the vessel collision frequency can be estimate through the number of collision candidates multiply by the causation probability.

Keywords: vessel collision frequency; Fault Tree Analysis (FTA); ship domain; Automatic Identification System (AIS) data.

1. Introduction

Due to brisk industrial growth, the marine traffic has become an imperative subject in transportation business nowadays. The intense ship traffic leads to high collision risks especially in archipelagic waters. The Islands in the vicinity of intense ship traffic yields complex maneuvering situations for ships and pose a potential collision hazard such as risk of loss of life, economic loss, environmental damage and other possible unwanted events. Therefore, the appropriate estimation of vessel collision frequency is a matter of great significance for navigation safety. A large number of models for vessel collision probability estimation have been reported in the literature. There are two major groups namely: static and dynamic models.

The static model is simpler and estimates the vessel collision probability on basis of ship collision accidents data and traffic flow analysis. Kristiansen (2005) described a method to assess ship collision probability in a fairway, distinguishing between head-on, crossing and overtaking collisions. The model uses traffic flow characteristics in the probability analysis. A detail accident statistics are described and the risk of ship collisions is studied through theoretical model by Kujala, Hänninen, Arola and Ylitalo (2009). About the causation probability of ship collision study, Hänninen and Kujala (2012) use a Bayesian network model to estimate the causation probability of ship collision and examine the effects of weather and human factors on collision probability in a heavily used crossing area. There are many causation factors affect ship collision, in order to determine collision criteria and causation factors Montewka, Goerlandt and Kujala (2012) propose a novel method of defining the collision criterion with respect to ship–ship collision, called MDTC (minimum distance to collision), and expand the evaluation of causation factors appropriate for the MDTC model. Collision frequency was evaluated for a specified route taking into account traffic data. AIS data contained ship's static and dynamic data is conducive to ship collision analysis, Weng, Meng and Qu (2012) use the real-time vessel movement data (AIS) to estimate vessel collision frequency, the frequency is obtained as the product of the number of vessel conflicts and the causation probability. Wang, Zhang, Chen, Chu and Yan (2013) introduce a spatial–temporal forensic analysis for inland–water ship collisions using AIS data.

In the case of dynamic models a collision between two simulated ships can be tantamount to physical contact between them. And the dynamic models for the collision frequency estimation on the basis of maritime traffic

flow. Przywarty (2008) outlined a probabilistic model for the assessment of navigational accidents in an open sea area, based on concepts proposed by Gucma (2003). The method makes use of a simplified model of maritime traffic, which is simulated in the time domain. Traffic is assumed to follow a Poisson process, a static critical encounter distance is assumed in the assessment of collision candidates and routes are defined based on a rather coarse analysis. Bukhari, Tusseyeva, Lee and Kim (2013) introduce a dynamic methodology of calculating the DCPA, TCPA and Bearing by using the VTS radar input directly to assess collision risk automatically. Montewka, Hinz, Kujala and Matusiak (2010) present a MDTC model for the geometrical probability of collision estimation on the basis of maritime and aviation experience, the innovative use of a ship motion model to determine the Minimum Distance to Collision.

A risk simulation model for the strait of Istanbul is proposed by Uluscu, Özbas, Ör, and Altiok (2009). Several attributes concerning the likelihood of accident are modelled, divided in vessel attributes and environmental conditions. Conditional probabilities for accident occurrence and consequence are evaluated based on pairwise comparison surveys and expert judgment. Goerlandt and Kujala (2011) present a new approach for the modelling of ship collision probability, the model is capable of providing detailed information about the circumstances in which ships encounter each other: geographic location, encounter angle, time of day and type, size and speed of striking and struck vessel can be analysed from the model output. This information is valuable for consequence analyses, which, combined with the probability analysis directly obtained from the model, provide the risk level.

From literature review, most of collision frequency estimation focus on the probability of vessel failing to avoid a collision (the causation probability) and the number of vessel encounters during a time period resulting in collision, provided no evasive action is taken (the number of collision candidates). However, the causation probability is taken from other literature in most study directly and it does not take into account the specific characteristics of the studied area. This paper presents a new approach for the probability of vessels colliding estimation on the basis of maritime accidents analysis and ship collision parameters calculating. The Fault Tree Analysis (FTA) model is introduced to estimate the causation probability based on accident statistics and ship traffic flows. And the ship domain theory was applied to calculate the number of collision candidates over a given time period on basis of Automatic Identification System (AIS) data.

2. Model Used for Causation Probability

The causation probability means the probability of vessel failed to avoid collision and it affected with different parameter, i.e. weather, technical failure and human factors. The ship collision FTA model of the archipelagic waters is built to estimate the causation probability based on the ship collision accident statistics data. The FTA can be seen as a logical and graphical method highly used to evaluate the probability of one undesirable event or accident occurring as a result of failures. It can be seen as a deductive approach, which starts from an effect and aims at identifying its causes. It starts with the event of interest, the top event, such as a hazardous event or equipment failure, and is developed from the top down. The ship collision is seen as the top event in this paper, and FTA model is used to identify its causes.

2.1 Vessel Collision Factors of FTA Model

There are many factors affected ship collision. This paper selects 14 factors as basic event based on collision accident data analysis. Fig.1 shows the fault tree of ship collision in archipelagic waters: X0 is negligence in guarding means overconfidence or gross negligence or not keep a safe speed on the voyage; X1 is wrong assessment collision risk means assessing risk failure lead to collision; X2 is improper emergency operation means could not take appropriate measures to avoid collision in emergency situation; X3 is improper steering control means improper steering control in maneuvering; X4 is improper lookout means not keep right lookout on the voyage; X5 is uncoordinated avoiding means not coordinated action of two ships lead to collision; X6 is improper avoiding means action to avoid collision is improper; X7 is ship dragging; X8 is unused safety speed means the speed of vessel exceed the safety speed; X9 is stand-on vessel failed in duty means the stand-on ship does not do its duty to avoid collision; X10 is poor visibility means fog or rain leads poor visibility; X11 is give-way vessel failed in duty means the give-way vessel does not do its duty to avoid

collision; X12 is main engine failed means the main engine cannot provide power; X13 is steering failed means rudder failure.

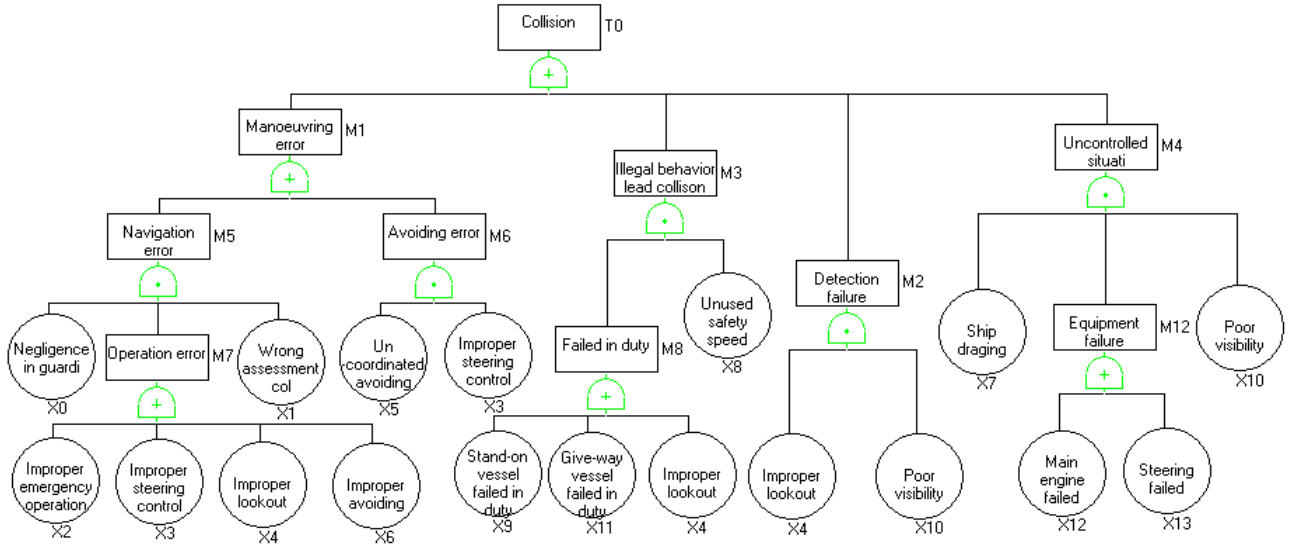


Fig.1 Fault Tree of vessel collision

2.2 Minimum Cut Sets of Fault Tree

In order to calculate the probability of ship collision, firstly the fault tree is expressed by Boolean algebra, then simplifying the Boolean algebra to acquire minimum cut sets. The ship collision event can be expressed by Eq.1.

$$\begin{aligned}
 T0 &= (M1 + M2 + M3 + M4) \\
 &= (M5 + M6) + X4 \bullet X10 + X8 \bullet M8 + X7 \bullet M12 \bullet X10 \\
 &= X0 \bullet M7 \bullet X1 + X5 \bullet X3 + X4 \bullet X10 + X8 \bullet (X9 + X11 + X4) + X7 \bullet (X12 + X13) \bullet X10 \\
 &= X0 \bullet (X2 + X3 + X4 + X6) \bullet X1 + X5 \bullet X3 + X4 \bullet X10 + X8 \bullet (X9 + X11 + X4) + X7 \bullet (X12 + X13) \bullet X10 \\
 &= X2 \bullet X0 \bullet X1 + X4 \bullet X0 + X9 \bullet X8 + X12 \bullet X10 \bullet X7 + X5 \bullet X3 \\
 &\quad + X11 \bullet X8 + X4 \bullet X8 + X13 \bullet X10 \bullet X7 + X3 \bullet X0 \bullet X1 + X4 \bullet X0 \bullet X1 + X6 \bullet X0 \bullet X1
 \end{aligned} \tag{1}$$

The minimum cut sets of ship collision event can be acquired based on Eq.1: {X2, X0, X1}, {X4, X0 }, {X9, X8 }, {X12, X7, X10 }, {X5, X3}, {X11, X8}, {X4, X8 }, {X13, X7, X10 }, {X3, X0, X1}, {X4, X0, X1}, {X6, X0, X1}.

2.3 Basic Event Probability

The probability of basic event means the frequency of basic event leading ship collision accident in this paper. It is calculated by Eq.2 based on the specific characteristics of ship collision accident and traffic flow in island water area.

$$q_i = \frac{N_i}{S} \tag{2}$$

Where, q_i is the probability of basic event, N_i is the number of ship collision accident caused by basic event X_i , S is the ship traffic flow annual of the studied area.

2.4 Top Event Probability

The probability of top event means the causation probability, and it can be expressed by Eq.3 based on

Boolean algebra.

$$P_c = 1 - (1 - q_{M1})(1 - q_{M2})(1 - q_{M3})(1 - q_{M4}) \quad (3)$$

Where, P_c is the causation probability, q_{M1} , q_{M2} , q_{M3} and q_{M4} is the probability of M1, M2, M3 and M4 respectively.

The q_i is far less than 0.1 in this study because of intense ship traffic increasing the value of S . Then the Eq.3 can be simplified into Eq.4

$$P_c \approx q_{M1} + q_{M2} + q_{M3} + q_{M4} \quad (4)$$

The probability of top event is the sum of the probability of minimum cut sets, and the Eq.4 can be expressed by Eq.5 based on Boolean algebra formula of ship collision fault tree.

$$P_c = q_2 \times q_0 \times q_1 + q_{10} \times q_4 + q_9 \times q_8 + q_{12} \times q_{10} \times q_7 + q_5 \times q_3 + q_{11} \times q_8 + q_4 \times q_8 + q_{13} \times q_{10} \times q_7 + q_3 \times q_0 \times q_1 + q_4 \times q_0 \times q_1 + q_6 \times q_0 \times q_1 \quad (5)$$

3. Ship Domain Model for Collision Candidate

The collision candidate is that vessel encounters at the critical distance resulting in collision, provided no evasive action is taken. To calculate the number of collision candidates, the ship domain model is introduced. Here, the ship domain is expressed as the area around the vessel that the navigator wants to keep clear of other vessels or objects. If two ship domains overlap, that is generating a collision candidate.

3.1 Fuzzy Quaternion Ship Domain

A fuzzy quaternion ship domain (FQSD) is proposed by Wang (2010), The main characteristics of FQSD are that the domain size is determined by the quaternion including four radii: fore, aft, starboard and port, which sufficiently take factors affecting the domain (ship maneuvering capability, speeds and courses, etc.) into account; and that the domain shape is modelled by another parameter which makes the QSD more flexible since the ship boundary could not only be linear or nonlinear, but also be thin or fat. FQSD can be formulated as follow:

$$FQSD_k(r) = \{(x, y) | f_k(x, y; Q(r)) \leq 1, k \geq 1\} \quad (6)$$

$$f_k(x, y; Q(r)) = \left(\frac{2x}{(1 + \text{sgn } x)R_{fore}(r) + (1 - \text{sgn } x)R_{aft}(r)} \right)^k + \left(\frac{2y}{(1 + \text{sgn } y)R_{starb}(r) + (1 - \text{sgn } y)R_{port}(r)} \right)^k \quad (7)$$

$$Q(r) = \{R_{fore}(r), R_{aft}(r), R_{starb}(r), R_{port}(r)\} \quad (8)$$

$$R_i(r) = \left(\ln \left(\frac{1}{r} \right) / \ln 2 \right)^{\frac{1}{k}} R_i, i \in \{fore, aft, starb, port\}, 0 < r < 1 \quad (9)$$

Where, the possibility value $r \in (0,1)$ is used to determine the fuzzy boundary of FQSD; $f_k(x, y; Q(r))$ is the boundary function of fuzzy quaternion ship domain; k is the shape index of FQSD; $R_{fore}, R_{aft}, R_{starb}, R_{port}$ represent the forward radius, backward radius, starboard side radius and port side radius, respectively.

$$\begin{cases} R_{fore} = (1 + 1.34\sqrt{1.55v^{0.72} + .017v^{1.09}})L \\ R_{aft} = (1 + 0.67\sqrt{1.55v^{0.72} + 0.17v^{1.09}})L \\ R_{starb} = (0.2 + 0.83v^{0.5441})L \\ R_{port} = (0.2 + 0.62v^{0.5441})L \end{cases} \quad (10)$$

The four radius of FQSD are estimated by Eq.10 based on the model proposed by Kijima and Furukawa (2003), the radius of domain along with the increase of ship velocity v and ship length L ; the r is equivalent to the fuzzy index of radius, the higher the r value is, the smaller the corresponding fuzzy ship domain is.

3.2 The Number of Collision Candidates Calculation

To calculate the number of collision candidates that is counting the number of ship domain overlaps. Firstly, the Eq.11 is used to determine the examining interval based on the average time of all ships pass through the study area. The examining interval is key factor for counting the number of domain overlaps, if the interval is too long the ship may have leave the study area, if the interval is too short the same collision candidate may be examined twice.

$$\bar{T} = \frac{1}{N} \sum_{i=1}^N (T_{i,max} - T_{i,min}) \quad (11)$$

Where, \bar{T} is the average time of all ships pass through the study area, $T_{i,min}$ is the time of the vessel i entering the study area, $T_{i,max}$ is the time of the vessel i leaving the study area, N is the number of all ships.

Then let $\{(x_{1,j}, y_{1,j}, v_{1,j}, L_{1,j}, c_{1,j}), \dots, (x_{n,j}, y_{n,j}, v_{n,j}, L_{n,j}, c_{n,j})\}$ denote a series of longitude and latitude coordinates, speed over ground, ship length, course over ground. These sets are input into the FQSD model to calculate the number of collision candidates. If the ship domains overlap, a collision candidate is generated.

4. Case Study of Archipelagic Waters

4.1 Brief Introduction of Study Area

A rectangular region (122°01.304'-122°10.000'E, 029°56.667'-030°00.000'N) of Zhoushan Islands in China is selected as study area. Zhoushan, the only city of islands in China, is located in the middle part of China coastline. It is a central hub of sea transport of Shanghai and the Yangtze Delta Economic Zone to the outside world. The ship traffic is busy, and the waterway is crisscross and complex. Ship navigates in these waters with high collision risk.

4.2 Result of Causation Probability

To calculate the causation probability, the collision accident data in 2011 and 2012 is analyzed. The accident cause and the number of the related accident are shown in Table.1. The number of accidents caused by improper emergency operation is larger, this show that the crew fail to deal with emergency situation. Human error is the main factor of ship collision. However the number of accident caused by ship dragging in archipelagic waters is larger than other water area, because of there are many islands and anchorage ground in the vicinity of waterway, the Islands change the hydrodynamic characteristics of flow, and the more complex flow aggravates ship dragging risk.

The traffic flow is estimated by AIS data, and the traffic flow is 57620 monthly in Zhoushan Islands waters. Then, the data of Table.1 and traffic flow is input into Eq.2 and Eq.5, the result of causation probability is $P_c = 1.03E-10$.

Table 1. Accident cause and the number of the related accident

	Accident cause	The number of related accident
X0	negligence in guarding	11
X1	wrong assessment collision risk	8
X2	improper emergency operation	26
X3	improper steering control	2
X4	Improper lookout	7
X5	Uncoordinated avoiding	3
X6	Improper avoiding	7
X7	Ship dragging	4
X8	Unused safety speed	2

X9	Stand-on vessel failed in duty	2
X10	Poor visibility	3
X11	Give-way vessel failed in duty	2
X12	Main engine failed	1
X13	Steering failed	1

4.3 Results of Collision Candidates

Automatic Identification System (AIS) is a technology which makes vessels ‘visible’ to each other. It can record information on vessel behavior, including the effects of human behavior and vessel maneuverability. The massive AIS data is very helpful for the study of ship collision risk. Two weeks’ AIS data of study area is used to calculate the collision candidates in this paper. The longitude and latitude coordinates, speed over ground, ship length, course over ground of vessel derived from AIS data are input into the fuzzy quaternion ship domain model, and the results are shown in Table.2.

Table 2. The number of collision candidates

Date	The number of collision candidates			
	r=0.8	r=0.6	r=0.4	r=0.2
0501	0	10	52	96
0502	0	4	42	103
0503	0	5	34	93
0504	1	6	44	99
0505	0	8	37	85
0506	0	13	51	101
0507	2	8	36	97
0508	0	6	33	94
0509	1	6	30	89
0510	1	12	60	107
0511	0	7	30	92
0512	1	10	43	100
0513	0	20	61	117
0514	0	14	55	105

4.4 The Estimation of Ship Collision Risk

The collision candidate is estimated on basis of ship domain overlaps counting. Ship domain is particularly useful to estimate collision risk in restricted waters such as Island water area. As ship domain refers to waters that navigators want to keep clear of other ships, the overlaps of ship domains indicate higher likelihood of ship collisions. Evidently, the more ship domain overlapping scenarios happen in study area, the riskier the study area is. Ship domain overlap data of one day when $r = 0.2$ is used to estimate collision risk of study area. Fig.2 shows the spatial distribution of domain overlaps, a red * represents a collision candidate. The red * is more intensive, the riskier the ship collision is. The water area in the vicinity of Dawukuishan Island is higher collision risk, because of intensive traffic flow and there are many anchorages and mooring equipment in water area. Because of the bridge between Songshan Island and Changzhidao Island, the ship collision risk is higher in this area. The spatial distribution of collision candidates located on the edge of the island is intensive, because of there are many berth located on the edge of the island, the traffic flow of the port water area is busy, and the wharf influence the hydrodynamic characteristics of the ship, increasing the difficulty of the ship maneuvering. Through the analysis of ship collision risk in Island water area, it can be concluded that the fuzzy quaternion ship domain model is useful for estimating collision risk, and the result of collision candidates on basis of ship domain overlap counting is proper.

4.5 Calculation of Vessel Collision Frequency

The number of collision candidates reduces along with the value of r increase from the Table.2. The r is equivalent to the fuzzy index of radius, when $r=0.2$ the corresponding fuzzy ship domain is bigger, much more vessels' domain overlap. Regardless of the value of r is too large or too small, that always have an impact on collision risk estimating. Therefore, $r=0.4$ is used to count the number of collision candidates, the collision candidates in a year can be proposed by Eq.12 shown as follow:

$$N_{candidates} = \frac{\sum_{i=1}^{N_{tw}} n_i}{N_{tw}} \times 365 \quad (12)$$

Where, $N_{candidates}$ is the number of collision candidates in a year, i is the date from 0501 to 0514, n_i is the number of collision candidates in a day of table.2 when $r=0.4$, N_{tw} is the total number of days of two weeks.

Then the frequency of vessel collision (P) in archipelagic waters can be estimated by $P = P_c \times N_{candidates}$. The $P_c = 1.03E-10$, and the $N_{candidates} = 15852$, so $P = 1.63E-6$, means that there are 0.163 collision accident of 100000 vessels in a year.

The traffic flow of the study area is 85045 in 2013, and the estimated collision accident is 0.139. There is one collision accident of the rectangular region between the years of 2007 and 2013, so the estimated collision accident (0.139) is quite close to the average actual collision accident (0.143). It indicates that the estimated vessel collision frequency is credible, and it can be used for collision risk estimation of study area, the larger the value of P is, the higher the collision risk level is. The collision frequency of the study is not large, while the number of collision candidates is larger. Because of the intensive traffic flow and complex waterway result in high collision risk, these collision candidates do not develop into collision accident. However, the large number of collision candidates should also be taken seriously, because if the traffic flow becomes more intensive or rough weather, these collision candidates are likely to cause serious accidents.

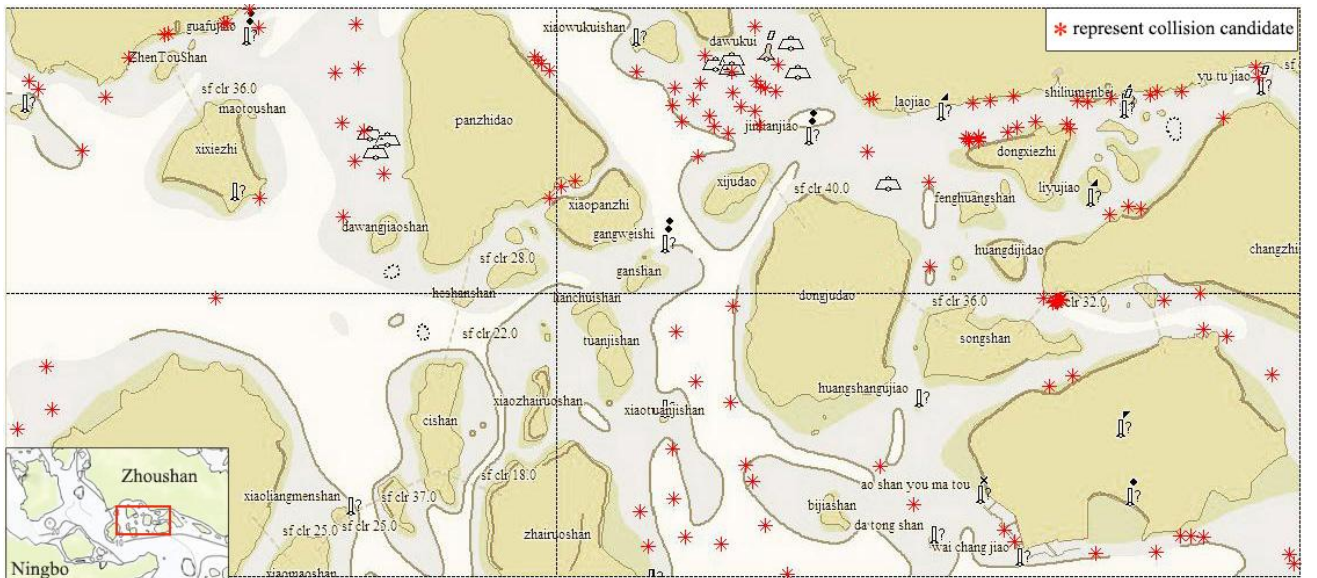


Fig 2. The spatial distribution of collision candidates

5. Conclusions

This study estimated Vessel Collision Frequency in the Island water area using vessel movement data on account of AIS data analysis. The Fault Tree Analysis (FTA) model is introduced to estimate the probability of vessel failing to avoid a collision based on accident statistics and ship traffic flows. And the fuzzy quaternion ship domain model is used to calculate the number of collision candidates. According to the results,

it can be seen that the water area in vicinity of anchorage and mooring equipment possess higher collision risk, due to ship dragging, busy traffic flow and other human errors; and the area in vicinity of berth around the edge of the island also possess high collision risk, because of the wharf influence the hydrodynamic characteristics of the ship, increasing the difficulty of the ship maneuvering. The vessel collision frequency in the archipelagic waters is found to be 0.163 per 100000 vessels in a year. The results of this paper could be beneficial for the China Maritime Safety Administration to further enhance the navigational safety strategies implemented in the archipelagic waters. The collision frequency of results is useful for the whole collision risk assessment of study area, and the spatial distribution of collision candidates can be used for partial collision risk research.

References

- Bukhari, A. C., Tusseyeva, I. and Kim, Y. G. (2013), An intelligent real-time multi-vessel collision risk assessment system from VTS view point based on fuzzy inference system, *Expert Systems with Applications* 40(4): 1220-1230.
- Goerlandt, F. and Kujala, P. (2011), Traffic simulation based ship collision probability modelling, *Reliability Engineering & System Safety* 96(1): 91-107.
- Gucma, L. (2003), Models of ship's traffic flow for the safety of marine engineering structures evaluation, *Proc the ESREL* 713-718.
- Hänninen, M. and Kujala, P. (2012), Influences of variables on ship collision probability in a Bayesian belief network model, *Reliability Engineering & System Safety* 102:27-40.
- Kijima, K. and Furukawa, Y. (2003), Automatic collision avoidance system using concept of blocking area, *Proc 6th IFAC Conference on Maneuvering and Control of Marine Craft*, Girona, Spain.
- Kujala, P., Hänninen, M., Arola, T. and Ylitalo, J. (2009), Analysis of the marine traffic safety in the Gulf of Finland, *Reliability Engineering & System Safety* 94(8): 1349-1357.
- Kristiansen, S. (2005), *Maritime transportation: safety management and risk analysis*, Oxford: Butterworth-Heinemann 508.
- Montewka, J., Goerlandt, F. and Kujala, P. (2012), Determination of collision criteria and causation factors appropriate to a model for estimating the probability of maritime accidents, *Ocean engineering* 40: 50-61.
- Montewka, J., Hinz, T., Kujala, P. and Matusiak, J. (2010), Probability modelling of vessel collisions. *Reliability Engineering & System Safety* 95(5): 573-589.
- Przywarty, M. (2008), Probabilistic model of ships navigational safety assessment on large sea areas, *Proc 16th international symposium on electronics in transport*, Ljubljana, Slovenia 9-10.
- Uluşçu, Ö. S., Özbaş, B., Altıok, T. and Or, İ. (2009), Risk analysis of the vessel traffic in the strait of Istanbul, *Risk Analysis* 29 (10): 1454-1472.
- Wang, Y., Zhang, J., Chen, X., Chu, X. and Yan, X. (2013), A spatial-temporal forensic analysis for inland-water ship collisions using AIS data, *Safety science* 57: 187-202.
- Wang, N. (2010), An Intelligent Spatial Collision Risk Based on the Quaternion Ship Domain, *Journal of Navigation* 63: 733-749.
- Weng, J., Meng, Q. and Qu, X. (2012), Vessel collision frequency estimation in the Singapore Strait, *Journal of Navigation* 65(2): 207-221.

The Development of a Slow Steaming Decision Support System for a Service Route in Trans-Pacific Trade

Eugene Y.C. Wong¹ and Henry Y.K. Lau²

¹Department of Supply Chain Management, School of Business, Hang Seng Management College, Hong Kong.

²Department of Industrial and Manufacturing Systems Engineering, The University of Hong Kong, Hong Kong.

Abstract

With the continuous increase of fuel prices and global environmental needs of carbon emission reduction, slow steaming has become one of the vital operations in maritime transportation. The development of slow steaming has moved forward from conceptual design to daily execution. Determining slow steaming speed often encounters a trade-off between fuel consumption and carbon emission reductions and shipment delays. A decision support modeling system is developed to assist maritime operations in consideration of fuel consumption, carbon emission, and shipment delay. The system has been applied to an Asia-North America service route in the Trans-Pacific trade to generate a recommended speed for slow steaming operations. Future development is discussed with an aim to improving the system by incorporating social cost of emission and emission regulation in emission control areas.

Keywords: Decarbonisation, maritime logistics, sustainability, carbon emission, decision support

1. Introduction

Constructive slow steaming has moved from conceptual design to detailed execution in recent years. Slow steaming strategy has been proposed by technical experts at Maersk Line to lower fuel consumption as well as reduce carbon emissions. Other ship liners started to implement slow steaming speed reduction to save fuel consumption due to the continuous increase in bunker costs. Vessel speed reduction has further brought environmental benefits by lowering the carbon emission volume. Initiatives in slow steaming addressing the need of decarbonisation was emphasized as one of the future developments in logistics and supply chain in the World Economic Forum in 2013. More studies on speed reduction in maritime transport have been carried out since. This paper reviews the recent development of slow steaming literature and proposes a decision support model for slow steaming operations. The model is verified and applied in the service route of a Trans-Pacific trade. Future development to improve the study and evaluation of the slow steaming model is discussed.

The development of slow steaming literature can be categorized into various stages. Early studies on slow steaming focused on increasing the awareness of speed reduction and its benefits to the environment. Corbett et al. (2009) evaluated the speed reduction impact towards greenhouse gas emissions, considering the factors of speed, energy consumption, and total cost. The study modeled the carbon emission in kg per trip with the carbon fraction, fuel used by main and auxiliary engines, operational and design at-sea speed, and distance between ports. Psaraftis and Kontovas (2010) studied various maritime policies on greenhouse gas emissions and discussed the ways of using a reduction of steaming speed, changing the number of vessels in the fleet, and proposing in-transit inventory holdings to address environmental protection needs. Cariou (2011) raised the question of whether slow steaming is a sustainable means of reducing CO₂ emissions. The study measured the emission in various tradelanes to evaluate whether this strategy is sustainable in the long run. It indicated that the speed reduction strategy could only be achieved in certain bunker price ranges for the major tradelanes. Lindstad et al. (2011) analyzed the effects of speed reduction on the direct emissions and the costs of maritime operations. The result of the analysis supported speed reduction initiatives towards minimizing CO₂ emissions. The study supplemented the finding that emissions from shipping can be reduced from 1,122 million ton CO₂ per year to 804 million ton CO₂ by lowering the vessel speed. Lai et al. (2011) examined the

environmental awareness and the environmental measures carried out in the shipping industry. The investigation further developed a conceptual framework to evaluate green shipping practices which included speed reduction initiatives. Similar studies on the concepts of slow steaming include Eefsen and Cerup-Simonsen (2010), Kontovas and Psaraftis (2011), and Lindstad et al. (2012).

Later stages of literature started to map the carbon footprint and estimate carbon emissions. Leonardia and Brownea (2010) proposed a method of calculating the carbon footprint of maritime transport of average vessel sizes in typical international routes of major container lines. Miola and Ciuffo (2011) estimated the ship emissions using the modeling approach. Gibbs et al. (2014) analysed the carbon footprint of international shipping in seaborne trade and investigated the role of sea ports in helping to mitigate the greenhouse gas emissions. There are also literature survey and analysis on maritime decarbonisation. Harilaos and Christos (2013) presented a survey of speed models in maritime transportation, including both non-emission and emission speed models. Armstrong (2013) provided a review on various low carbon shipping and optimization practices.

Recent studies further added different factors during speed reduction optimization and modeling. Qi and Song (2012) investigated the problem of designing an optimal vessel schedule to minimize the fuel consumption and carbon emissions with the consideration of uncertain port times and frequency requirements. Simulation-based stochastic approximation methods are proposed to solve the problem. The paper indicated the fuel consumption and emission from a ship per nautical mile is a quadratic convex function with respect to speed. Norlund and Gribkovskaia (2013) examined various speed optimization strategies with periodic vessel schedules. The modeling results showed that a 25% emissions and fuel cost reductions can be achieved without any fleet size increase. Doudnikoff and Lacoste (2014) reviewed the difference between vessel speeds within and outside the Sulphur Emission Control Areas (SECA) and whether the speed increase due to the slow steaming within SECA might increase the carbon dioxide (CO₂) emissions in the total voyage cycle. The study proposed a cost model by minimizing the combined-effect of speeds inside and outside the SECA. The model is further applied to serve North Europe services.

2. The development of a slow steaming model

There are several major assumptions used in the study. The study focuses on three types of containers, namely general cargo containers, reefer containers, and empty containers. The vessel size of SX classes with 8,888 TEU is used in the analysis. Bunker cost is the major cost to be studied in the model. The model assumed penalties are incurred for any shipment delay.

The speed reduction model focuses on the major factors of carbon emission, fuel consumption, and on time delivery. The objective function is established using the carbon emission volume, bunker cost and shipment delay. The objective function is represented as: Minimise $\alpha_1 f(v) + \alpha_2 g(v) + \alpha_3 h(v)$

where α_1 , α_2 and α_3 are importance weightings on carbon emissions, bunker costs, and number of days delayed. The carbon emission function $f(v)$ is the function of the difference between carbon emission volume before and after slow steaming implementation. The bunker cost function $g(v)$ represents the functions of the difference between bunker cost before and after slow steaming. The shipment delay function $h(v)$ is the function of number of days delayed before and after slow steaming.

Two constraints of the model are considered. The total number of container loaded in the model is within the vessel capacity. The total number of containers includes the three types of containers concerned. The slow steaming speed is controlled within a recommended range. The model has been developed using Microsoft Solver and Visual Basic for Application (VBA). User can input the corresponding weighting on the three factors and the total number of general cargo, reefer, and empty containers onboard. Slow steaming speed will be recommended after evaluating the factors of carbon emission, fuel consumption, and on time delivery. The flow of the model is presented in Figure 1.

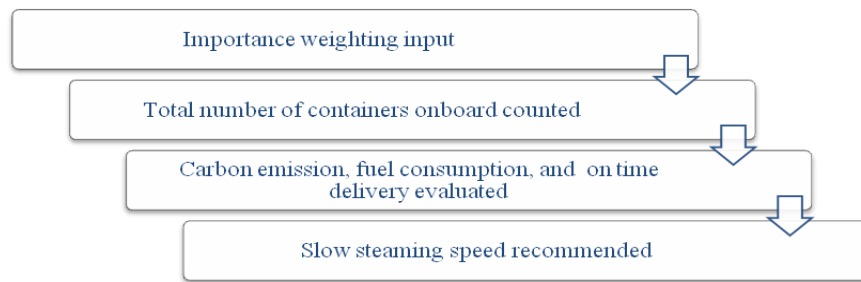


Fig 1. The flow of the slow steaming model

3. Slow steaming system on Asia-North America route in Trans-Pacific trade

A regular service running between Asia and North America in Trans-Pacific Trade is examined. The eastbound calls include: Xiamen (XMN) – Yantian (YAT) – Da Chan Bay (DCB) – Hong Kong (HKG) – Long Beach (LGB) while the westbound calls include Long Beach (LGB) – Kaohsiung (KHH) – Xiamen (XMN) – Hong Kong (HKG) – Yantian (YAT) – Da Chan Bay (DCB). Six vessels are the services with the vessel sizes of 8,888 TEU and 8,063 TEU. The study focuses on the westbound of the services as the cost-benefits of slow steaming is higher for westbound than eastbound.

The developed system provides users the user-interface for inputting the preference weighting factor on carbon emission, bunker cost, and customer delays. An example is input as shown in the Table 1. The system allows users to further input the number of containers loaded onboard. The input of container quantity is by cargo type, in terms of Twenty-foot Equivalent Units (TEU), refer to the Table 2. The results generated by the decision support system are shown in the Table 3. The cost savings are deducted with the shipment delay costs, in the form of penalty cost per unit of cargo. Considering the basic factors of bunker cost, carbon emission, and number of days delayed, the corresponding cost savings could be provided immediately to assist the decision making of the marine planners and commercial personnel.

Table 1. User input in the percentage of weighting factor

Factor	Weighting
Carbon emission	20%
Bunker cost	40%
Customer delays	40%
Total	100%

Table 2. The container onboard to be input in the decision support system (in TEU)

From Port	To Port	General		Empty		Reefer	
		Loading	Discharge	Loading	Discharge	Loading	Discharge
LGB	KHH	1,500	0	720	100	100	10
KHH	XMN	50	350	0	100	0	10
XMN	HKG	0	200	0	120	0	20
HKG	YAT	30	630	40	240	0	30
YAT	DCB	0	400	0	200	0	30

Table 3. Simulation results with recommended speed by the system

Speeds (knots)	Cost savings (USD)
14	10,130
16	10,521
18	7,888

4. Conclusion

In view of environmental protection, more stringent government restrictions on carbon emission and increasing fuel prices, slow steaming strategy is considered as one of the important maritime operations in a

ship liner business. A slow steaming decision support system is developed to assist marine planners and trade commercial personnel to design an optimal speed with considerations of fuel consumption, carbon emission and shipment delay. The simulated results showed the cost savings of each speed options, facilitating the complex decision process in slow steaming. The system is verified using an Asia-North America service route in the Trans-Pacific trade to generate a recommended speed for slow steaming operations. In practice, the instant results generated by the system will assist trade and marine personnel in their decision making process which involves complex data analysis. The decisions are often needed to be made within several hours or even less. With the support from the developed model, the management would be able to instantly determine the optimal speed in a more systematic and accurate way. This study applied the context cost of emission and put into the decision model in slow steaming. The slow steaming research is moved forward from the literature survey, awareness programs, and carbon footprint mapping to carbon and cost modeling. Future development is suggested to incorporate social costs of emissions and emission regulations in emission control areas. The next question of whether slow steaming is sustainable is needed to be continuously evaluated, considering the fluctuations of bunker price, vessel chartering cost, and ship building cost.

References

- Armstrong, V.N. (2013), Vessel optimization for low carbon shipping, *Ocean Engineering*.
- Cariou, P. (2011), Is slow steaming a sustainable means of reducing CO₂ emissions from container shipping? *Transportation Research Part D*, 16: 260-264.
- Corbett, J., Wang, H. and Winebrake, J. (2009), The effectiveness and costs of speed reductions on emissions from international shipping, *Transportation Research Part D: Transport and Environment* 14: 593–598.
- Eefsen, T. and Cerup-Simonsen, B. (2010), Speed, carbon emissions and supply chain in container shipping, In: *Proceedings of the Annual Conference of the International Association of Maritime Economists, IAME 2010*, Lisbon, Portugal.
- Gibbs, D., Rigot-Muller, P., Manfan, J. and Lalwani, C. (2014), The role of sea ports in end-to-end maritime transport chain emissions, *Energy Policy* 64: 337-348.
- Harilaos N. P. and Christos A. K. (2013), Speed models for energy-efficient maritime transportation: A taxonomy and survey, *Transportation Research, Part C* (26): 331-351.
- Kontovas, C.A. and Psaraftis, H.N. (2011), Reduction of emissions along the maritime intermodal container chain, *Maritime Policy & Management* 38 (4): 455–473.
- Lai, K.H., Lun, V.Y.H., Wong, C.W.Y. and Cheng, T.C.E. (2011), Green shipping practices in the shipping industry: Conceptualization, adoption and implications, *Resources, Conservation and Recycling* 55: 631-638.
- Leonardia, J. and Brownea, M. (2010), A method for assessing the carbon footprint of maritime freight transport: European case study and results, *International Journal of Logistics Research and Applications*, 13(5): 349-358.
- Lindstad, H., Asbjørnslett, B.E. and Strømman, A.H. (2011), Reductions in greenhouse gas emissions and cost by shipping at lower speeds, *Energy Policy* 39: 3456-3464.
- Lindstad, H., Asbjørnslett, B.E. and Strømman, A.H. (2012), The importance of economies of scale for reductions in greenhouse gas emissions from shipping, *Energy Policy* 386-398.
- Miola, A. and Ciuffo, B. (2011), Estimating air emissions from ships: Meta-analysis of modeling approaches and available data sources, *Atmospheric Environment* 45: 2242-2251.
- Norlund, E.K. and Gribkovskaia, I. (2013), Reducing emissions through speed optimization in supply vessel operations, *Transportation Research Part D* 23: 105-113.
- Psaraftis, H.N. and Kontovas, C.A. (2010), Balancing the economic and environmental performance of maritime transportation, *Transportation Research Part D* 15: 458-462.
- Qi, X. and Song, D.P. (2012), Minimizing fuel emissions by optimizing vessel schedules in liner shipping with uncertain port times, *Transportation Research Part E: Logistics and Transportation Review* 48(4): 863–880.
- Wong, E.Y.C., Lau, H.Y.K. and Raman, M. (2014), Supply chain decarbonisation - a cost-based decision support model in slow steaming maritime operations, *International Journal of Social, Human Science Science and Engineering* 8(3): 58-61.

The Impact of Panama Canal Expansion and Clean-Lines Strategy on Unit Emission of Trunk Route Deployments in International Container Shipping

Hui-Huang Tai¹ and Dung-Ying Lin^{2*}

¹Department of Shipping and Transportation Management, National Kaoshiung Marine University, No. 142, Hai-Jhuan Road, Nan-Tzu, Kaohsiung, 81143, Taiwan. E-mail address: dia@webmail.nkmu.edu.tw.

²Department of Transportation and Communication Management Science, National Cheng Kung University, No. 1, University Road, Tainan City, 70101, Taiwan. E-mail: dylin@mail.ncku.edu.tw.

* Corresponding Author

Abstract

The current container ship capacity in the global container shipping industry is in surplus. Operating costs can no longer be satisfied if container carriers leave numerous very-large container ships (VLCSs) idle according to the strategy implemented in 2009. Therefore, expansion of the Panama Canal (completion expected in 2015) is anticipated to provide container carriers with new opportunities to consume ship capacity and redeploy oceangoing trunk routes. This study examined the cargo sources and geographical locations of three trunk routes, the departure points of which are all in East Asia. The operating conditions of various shipping practices were used to simulate the trunk route deployment in the Panama Canal following its expansion. Subsequently, a clean-line strategy featuring liquefied natural gas (LNG) as a replacement for heavy oil was proposed to explore the effects that container carriers have on energy savings and emission reductions.

The results showed that the unit emissions of ships traveling trunk routes in East Coast North America (ECNA) and East Coast South America (ECSA) did not differ significantly regardless of whether the container carriers employed a conventional method or the new deployment plan following the expansion of the Panama Canal. By contrast, the adoption of a new method for sailing through the canal yields significant emission reductions in Far East/Europe (F/E) routes. In addition, the slow-steam strategy adopted by carriers and the more costly clean-line strategy are both effective when applied to trunk routes. The results of this study can provide a reference to container carriers deploying route structures and the International Maritime Organization when promoting emission-reduction policies.

Keywords: unit emissions, trunk route deployment, clean-lines strategy, ship-idle

1. Introduction

The expansion of the Panama Canal, which should be completed in 2015, is expected to substantially influence the container shipping industry. The canal will be accessible to container ships with a capacity of at least 12,000 twenty-foot equivalent units (TEU), rather than the current limit of less than 4,000 TEU. In addition, container transport from Asia to East Coast North America (ECNA) will no longer be reliant on U. S. Landbridge services. In response, the United States' east coast ports are building deep-water piers and new equipment in preparation for the anchorage of very-large container ships (VLCSs). However, for container carriers, the current global container ship capacity is already in surplus. After numerous VLCSs join the fleets of carriers, the first decision facing carriers is whether a portion of the ships should be left idle or if all the ships should be directly placed into operation. Furthermore, carriers must formulate trunk route deployment plans capable of satisfying market demands following canal expansion. These are the crucial issues currently encountered by container carriers.

However, from the perspective of environmental protection, having container transport as the primary means for transporting international trade goods raises environmental concerns. Specifically, pollutant emissions have increased since over 10,000-TEU VLCSs were put into operation in 2007, resulting in more container

ship fleets traveling oceangoing trunk routes (UNCTAD, 2011). Future trunk route re-structuring in response to the expansion of the Panama Canal will cause emission changes. This issue should attract global attention.

The aim of this study was to analyze possible changes in the traditional Trans-Pacific (T/P) routes, Far East/Europe (F/E) routes, and South America East Asia Coast (to ECSA) routes following expansion of the Panama Canal. Another objective of this study was to compare traditional trunk routes and new routes to determine which provides greater emission-reduction effects. In addition, the International Maritime Organization (IMO) has enforced increasingly strict regulations regarding the gas emissions of ships. To adhere to the 2015 limit regarding the SO_x content of marine fuels established by the International Convention for the Prevention of Pollution from Ships (MARPOL), the first batch of container ships that are fueled by liquefied natural gas (LNG) is being constructed, and is expected to join the shipping market in 2015. Consequently, container carriers are beginning to formulate strategies for using LNG as the fuel for container ships; this is known as the clean-line strategy (Fossey, 2012). Therefore, this study also explores whether LNG-fueled ships provide greater energy-saving and emission-reduction effects compared to traditional ships that are powered by heavy fuel oil (FO).

It should be highlighted that, to concentrate on analyzing the impact of Panama Canal expansion on international container shipping, the current research does not consider the seasonal fluctuation of the industry. Furthermore, the scenarios considered in the section of empirical analysis have emerged in major container shipping carriers recently. For instance, the P3 alliance (including Maersk, MSC and CMA CGM) who owns most of the big ship capacity and operates major trunk-routes have adopted the operating patterns presented in the current paper (Bennet, 2013; Porter, 2013; Hailey, 2013; Garratt and Teodoro, 2013). After the expansion of Panama Canal in 2015, the trunk-route trends mentioned in Section 2.3 are expected to be the common deployment and routine practice in container shipping industry. As the changes in the size and number of ships used on trunk-routes are directly related to the pollutant emission levels and the use of fuel alternatives, these critical issues must be addressed by carriers who need to cater to the emission control area (ECA) requirements of major ports in North America and Europe regions (UNCTAD, 2013).

2. Changes in Trunk-Route Deployment

The expansion of the Panama Canal will prompt numerous container carriers to re-structure their trunk route deployment considering the surplus capacity of container ships and the ship-idle costs. The factors that influence carriers' trunk route deployment are similar to those that influence their hub port choices. These factors include the ports' internal and external factors and the operational strategies of container carriers (Hwang & Tai, 2008). The two factors mentioned previously, that is, ship capacity and costs, are aspects of container carriers' operational strategies.

2.1 The Surplus Capacity of VLCSs

Container carriers are likely to redeploy their trunk routes based on the expanded Panama Canal, which is a good method for consuming large amounts of ship capacity while exploring new markets. According to a survey conducted by Alphaliner (2013, Issue 10), in 2014, the global container ship capacity will reach a record high of 17 million TEUs, a third of which will be from VLCSs. However, before 2014, no VLCSs will be scrapped for old age alone (IOT, 2012), resulting in a surplus of ship capacity. Therefore, in addition to the traditional trunk routes that comprise eastward T/P routes and westward F/E routes, carriers must formulate new plans for route deployment to efficiently exploit the capacity of VLCSs and acquire more cargo sources when using VLCSs to serve shippers in Asia, which is the region with the most cargo sources in the world.

An example of carriers adjusting their conventional trunk route deployment and ship capacity investment in response to a surplus of VLCS capacity was observed at the end of 2012 (Tai & Lin, 2013). In addition to the cost considerations of commercial operations, a crucial reason for container carriers' early response and preparations was the upcoming expansion of the Panama Canal. Shipping statistics published in the Alphaliner (2013) and monthly analyses in Containerization International (2013) show that the shipping capacity investments in F/E and T/P routes during the first quarter of 2013 reached a historical high. The G6 Alliance (comprising APL, Hapag-Lloyd, Hyundai Merchant Marine, Mitsui O.S.K. Lines, Nippon Yusen Kaisha, and

Orient Overseas Container Line) and the CKYH-Green Alliance (comprising Coscon, K Line, Yang Ming, and Hanjin Shipping) alone have invested more than 30 VLCSs as motherships in T/P routes. Although the scale of traditional motherships sailing on T/P routes does not exceed 8,000 TEU, the Mediterranean Shipping Company (MSC) has deployed VLCSs exceeding 13,000 TEU on T/P routes bound for the U.S. West Coast. In addition, Maersk Line Shipping Containers Worldwide and its associates replaced their traditional ECNA services with a trunk route from Far East-Europe to the U.S. East Coast, which comprises numerous F/E routes and extensions to the west. This phenomenon was implemented in 2000, when the shipping demand was lower than the tonnage supply. However, the adjustment executed in 2000 was aimed at reducing canal toll expenses, whereas the purpose of the current adjustment is to consume tonnage.

2.2 Changes in Ship-Idle Strategies

Carriers consider ship idling a highly uneconomic operating behavior that has adverse effects on hulls and engines. Table 1 shows the voyage cost structure for VLCSs; the data indicate that the fixed costs account for 51% to 62% of the total cost when ships are operating, whereas the necessary costs for idle ships, which include capital costs, insurance and depreciation costs, a portion of wages and welfare, and maintenance and repair costs, account for more than 30% of the total cost.

Table 1. The comparison of total cost of VLCS between running and idle status

The total cost of VLCS(10,000 TEU+) on each voyage	Running status	Idle status
Fixed cost 51%~62%		
Capital cost (15%~18%)	★★★	★★★
Wage and welfare (6%)	★★★	★
Insurance (2%)	★★★	★★★
Maintenance and repair cost (4%)	★★★	★
Depreciation (for 15 years) (12%~16%)	★★★	★★★
Store, overhead, running cost, container, chassis, rental, insurance, repair and others (12%~16%)	★★★	none
Variable cost 38%~49%		
Port expenses including customs, immigration, quarantine, dockage, pilotage, tuggage, launch hire, ferry, mornings, un mornings, anchorage, harbor dues, tonnage dues, terminal expenses (6%)	★★★	none
Bunkers expenses including fuel oil and diesel oil (15%~25%)	★★★	none
Cargo handling expenses including CY & CFS expenses, and stevedoring expenses including loading, discharging, shifting, lashing, un lashing, equipment hire (9%~12%)	★★★	none
Transshipment expenses (based on volumes, 4%~7%)	★★★	none
Water expenses, canal toll, commission, agency fee and others (4%)	★★★	none

Source: data compiled by authors, which collected from CKYH alliance; Stopford (2002); Lin and Chang (2010).

During the financial crisis at the end of 2009, the capacity of idle container ships reached 1.5 million TEU, and globally, approximately one tenth of all container ships were idle (IOT, 2012; Alphaliner, 2012). According to numerous shipping forecasts, the issue of idle container ships will emerge again in 2014. However, the situation will not be as severe as in 2009, because carriers have accumulated experience with the cost structure of idle ships. In addition, carriers understand that extra maintenance and repair costs are required when idle ships are returned to operation, and these costs will significantly exceed that indicated in Table 2. Furthermore, the European Union (EU) has begun prohibiting carriers from using idle ship capacity to increase freight rates (Alphaliner, 2013). Consequently, carriers must adopt a slow-steam strategy and formulate revised trunk route deployment plans to consume a greater amount of ship capacity. Incidentally, the expansion of the Panama Canal offers an excellent opportunity to implement these adjustments.

2.3 Trunk Route Trends

Trunk route deployment essentially related to the hub port choices of container carriers (Hwang & Tai, 2008). However, the factors that affect trunk route deployment are more complex than the determinants of container port choices because the en route ports for VLCSSs are all hub ports with high location, facility, draft, centrality, connectivity, accessibility, cargo source, and cargo handling standards (Song & Yeo, 2004; Tai & Hwang, 2007; McCalla, 2008; Ducruet, Lee, & Ng, 2010; Laxe, Seoane, & Montes, 2012; Tai, 2012). The majority of the ports marked in Fig. 1 satisfy the requirements for being a hub port for trunk routes.

Hwang and Tai (2008) employed two research methods to evaluate the crucial factors that influence carriers' hub port choices for trunk route deployment. The results showed that external factors, which included the cargo source, connectivity, and location, had the highest weights. This implies that the form factors for any new trunk routes are diverse. Therefore, the expansion of the Panama Canal has increased container carriers' cargo sources and enabled them to connect locations of more deep-water ports. Previous studies (Ashar, 2010; Fan, Wilson, & Tolliver, 2010; Lax et al., 2012; Marucci, 2012) have indicated that Panama Canal influences container transport in North and Central America and the changes in port operations caused by route connectivity. The possible changes to the deployment of the world's three main trunk routes resulting from the expansion of the Panama Canal are detailed in the following paragraphs.

The trunk routes shown in Fig. 1a are traditional F/E trunk routes that connect East Asia and Europe. The routes cover an extensive area and require the largest ships; the demands of the en route ports are based on crucial factors, such as the cargo source and location. The export-oriented cargo sources in central and southern China have attracted direct calls from motherships traveling trunk routes. Hong Kong and Singapore are the primary ports for transport container concentration. F/E routes begin from Asia, run through the Middle-East, and reach the Mediterranean and Nordic countries via the Suez Canal. Container carriers select various en route ports or home-ports in different sections of the route based on their operating characteristics. Because the current ships traveling on these routes are large (this study assumes that the motherships traveling trunk routes are 10,000-TEU VLCSSs), container carriers generally fill their ships with cargo from Southeast Asia, where their voyage begins, to satisfy economies of scale. For example, if cargos loaded in Shanghai use only 60% of the container volume (i.e., 6,000 TEU), carriers must fill their ships with cargo from Hong Kong and Singapore or neighboring hub ports, such as Shenzhen and Tanjung Pelepas, or use feeder vessels to collect and ship containers from the ports of Kaohsiung, Lam Chabang, and Jakarta to Hong Kong and Singapore before the cargos are shipped to Europe. Carriers adopt this method to integrate the export cargo sources in areas such as Taiwan, Thailand, and Indonesia. The container volumes listed in parentheses in Fig. 1 are the ports' reasonable loading and unloading volumes that we assumed following interviews with the carriers. This information is provided to better describe shipping practices.

After the Panama Canal expansion is complete in 2015, assuming that Singapore and Hong Kong are still hub ports, VLCSSs sailing on trunk routes to Europe require more Southeast Asian transport cargo sources to satisfy economies of scale before they sail from Asia across the Pacific Ocean to Europe. Therefore, in practice, carriers do not begin their voyages in China (e.g., the port of Shanghai); instead, routes generally begin in Singapore, thereby ensuring that the ships are full, which earn actual benefits for the carriers.

Considering the locational advantages of Central America and the Caribbean Sea, numerous carriers select particular transport ports (e.g., Jamaica or Manzanillo, PA) to connect ECNA and ECSA routes with European and Asian routes (McCalla, 2008). This trend of eastward F/E routes is shown in Fig. 1b. During an interview with an international container carrier that operates at a daily frequency, the carrier considered this deployment highly possible and feasible.

For a long time, the Trans-Atlantic (T/A) container transport market between Europe and North America was dominated by a few European carriers. However, since the end of 2012, carriers such as the G6 and Maersk have invested numerous VLCSSs in trunk routes among F/E and ECNA routes (Fig. 1c) to reduce the pressures of tonnage (Alpharliner, 2013) and canal toll expenses. With the expansion of the Panama Canal in 2015, numerous carriers will adopt the practice shown in Fig. 1d because these voyages consume less time and allow smaller carriers to enter the shipping market for T/A routes between Europe and North America without having to compete with a few strong large-scale carriers.

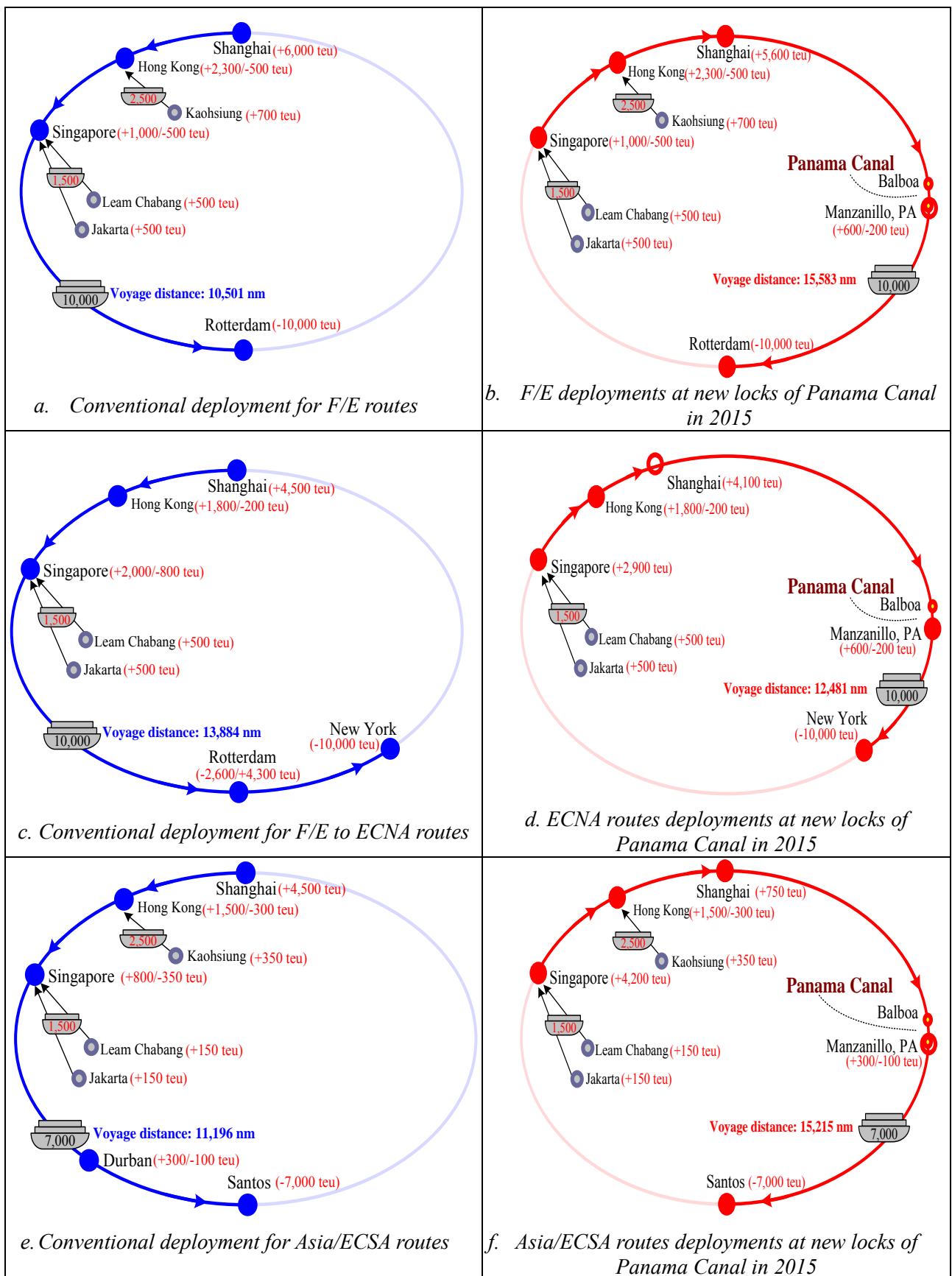


Fig 1. Scenarios in different directions on major trunk-routes

In recent years, the number of containers traveling from South America has multiplied because of rapid

economic growth. However, 10,000 -TEU V LCSs can not be deployed in the area because the port infrastructure requires improvements. Therefore, we used the example of a 7,000-TEU mothership and Fig. 1e to demonstrate why carriers operating on current ECSA routes, which are long and similar to F/E routes, must employ larger ships and attract sufficient cargo sources from South Asian ports before sailing to ECSA via South Africa (e.g., Durban) for transport and supply. Following the expansion of the Panama Canal, carriers sailing on eastward ECSA routes will also have to canvass cargo from Southeast Asian ports, and select Central American ports that serve the purposes of supply and transit (e.g., Manzanillo, PA) before traveling to South America, as shown in Fig. 1f. The results of interviews with current major carriers have shown that this situation already exists, and that the application of this model will increase significantly following the canal expansion.

3. Empirical Studies of Emission Reductions

3.1 Commercial navigation and the clean-lines strategy

Greenhouse gas emissions lead to the distribution of numerous pollutants that contain the following five main components: NO_x, SO₂, CO₂, hydrocarbons (HC), and particulate matter (PM). Specifically, CO₂ emissions account for the highest percentage (UNCTAD, 2011), and PM and SO₂ are detrimental to people's health (Corbett et al., 2009). Zervas (2006) reported that a decline in CO₂ emissions is the most effective method for reducing the impact of climate change; therefore, the transport industry's formulation and implementation of emission reduction measures has attracted global attention. This is because the oil consumed by the transport sector accounts for the highest percentage of the world's oil consumption. As shown in Table 2, this percentage reached 62% in 2010. The CO₂ emissions of the transport sector were second only to the electricity and heat production sector, accounting for 23%. Furthermore, the majority of these emissions are maritime and aviation pollutant emissions (UNCTAD, 2012).

Table 2. Energy use and emissions on transport sector

World oil consumption, 1973 and 2010					
Year	Transport	Industry	Non-energy use	other	
1973	45%	20%	12%	23%	
2010	62%	9%	17%	12%	
World CO ₂ emissions from fuel combustion by sector, 2009					
Year	Transport	Electricity and heat production	Other energy industry own use	Manuf. Industries and construction	Other sectors
2009	23%	41%	5%	20%	11%

Source: UNCTAD (2012), Chapter 6, B section.

In addition to the traditional practice of enforcing IMO regulations to regulate ship navigation and port operations, another method for effectively reducing the emissions of commercial navigation is to alter the fuels used by ships and offer incentives for carriers and shipyards. Chang and Wang (2012) found that slow steaming in the reduced speed zones (RSZ) of ports significantly reduced fuel consumption, costs, and pollutant emissions. In addition, adopting the concept of emission control areas (ECAs) and onshore power supply systems can reduce ships' CO₂ and PM emissions. The IMO's standard for the sulfur oxide content of the fuel powering ships in ECAs was reduced from 1.5% (m/m) in 2000 to 1.0% in 2012, and by 2015, it will be decreased to 0.1% (MARPOL Annex VI). Therefore, traditional ship engines, which were designed to consume heavy oil, and power generators, which were designed to consume diesel oil, will be gradually replaced. The construction of two LNG-powered container ships was initiated in December 2012 (Fossey, 2012). Tri-fuel design ships that can be powered by heavy oil, diesel, or LNG are also being manufactured (BRS, 2012; UNCTAD, 2012).

The clean-line strategy refers to carriers' using LNG to replace heavy oil as ship fuel to save energy saving and reduce emissions. This method offers numerous advantages. For example, at similar prices, LNG satisfies MARPOL Annex VI for 2015 and can reduce SO₂ emissions by more than 90% and CO₂ emissions by more than 20%. However, the following operational conditions must be satisfied in various countries' shipping and

port industries: more than 3 % of ship space must be reserved for LNG storage tanks; the temperature of storage tanks and pipelines must be maintained below -163°C ; the safety training procedures for ship crews must be modified accordingly; the ship operating costs will increase by 10%; and LNG supply stations must be established in en route ports. Only when these conditions are satisfied can the energy-saving and emission-reduction effects of this strategy be fully realized (Fossey, 2012).

3.2 Refined model for estimating unit emissions

This study assesses the unit emission reductions by comparing the pollutant inventories of the global trunk routes shifted from conventional deployments (e.g., Figs. 1a, 1c, and 1e) to the new locks of the Panama Canal, which is due for completion in 2015 (e.g., Figs. 1b, 1d, and 1f). Several commercial navigation periods must be first interpreted to estimate and compare the effectiveness of unit emission reductions for ship sailing. Winnes and Fridell (2010) categorized ship operations into three activities, namely, at berth, maneuvering, and at sea on a voyage. Each activity possesses specific factors and a complete emission evaluation model. Chang and Wang (2012) and Tai and Lin (2013) used the three periods to evaluate the pollutant emissions of ships. In this study, we categorized the sailing periods related to the Panama Canal into the following two activities: at a navigable canal (including lakes and rivers), and at locks (including the Gatun, Pedro Miguel, and Miraflores Locks). Table 3 shows the detailed equations used throughout the remainder of this paper.

Table 3. Notations for emission estimations

Notations	Contents
P^e	The sum of pollutant emissions (ton) including sailing, manoeuvring, navigable canal, locks and port periods.
$P_{Sailing}^e$	The total emissions (ton) of pollutant e (including NO_x , SO_2 , CO_2 , HC, PM) when ship is at sailing period.
$P_{Manoeuvring}^e$	The total emissions (ton) of pollutant e (including NO_x , SO_2 , CO_2 , HC, PM) when ship is at manoeuvring period.
$P_{Canal-time}^e$	The total emissions (ton) of pollutant e (including NO_x , SO_2 , CO_2 , HC, PM) when ship is sailing on navigable canal of Panama.
$P_{Locks-time}^e$	The total emissions (ton) of pollutant e (including NO_x , SO_2 , CO_2 , HC, PM) when ship is at major locks (Gatun, Pedro Miguel and Miraflores Locks).
P_{Port}^e	The total emissions (ton) of pollutant e (including NO_x , SO_2 , CO_2 , HC, PM) when ship is at port.
$Time_{Sailing}$	The sailing time from i-port to j-port (hour).
$Time_{Manoeuvring}$	The manoeuvring time (hour) including terminal-waiting time for each ship, liner owned private-terminals operators estimated similarly 8 hours at hub-port and 5 hours at feeder-port.
$Time_{Navigable-canal}$	The sailing time (hour) at navigable canal for each ship and estimated similarly 8 hours on the sailing period.
$Time_{Locks-time}$	The waiting time (hour) at major locks for each ship and estimated similarly 10 hours on the spillway.
$Time_{Port}$	The terminal handling time at port (hour) for each ship based on variable handling and operating situations on terminals.
D_{i-j}	The distance (nm; nautical mile) from i-port to j-port.
V	The speed of container ships (kt; nm/hour).
Q_i	The quantity of container (TEU) handling at i-port, including loading and unloading boxes for some ship.
EF_i	The terminal gross handling efficiency on i-port, consulting with terminal operators and showing that operators always using more than 4 gantry cranes once on a ship calling in most of hub-ports, the gross efficiency is more than 150 TEU/hour in some mega-hub ports, and others just within the range of efficiency (100-170 TEU/hour). All these ones have a uniform efficiency 150 TEU/hour for Shanghai, and 120 TEU/Hour for other ports.

F_t^o	The main engine fuel economy (ton/hour) of oil type o, including heavy oil(ho), LNG and diesel oil(do), t is the ship-type of 2,500 TEU or 10,000 TEU.
$K_{n,e}^o$	The emission factors (ton/ ton of fuel type) of pollutant e (including NO _x , SO ₂ , CO ₂ , HC, PM) for heavy oil, LNG and diesel on sailing, manoevring, navigable-canal, locks-time and port time (n).
k	Main engines fuel using heavy oil (ho), then $k = 1$, using LNG then $k = 0$.

Activity-based methods are effective for estimating pollutant emissions (Liao et al., 2009; Winnes & Fridell, 2010; Song & Xu, 2012; Tai & Lin, 2013). Activity data (e.g., port operations, service operation activities, and ship static data) aggregated for various ship sizes and types are employed for the entire process. Details of the activity-based method for evaluating emission levels can be found in Song and Xu (2012) and Tai and Lin (2013). In (1) to (6), five fuel consumptions can be obtained by multiplying the activity duration (hour) and engine fuel economy (tons/hour) for various activities (e.g., sailing, maneuvering, navigable canal, locks time, and port time). The total emissions (ton) of pollutant e are estimated by multiplying consumption (fuel types in tons) and emission factors (ton/ton for fuel types). The sum (Pe) of emissions can then be estimated by including the sailing, maneuvering, canal, spillway, and port periods accordingly.

$$P^e = P_{Sailing}^e + P_{Manoevring}^e + P_{Canal-time}^e + P_{Locks-time}^e + P_{Port}^e \quad (1)$$

$$P_{Sailing}^e = Time_{Sailing} \cdot F_t^o \cdot K_{Sailing,e}^o = \left(\frac{D_{i \sim j}}{V} \cdot F_t^{ho} \cdot K_{Sailing,e}^{ho} \right) \cdot k + \left(\frac{D_{i \sim j}}{V} \cdot F_t^{LNG} \cdot K_{Sailing,e}^{LNG} \right) \cdot (1-k) + \frac{D_{i \sim j}}{V} \cdot F_t^{do} \cdot K_{Sailing,e}^{do} \quad (2)$$

$$P_{Manoevring}^e = Time_{Manoevring} \cdot F_t^o \cdot K_{Manoevring,e}^o = Time_{Manoevring} \cdot \left((F_t^{ho} \cdot K_{Manoevring,e}^{ho}) \cdot k + (F_t^{LNG} \cdot K_{Manoevring,e}^{LNG}) \cdot (1-k) + F_t^{do} \cdot K_{Manoevring,e}^{do} \right) \quad (3)$$

$$P_{Canal-time}^e = Time_{Navigable-canal} \cdot F_t^o \cdot K_{Navigable-canal,e}^o = Time_{Navigable-canal} \cdot \left((F_t^{ho} \cdot K_{Navigable-canal,e}^{ho}) \cdot k + (F_t^{LNG} \cdot K_{Navigable-canal,e}^{LNG}) \cdot (1-k) + F_t^{do} \cdot K_{Navigable-canal,e}^{do} \right) \quad (4)$$

$$P_{Locks-time}^e = Time_{Locks-time} \cdot F_t^{do} \cdot K_{Locks-time,e}^{do} \quad (5)$$

$$P_{Port}^e = Time_{Port} \cdot F_t^o \cdot K_{Port,e}^o = \frac{Q_i}{EF_i} \cdot F_t^{do} \cdot K_{Port,e}^{do} \quad (6)$$

To analyze the scenarios shown in Figs. 1b, 1d, 1f, we employed the data presented in Tables 4 and 5. Table 4 shows the main engine fuel economy of different oil types and LNG; several ships (10,000/7,000 TEUs for trunk and 1,500/2,500 TEUs for feeder ships) with three levels of speed (22, 18, and 15 kt) were adopted for engine power factor and fuel consumption data. Table 5 shows the emission factors for various pollutants based on data reported by the IMO (2008, 2009), Liao et al. (2009), Chang and Wang (2010), and the LNG emission factors estimated and compiled by Kumar et al., (2011), Ports and Harbors (2012) and Containerization International (2012).

Table 4. The main engine fuel economy of oil type and LNG

				(Unit: ton / hour)
F (fuel economy)	V(kt; nm/hour)	Heavy oil(ho)	Liquefied Natural Gas(LNG)*	Diesel oil(do)
VLCS (about 7,500~10,000+ TEUs)	15kt	2.50	1.55	0.06
	18kt	3.96	2.45	0.06
	22kt	6.25	3.87	0.06
Handymax type (about 2,000~2,500 TEUs)	15kt	1.67	0.99	0.04
	18kt	2.92	1.73	0.04
	22kt	4.58	2.71	0.04
Handy type (about 1,000~2,000 TEUs)	15kt	1.50	0.89	0.04
	18kt	2.83	1.67	0.04
	22kt	4.58	2.71	0.04

Source: Corbett and Koehler (2003); Liao, et al. (2009); Alphaliner (2012).

*: If heavy oil (ho) replaced by LNG, estimated and compiled from Kumar, et al., (2011),

<http://alternativefuels10.tpub.com> and <http://www.fueleconomy.gov/feg>.

Table 5. Emission factors for pollutants unit: ton / ton of fuel type

K (emission factors)	NO _x	SO _x	CO ₂	HC	PM
Sailing at open-sea :ho ¹	0.089	0.054	3.179	0.003	0.0067
Sailing at open-sea :LNG ²	0.0178	0	2.25709	0.003	0.0006
Sailing at open-sea :do ¹	0.0887	0.0538	3.1688	0.003	0.0067
Maneuvering ³ period: ho ¹	0.064	0.055	3.179	0.0076	0.0106
Maneuvering ³ period: LNG ²	0.0128	0	2.25709	0.0076	0.00095
Maneuvering period: do ¹	0.0638	0.0538	3.1688	0.0076	0.0106
In port ³ : do (ho=0)	0.0615	0.0693	3.1688	0.0017	0.0035

Source:

1. IMO (2008, 2009); Liao, et al. (2009); Chang and Wang (2010).

2. If heavy oil (ho) replaced by LNG, estimated and compiled from Ports & Harbors, July/August, 2012, pp. 18-19./ Containerization International, June, 2012, pp.76-77./ TRI-ZEN(2012), LNG Markets Perspective, Jan. 2012, pp.3-4./ Lack, et al., (2012). Compared with ho, per unit of energy, natural gas reduces NO_x emissions by around 80%, SO_x by virtually 100%, CO₂ by around 29% and PM by 90%. This means that LNG fuelled vessels meet all current planned emissions criteria.

3. The emission factors (K) of navigable time in canal are the same as maneuvering period, and K values of port and locks-time are also identical for ship operations.

3.3 Results

Table 6 shows the pollutant emission of conventional F/E route deployment (Fig. 1-a). There are primarily five pollutants (NO_x, SO₂, CO₂, HC, and PM) summarized for different shipping activities (e.g., sailing, maneuvering, and port time). The total pollutant emission is 9086.8 tons and the voyage days are 34.3 days, including mother ship and feeder ship. We can observe that the new F/E deployments are in the opposite direction of mother ship in 2015 after canal expansion (Fig. 1-b). Furthermore, the shipping carriers would deploy big-vessel on navigable canal and major locks, including Gatun, Pedro Miguel, and Miraflores locks in the Panama Canal (i.e., P_{Canal-time} and P_{Locks-time}). Table 7 shows that the resulting pollutant emission and voyage day of mother ship increase from 8122.4 tons and 29.3 days to 8362.3 tons and 42.0 days respectively. These results show that the canal expansion changes the direction F/E trunk-route and simultaneously increases the carriers' total emissions and voyage days.

Table 6. Pollutant emissions for Fig. 1-a. Conventional deployment for F/E routes

							(Unit: ton)
V(kt)=18	NO _x	SO ₂	CO ₂	HC	PM	Pollutant emissions	Voyage days
Mothership							
P _{sailing}	208.8	126.7	7456.6	7.0	15.7		24.31
P _{Manoevring}	5.2	4.4	260.7	0.6	0.9		1.33
P _{Port}	0.7	0.8	34.3	0.0	0.0		3.61
subtotal	214.7	131.8	7751.6	7.7	16.6	8122.4	29.3
Feedership							
P _{sailing}	17.0	14.4	844.8	2.0	2.8		3.83
P _{Manoevring}	1.5	1.3	76.2	0.2	0.3		0.63
P _{Port}	0.1	0.1	3.7	0.0	0.0		0.59
subtotal	18.6	15.7	924.7	2.2	3.1	964.3	5.0
TOTAL	233.3	147.6	8676.3	9.9	19.7	9086.8	34.3

Table 7. Pollutant emissions for Fig. 1-b. F/E deployments in 2015

(Unit: ton)

V(kt)=18	NO _x	SO ₂	CO ₂	HC	PM	Pollutant emissions	Voyage days
Mothership							
P _{sailing}	309.8	126.7	7456.6	7.0	15.7		36.07
P _{Manoevring}	6.6	5.5	325.8	0.8	1.1		1.67
P _{Canal-time}	1.3	1.1	65.2	0.2	0.2		0.33
P _{Locks-time}	0.0	0.0	2.0	0.0	0.0		0.21
P _{Port}	0.7	0.8	35.1	0.0	0.0		3.69
subtotal	318.4	134.1	7884.7	8.0	17.1	8362.3	42.0
Feeder ship							
P _{sailing}	17.0	14.4	844.8	2.0	2.8		3.83
P _{Manoevring}	1.5	1.3	76.2	0.2	0.3		0.63
P _{Port}	0.1	0.1	3.7	0.0	0.0		0.59
subtotal	18.6	15.7	924.7	2.2	3.1	964.3	5.0
TOTAL	337.0	149.8	8809.4	10.2	20.1	9326.6	47.0

Table 8 shows the emission reductions for various trunk routes and voyage directions following the Panama Canal expansion. Among the five pollutants, CO₂ and NO_x emissions are the highest in all scenarios. Using Fig. 1a as an example, when ships traveling traditional F/E routes reduce their speed from 22 kt to 15 kt through slow steaming, the sum of the five pollutants (i.e., NO_x, SO₂, CO₂, HC, and PM) released by motherships decreased from 10,346 to 6,284 tons, and the unit emissions per nm and per day also decreased from 0.99 and 416.63 tons to 0.60 and 184.21 tons, respectively. Similar trends were observed for all the scenarios explored in this study. In conclusion, the results showed that the slow-steam strategy that carriers adopt to reduce fuel consumption also has emission-reduction effects.

Table 8. Pollutants comparisons for various scenarios and directions

(Unit: ton)

V(kt)	NO _x	SO ₂	CO ₂	HC	PM	Total pollutant Emissions	Trunk voyage (motherships)			
							Pollutant Emissions	Voyage days	Emissions per nm	Emissions per day
Fig. 1-a Conventional deployment for F/E routes (voyage distance: 10,501 nm)										
22	292.7	183.6	10798.0	11.9	24.2	11310.3	10346.0	24.8	0.99	416.63
18	233.3	147.6	8676.3	9.9	19.7	9086.8	8122.4	29.3	0.77	277.67
15	184.2	117.8	6922.1	8.2	16.0	7248.3	6284.0	34.1	0.60	184.21
Fig. 1-b F/E deployments in 2015 (voyage distance: 15,583 nm)										
22	425.1	185.9	10931.1	12.2	24.6	11578.9	10614.5	35.4	0.68	299.71
18	337.0	149.8	8809.4	10.2	20.1	9326.6	8362.3	42.0	0.54	199.22
15	264.1	120.0	7055.2	8.5	16.4	7464.4	6500.0	49.2	0.42	132.14
Fig. 1-b F/E deployments if heavy oil replaced by LNG										
22	57.1	2.9	4875.0	7.6	1.7	4944.2	4541.6	35.3	0.29	128.74
18	46.9	3.3	3955.7	6.3	1.5	4013.7	3611.1	41.8	0.23	86.32
15	38.8	3.6	3196.3	5.3	1.3	3245.3	2842.8	49.1	0.18	57.96
Fig. 1-c Conventional deployment for F/E to ECNA routes (voyage distance: 13,884 nm)										
22	376.4	233.8	13748.9	14.5	30.2	14403.7	13655.6	32.4	0.98	422.06
18	297.8	186.1	10943.8	11.8	24.3	11463.8	10715.8	38.2	0.77	280.53
15	232.9	146.7	8624.4	9.6	19.4	9033.1	8285.0	44.6	0.60	185.66
Fig. 1-d F/E to ECNA deployments in 2015 (voyage distance: 12,481 nm)										
22	341.7	213.0	12528.9	13.4	27.7	13124.8	12376.7	29.3	0.99	422.14
18	271.1	170.2	10007.3	11.0	22.4	10482.0	9733.9	34.6	0.78	281.56
15	212.8	134.8	7922.3	9.1	18.0	8296.9	7548.8	40.4	0.60	187.08

Fig. 1-d F/E to ECNA deployments if heavy oil replaced by LNG										
22	46.0	3.1	5588.0	8.3	1.9	5647.3	5335.6	29.3	0.43	181.99
18	37.9	3.5	4495.4	6.9	1.6	4545.3	4233.6	34.6	0.34	122.46
15	31.3	4.0	3592.9	5.6	1.4	3635.2	3323.6	40.4	0.27	82.37
Fig. 1-e Conventional deployment for Asia/ECSA routes (voyage distance: 11,196 nm)										
22	311.5	195.2	11484.5	12.6	25.7	12029.6	11067.6	25.4	0.99	435.63
18	248.2	156.8	9222.5	10.5	20.9	9658.9	8696.9	30.1	0.78	288.76
15	195.8	125.0	7352.2	8.7	17.0	7698.7	6736.8	35.3	0.60	190.84
Fig. 1-f Asia/ECSA deployments in 2015 (voyage distance: 15,215 nm)										
22	415.5	258.6	15217.5	16.2	33.7	15941.5	14979.6	33.6	0.98	446.36
18	329.4	206.4	12143.5	13.3	27.2	12719.8	11757.9	40.0	0.77	294.22
15	258.3	163.2	9601.8	10.9	21.8	10056.0	9094.1	47.0	0.60	193.46
Fig. 1-f Asia/ECSA deployments if heavy oil replaced by LNG										
22	55.6	3.3	6775.1	10.1	2.2	6846.3	6446.2	33.6	0.42	192.08
18	45.7	3.8	5443.1	8.3	1.9	5502.9	5102.8	40.0	0.34	127.69
15	37.7	4.4	4342.9	6.8	1.7	4393.5	3993.4	47.0	0.26	84.95

With the example of F/E routes (Figs. 1a and 1b), mothership unit emissions declined significantly when container carriers used the Panama Canal to plan reverse eastward F/E routes based on considerations of the canvassing conditions in Asian ports and port selection behavioral patterns. For instance, at 18 kt, the unit emissions per nm and per day declined from 0.77 and 277.67 tons to 0.54 and 199.22 tons, respectively. With future implementation of the clean-line strategy, these emissions may be reduced to 0.23 and 86.32 tons.

In the example of F/E to ECNA routes (Figs. 1c and 1d), the mothership unit emissions remained similar when container carriers deployed eastward or westward trunk routes based on actual operations. For instance, at 18 kt, the traditional unit emissions per nm and per day increased from 0.77 and 280.53 tons to 0.78 and 281.56 tons, respectively, following redeployment. With future implementation of the clean-line strategy, unit emissions may decline to 0.34 and 122.46 tons with reductions of more than 50%.

The unit emissions yielded by the traditional deployment of Asia/ECSA routes (Figs. 1e and 1f) are similar to those of F/E to ECNA routes. The unit emissions of motherships traveling trunk routes showed no significant differences despite changes in voyage directions following canal expansion. By contrast, significant changes occurred after implementing the clean-line strategy.

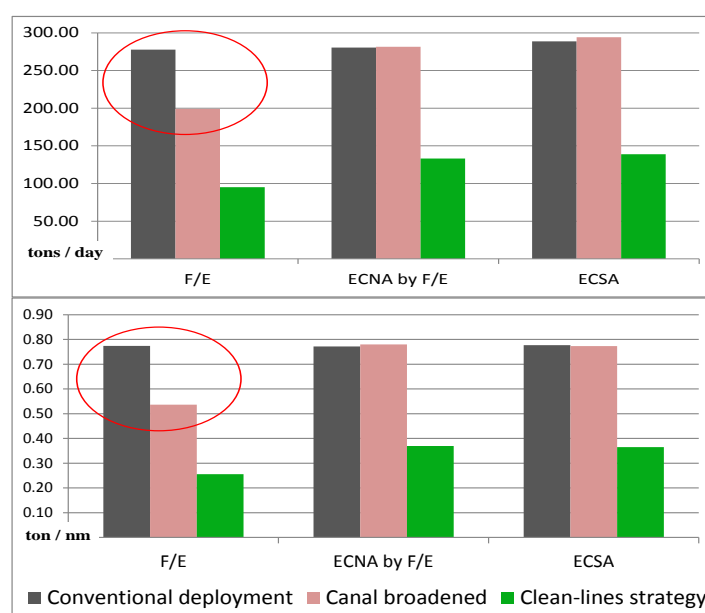


Fig 2. Pollutant comparisons for different scenarios (V=18 kt)

A comparison of the unit missions in Fig. 2 showed that following the Panama Canal expansion and voyage direction alterations, significant emission reductions only occurred for traditional F/E routes. By contrast, no significant differences in the unit emissions per day or per nm for F/E to ECNA routes and Asia/ECSA routes were observed following route redeployment. However, significant emission reductions were achieved after implementing the clean-line strategy, which involves using LNG to replace heavy oil as fuel.

4. Conclusion and Remarks

The trunk route deployments of container carriers are based on numerous factors. However, previous studies have primarily examined the cargo source, geographical location, port condition, carrier preference, and connectivity, without considering the subsequent influence of the Panama Canal expansion. The completion of this project in 2015 will directly influence container carriers' thinking regarding energy savings, emission reductions, and operations, as well as their deployment of global trunk routes.

Consulting oceangoing container carriers, we found that various operating environments must be considered when altering voyage directions. Specifically, VLCS operations will face even greater restrictions. Subsequently, this study developed future deployment models for three traditional trunk routes to understand the energy-saving and emission-reduction effects of the deployments. The results showed that no significant differences existed in the unit emissions of VLCSSs traveling all trunk routes, except for F/E routes. However, the slow-steam and clean-line strategies were effective.

Although various conditions of VLCS business practices, such as the cargo source, ship type, and port were considered, only fuel economy and various fuel emission factors at differing speeds could be used to determine the emission-reduction effects and differences of VLCSSs traveling various trunk routes. Whether the differences result from complex nautical practices or other factors must be examined by nautical experts.

In addition, to reduce the effects of greenhouse gas emissions and fuel costs, a clean-line strategy for the container ship industry was proposed. However, this strategy simultaneously increases ship operating costs. Therefore, future studies should investigate how carbon trading can become an incentive for carriers to adopt this strategy.

Acknowledgment

The authors would like to acknowledge the National Research Council, Taiwan, ROC, for providing partial funding support under contract number NSC 100-2410-H-006-069-MY3 and NSC-101-2410-H-022-007. The contents of the article remain the sole responsibility of the authors.

References

- Alphaliner (2013), Weekly Newsletter 2013: 1-12.
- Alphaliner (2012), Weekly Newsletter 2012: 1-52.
- Ashar, A. (2010), An Expanding Brief, Containerization International (28–29 July).
- BRS (2012), Shipping and Shipbuilding Markets Annual Review 2012, Paris, 2012.
- Bennet, S. (2013), Asia-North America trade Lane Analysis: Changes abound, Containerization International, 45-47.
- Chang, C. C. and Wang, C. M. (2012), Evaluation the effects of green port policy: Case study of Kaohsiung harbor in Taiwan, Transportation Research Part D, 17:185-189.
- Corbett, J.J., Wang, H. and Winebrake, J. J. (2009), The effectiveness and costs of speed reductions on emissions from international shipping, Transportation Research Part D: Transport and Environment 14: 593–598.
- Corbett, J. J. and Koehler, H.W. (2003), Updated emissions from ocean shipping, Journal of Geophysical Research 108: 4650-4665.
- Ducruet, C., Lee, S. W. and Ng, A. K. Y. (2010), Centrality and Vulnerability in Liner Shipping Networks: Revisiting the Northeast Asian Port Hierarchy, Maritime Policy and Management 37(1): 17–36.
- Fossey, J. (2012), Clean Lines, Containerization International (76-77 June 2012).

- Fan, L., Wilson, W. W. and Tolliver, D. (2010), Optimal Network Flows for Containerized Imports to the United States, *Transportation Research Part E*, 46: 735-749.
- Garratt, M and Teodoro, A. (2013), The P3 Network/What the Analysts Say: P3 Aftermath, *Containerization International*, July 2013: 28-29.
- Hailey, R. (2013), The P3 Network/What the Ports Say: Mega Alliance Poses Landside Challenges, *Containerization International*, July 2013: 26.
- Hwang, C. C. and Tai, H. H. (2008), Analysis of Relative Competitiveness Among Major Hub-Ports Across Taiwan Strait: *Journal of the Chinese Institute of Transportation*, 20 (1): 1-38.
- IMO-International Maritime Organization (2008), MEPC 58/WP. 9. Report of the drafting group on amendments to MARPOL Annex VI and the NO_x Technical Code.
- IMO-International Maritime Organization (2009), Second IMO GHG Study 2009 Update of the 2000 GHG Study: Final Report covering Phase I and 2, MEPC 58/INF. 10, 9 April, 2009, IMO, London.
- IOT-Institute of Transportation (2012), Terminal Patterns for Change of Environment of Taiwan Container Port Operation, Ministry of Transportation and Communications (IOT), Taiwan, Government Publication & Project No. IOT-IOT-101-H1DB001a.
- Kumar, S., Kwon, H. T., Choi, K. H., Lim, L., Cho, J. H. and Tak, K. (2011), LNG: An Eco-friendly Cryogenic Fuel for Sustainable Development, *Applied Energy* 88: 4264-4273.
- Lack, D. A., Thuesen, J. and Elliot, R. (2012), Investigation of Appropriate Control Measures (Abatement Technologies) to Reduce Black Carbon Emissions from International Shipping, Study Report and Prepared by Litehauz, ERRIAZ.
- Laxe, F. G., Seoane, M. J. F. and Montes, C. P. (2012), Maritime Degree, Centrality and Vulnerability: Port Hierarchies and Emerging Areas in Containerized Transport (2008–2010), *Journal of Transport Geography* 24: 33-44.
- Liao, C. H., T seng, P. H. and Lu, C. S. (2009), Comparing carbon dioxide emissions of trucking and intermodal container transport in Taiwan, *Transportation Research Part D*, 14: 493-496.
- Lin, K. and Chang, C. C. (2010), Management and Operation for Shipping Industries, S&T Co., 2010, Taipei.
- McCalla, R. J. (2008), Container transshipment at Kingston, Jamaica, *Journal of Transport Geography* 16: 182–190.
- Marucci, S. D. (2012), The Expansion of the Panama Canal and its Impact on Global CO₂ Emissions from Ships, *Maritime Policy & Management* 39(6): 603–620.
- Poter, J. (2013), The View from the Bridge, The P3 Network/What the Carriers Say: The Trio Reshaping Container Shipping, *Containerization International*, July 2013: 19-21.
- Stopford, M. (2002), Is the Drive for Ever Bigger Containerships Irresistible? *CI Shipping Forecasting Conference*, 25th April 2002, Clarkson Research.
- Song, D. P. and Xu, J. (2012), An operational activity-based method to estimate CO₂ emissions from container shipping considering empty container repositioning, *Transportation Research Part D*, 17: 91–96.
- Song, D. W. and Yeo, K. T. (2004), A Competitive Analysis of Chinese Container Ports Using the Analytic Hierarchy Process, *Maritime Economics & Logistics* 6: 34-52.
- Tai, H. H. (2012), The Influence on Transshipment Function of Kaohsiung Port by the Trunk-route Developments in the East Asia and Cross-strait Direct Shipping, *Transportation Planning Journal* 41(4): 435-463.
- Tai, H. H. and Hwang, C. C. (2007), Hub Port Selection Factors for Container Carriers Across Taiwan Strait, *Transportation Planning Journal* 36(1): 31-62.
- Tai, H. H. and Lin, D. Y. (2013), Comparing the Unit Emissions of Daily Frequency and Slow Steaming Strategies on Trunk Route Deployment in International Container Shipping, *Transportation Research Part D: Transport and Environment* 21: 26-31.
- TRI-ZEN (2012), LNG Markets Perspective, TRI-ZEN LNG Perspective, January 2012: 1-11.
- UNCTAD (2012), Review of Maritime Transport, United Nations Conference on Trade and Development, United Nations publication.
- UNCTAD (2011), Review of Maritime Transport, United Nations Conference on Trade and Development, United Nations publication.
- Winnes, H. and Fridell, E. (2010), Emissions of NO_x and Particles from Maneuvering Ships, *Transportation Research Part D*, 15: 204–211.
- Zervas, E. (2006), CO₂ benefit from the increasing percentage of diesel passenger cars, *Case of Ireland*, *Energy Policy* 34: 2848–2857.

Impact of Different Factors on the Risk Perceptions of Employees in Container Shipping Companies

Chia-Hsun Chang¹, Jingjing Xu² and Dong-Ping Song³

¹Plymouth Business School, Plymouth University, Plymouth, UK.

²Plymouth Business School, Plymouth University, Plymouth, UK.

³Department of Supply Chain Management, University of Liverpool, Liverpool, UK.

Abstract

This paper attempts to investigate the impact of several factors on the risk perception of the employees in container shipping companies. The investigation is conducted through an empirical study using Analysis of Variance (ANOVA) based on the Taiwan container shipping companies as a case study. The data were collected through a questionnaire survey in which the respondents were required to indicate their details (e.g. work experience, position, and department, etc.) and perceived risk factors in relation to container shipping logistics operations.

The study reveals that work experience has a significant impact on the perception of risks in respect of almost all risk elements. It is notable that the respondents whose work experience is less than 10 years have a significantly higher perception of risks than the others, and those who have more than 25 years of work experience have a significantly lower perception of risks. The study also shows that the size of company impacts on risk perceptions only in respect of the risks associated with payment flow. In addition, position of the employee in the company does not affect his/her risk perception.

Keywords: Container shipping, Risk perception, Risk analysis, ANOVA.

1. Introduction

Container shipping plays an increasingly important role in international trade. At present, about 52% of the world seaborne trade in value is carried by container ships (World Shipping Council, 2011a; 2011b). However, due to the involvement of multi-entities in its operations and its international nature, container shipping faces various risks ranging from information inaccuracy, pirate attack to having partners with bad credit. To tackle these risks, a great deal of effort has been made in academia to identify the associated risks and assess the impacts of these risks on shipping operations (e.g., Fu et al., 2010; Husdal and Bråthen, 2010; Chang et al., 2014). A number of risks elements have been identified in previous studies, including IT failure, transportation delay, recession, etc. Many of these studies are empirical in nature and the data are normally collected through interview and/or questionnaire survey.

One issue which is normally overlooked in risk analysis studies in the maritime field is how people perceive risks. Many risk analysis studies are empirical in scope where the data were collected through questionnaire and/or interview survey. The respondents normally have different background such as gender, work experience, position, etc. The difference in background may impact on their risk perceptions.

Risk perception is defined as “the subjective assessment of the probability of a specified type of accident happening and how concerned we are with the consequences” (Sjöberg et al., 2004, p.8). A number of studies found that personal background may have impact on risk perceptions. For example, Sjöberg (1998) looked into the differences in risk perceptions of experts and the public. He concluded that “groups that are different with regard to education, interest, and employment differ greatly in how they perceive risks”. Dake (1991), Weber and Hsee (1998), and Renn and Rohrman (2000) focused on the difference in risk perception on cross-cultural/countries, and found that different cultural can impact respondents’ risk perception. Belrose and Pilisuk (1991) addressed on different groups of respondents’ occupation (firefighters, insurance salespeople,

and radiation specialist), and suggested that different occupation have differences in risk judgements. Flynn et al. (1994), Davidson and Freudenburg (1996), and Gustafson (1998) focused on how the difference in gender impact on risk perceptions.

In the maritime field, studies on this issue has been lacking. Notably, information about employees' personal information are usually included in questionnaires in the maritime studies, such as work experience (year) (Lu and Shang, 2005; Yang et al., 2009), position (Lu and Shang, 2005; Lu and Tsai, 2008; Yang et al., 2009), department (Lu and Shang, 2005; Oltedal and Wadsworth, 2010), company's ownership (Lu and Tsai, 2008; Yang et al., 2009) company's main business (Yang et al., 2009), and company's size (Yang et al., 2009). However, the respondents are normally treated as a homogenous group and the differences in how they perceive risks are not considered.

Against this background, this paper attempts to investigate the impact of these factors on the perception of risks of the employees in container shipping companies using an empirical approach. The rest of the paper are structured as follows: Section 2 describes the research methodology; Section 3 presents the data analysis and research findings; and Section 4 includes discussions and conclusions.

2. Research Methodology

To identify risk perceptions of container shipping managers in different department or with different characteristics, this paper uses Analysis of Variance (ANOVA) which is a common method to test whether significant differences exist among different respondent groups. To conduct ANOVA in this paper, three steps were taken: (1) in order to identify risk factors, a systemic review of literature about container shipping operations and general supply chain was conducted; (2) to confirm the identified risk factors and to explore addition risk factors, a number of interviews were conducted; (3) a large scale of questionnaire survey were then conducted and ANOVA was applied to analyse the impact of the respondents' background on their risk perceptions. Detailed about the methods and steps are presented below.

2.1 Taiwan case study

This paper uses Taiwan's container shipping companies as a case study. Taiwan is an island country which largely relies on international trade. According to the Ministry of Transportation and Communications (2011), ships transport around 99% of international trades in Taiwan. Under this situation, container shipping plays an important role for Taiwan's economy. It is expected that a case study of Taiwan will be able to provide some insight into the risk analysis issues in the wider maritime context.

2.2 ANOVA

ANOVA is a common statistic method mainly used to analyse whether the results have significant difference from different groups by analysing and comparing different groups' mean value. It is used to deal with the problem that statistics data is usually impacted by different groups' background (Chen, 2004). As explained below, before using ANOVA, a set of steps were conducted in the paper, including identifying risk factors through literature review and interview, and measuring risk perceptions through a questionnaire survey.

2.2.1 Identify risk factors through literature review and interview

Waters (2007) stated that risk identification is usually deemed as the first stage of a risk research, and he suggested that relative literature review and interviews are common method to identify risk in risk analysis studies. In this study, both methods were used to identify risk factors in container shipping operations. The literature review includes the risk factors in container shipping operations and in general supply chain. The purpose to review literature about general supply chain is to make an inclusive risk factor list. As some of the risk factors were identified from general supply chain, a further set of interview with open questions was used to confirm the existing risk factors from the previous literature review and explore new risk factors that do not mention in previous studies.

2.2.2 Measure risk perception through questionnaire survey

After identifying an inclusive risk factor list, a large scale questionnaire survey was used to collect the respondents' risk perception. This survey consists of two major parts: respondent's details and their risk perception. The respondent's details part includes several questions such as the respondent's work experience (1-10 years; 11-20 years; 21-25 years; and over 25 years), department (president/vice-president; information/document; financial/accounting; and operation/ shipping), job title (president; manager; director; clerk; sales; and others), company's main business (shipping company; shipping agency; other), company's ownership (Taiwan's company; foreigners' company; and Taiwan with foreigner cooperation), and company's size (1-50 employees; 51-100 employees; 101-500 employees; and over 500 employees).

The respondent's risk perception part is measured through two major elements: risk likelihood (or probability of loss) and risk consequence (or significance of loss) (Sjöberg et al., 2004). Risk likelihood is the probability that a risk caused by a risk-source will occur (Elky, 2006); and risk consequence is the outcome or the potential outcome of a risk event (NPSA, 2008). Risk consequences are normally measured in monetary terms. However, in some cases it is not that straightforward, e.g. it is difficult to measure a delayed delivery in monetary terms owing to the intangible characteristics of the consequence. In risk analysis, reputation loss (Bebbington et al., 2008) is normally considered as a non-financial loss. In container shipping operations, some types of safety (Kasperson et al., 1988; IMO, 2009) and security (Tzannatos, 2003; IMO, 2009) damage (e.g., pain and suffering of the crew and their family) are the characteristics of non-financial loss. In this paper, three types of risk consequences are considered, namely, financial loss, reputation loss, and safety and security incident related loss.

The questions of the respondent's risk perception part are designed with a five-point Likert scale to measure the level of risk likelihood and consequence from the respondents' reception. The value of likelihood is normally described by a number between 0 and 1; however, many studies (e.g. Waters, 2007; NPSA, 2008) have used five abstractive categories to describe the probability of an event: very low (or impossible; rare), low (or unlikely), medium (or occasional; possible), high (or frequent; likely), and very high (or almost certain). In this paper, numbers 1, 2, 3, 4, and 5 are used to represent "rare", "unlikely", "possible", "likely", and "almost certain" respectively. In addition, the value of risk consequence is also used five abstractive categories in many studies (e.g. Waters, 2007; NPSA, 2008) to describe the severity of a risk factor, such as negligible (or no effect), minor, moderate (or major), serious (or hazardous), and critical (or catastrophic). In this paper, numbers 1, 2, 3, 4, and 5 are used to represent "insignificant", "minor", "moderate", "major", and "catastrophic" respectively.

After obtaining the value of risk likelihood and risk consequence, this study uses risk scale method to calculate the respondents' risk perception through combining these two elements together. Risk scale is usually calculated through the level of risk likelihood multiplied with the level of risk consequence (Shen et al., 2001; Tzannatos, 2003; Zou et al., 2007; Cox, 2008; NPSA, 2008). It is a simple and effective method to rank risks. This method can produce a complete risk perception from each respondent. In this study, we firstly multiply each risk factor's likelihood and consequence from each respondent, and then average the value to represent the importance of a specific risk factor. The equation can be formed as Eq. 1:

$$R_r = \frac{1}{N} \sum_{i=1}^N R_{ri} = \frac{1}{N} \sum_{i=1}^N l_{ri} \cdot c_{ri}, \text{ for } 1 \leq r \leq M \quad (1)$$

Where

R_r = the mean value of the risk factor r

M = the total number of risk factors under investigation

N = the total number of respondents

R_{ri} = the risk scale assessed by respondent i for the impact of risk factor r

l_{ri} = the level of risk likelihood for risk factor r given by the respondent i

c_{ri} = the level of risk consequence for risk factor r given by the respondent i

The survey population is based on the list of 2010 ROC National Association of Shipping Agencies in Taiwan. All of the 116 container shipping companies in the list were included. Three shipping managers in each container shipping companies, from information/ documentation department, physical/ operation department, and financial/ accounting department, are selected. A total 342 questionnaires were sent in 2011.

2.2.3 ANOVA

ANOVA is based on three assumptions: (1) each data value is independent and does not relate to any of the other data values; (2) the data for each group should follow normal distribution; and (3) the data for each group have the same variance (i.e. standard deviation squared)(Hays, 1994). ANOVA uses sum of square and degree of freedom to calculate within groups mean square (MSW) and between groups mean square (MSB), and then obtain a F ratio through dividing MSB with MSW (Chen, 2004), which can be denoted as Eq. 2

$$F = \text{MSB}/\text{MSW} \quad (2)$$

Where F ratio represents the differences within and between groups of data, and a large F ratio indicates the significant difference within and between groups (Saunders et al., 2007). If a significant difference pair of groups are obtained, we need to conduct multiple comparison to check which groups are significant different. The common methods for multiple comparison are Scheffe, Tukey's Honestly Significant Difference (Tukey's HSD), and Bonferroni correction (Chen, 2004).

In this paper, various types of group categorisation were developed from the categorisation of respondents' details (Section 2.2.2), i.e. work experience (by years), departments, positions, company types (main business), company owners, and employee numbers. The analysis was carried out using SPSS 20 for Windows and the results of the data analysis are discussed in the next section. The difference will be called "significant" when the p value is less than 0.05. This paper use Tukey's HSD to conduct the multiple comparison and examine which groups are "significant" different.

3. Data Analysis And Research Findings

3.1 Identification of Risks in Container Shipping

Risks in container shipping operations are many; they can be roughly classified into three risk categories: risks associated with the information flow, risks associated with the physical flow, and risks associated with the payment flow (Chang et al., 2014). Each risk category consists of several risk elements, and each risk element consists of several risk factors. The detailed lists of the risks identified in previous studies are presented below.

3.1.1 Risks associated with information flow

As shown in Table 1, three risk elements associated with information flow are identified, namely, information delay, inaccurate information, and IT failure. There are 4 risk factors under information delay, 5 risk factors under inaccurate information, and 3 risk factors under IT failure.

Table 1. Risks associated with information flow

<i>Information delay</i>		
Code	Risk factor	Literature sources
InfoD_1	Using different communication channels in the supply chain and consequently increasing the time of information transmission. (e.g. telephone, Email, EDI)	Metters, 1997
InfoD_2	Supply chain partners not transmitting essential information on time	Angulo <i>et al.</i> , 2004; Yang, 2010, 2011
InfoD_3	Processing documents being detained by government departments (e.g. customs)	Husdal and Bråthen, 2010; Yang, 2010
InfoD_4	Shipping company not transmitting essential information on time	Angulo <i>et al.</i> , 2004

<i>Inaccurate information</i>		
InfoI_1	Lack of information security during the information flow	Sharma and Gupta, 2002; Finch, 2004; Qi and Zhang, 2008
InfoI_2	Information asymmetry/incompleteness	Forrester, 1961; Lee <i>et al.</i> , 1997; Angulo <i>et al.</i> , 2004; Husdal and Bråthen, 2010
InfoI_3	Lack of information standardisation and compatibility	Tummala and Schoenherr, 2011
InfoI_4	Shippers requesting extra service information	Interviews
InfoI_5	Shippers hiding cargo information (non-declare)	Interviews
<i>IT failure</i>		
InfoIT_1	IT infrastructure breakdown or crash	Qi and Zhang, 2008; Swabey, 2009; Tummala and Schoenherr, 2011
InfoIT_2	Unsuitable human operation on IT infrastructure	Millman, 2007
InfoIT_3	Unsuitable human operation on application software	Millman, 2007

3.1.2 Risks associated with physical flow

Table 2 shows the two risk elements associated with physical flow, i.e., transportation delay and cargo/asset loss or damage. There are 9 risk factors identified under transportation delay and 6 risk factors identified under cargo/asset loss or damage.

Table 2. Risks associated with physical flow

<i>Transportation delay</i>		
Code	Risk factor	Literature sources
PhTD_1	Port strikes	Notteboom, 2006; Drewry, 2009; Husdal and Bråthen, 2010; Tummala and Schoenherr, 2011
PhTD_2	Port congestions (unexpected waiting times before berthing or before starting loading/discharging)	Notteboom, 2006; Drewry, 2009; Tummala and Schoenherr, 2011
PhTD_3	Port/terminal productivity being below expectations (loading/discharging)	Notteboom, 2006; Tummala and Schoenherr, 2011
PhTD_4	Unstable weather	Notteboom, 2006; Husdal and Bråthen, 2010
PhTD_5	Inappropriate empty container transportation	Song <i>et al.</i> , 2005; Drewry, 2006; Song and Dong, 2011
PhTD_6	Container shortage (e.g. Shippers use containers as storage, container revamp, unexpected demand)	Interviews
PhTD_7	Lack of flexibility of fleet size and designed schedules	Song <i>et al.</i> , 2005; Qi and Song, 2012
PhTD_8	Cargos being detained by customs	Interviews
PhTD_9	Oil price rise	Notteboom and Vernimmen, 2009; Husdal and Bråthen, 2010
<i>Cargo/asset loss or damage</i>		
PhCD_1	Damage to containers or cargo due to terminal operators' improper loading/unloading operations	Husdal and Bråthen, 2010
PhCD_2	Cargo being stolen from unsealed containers	Drewry, 2009; Husdal and Bråthen, 2010
PhCD_3	Damage caused by transporting dangerous goods	Talley, 1996; Husdal and Bråthen, 2010
PhCD_4	Damage to ship or quay due to improper berth	Talley, 1996; Husdal and Bråthen,

	operations	2010
PhCD_5	Damage to frozen cargo/ reefer containers due to electricity failure	Interviews
PhCD_6	Attack from pirates or terrorists	Drewry,2009; Fu <i>et al.</i> , 2010; Tummala and Schoenherr, 2011; Liwång <i>et al.</i> , 2013

3.1.3 Risks associated with payment flow

The three risk elements associated with payment flow are listed in Table 3. They are currency exchange, payment delay, and non-payment. There are 2 risk factors identified under currency exchange, 2 risk factors identified under payment delay, and 4 risk factors identified under non-payment.

Table 3. Risks associated with payment flow

<i>Currency exchange</i>		
Code	Risk factor	Literature sources
PayCE_1	Change of currency exchange rate during payment process	Tummala and Schoenherr, 2011
PayCE_2	Financial crisis in the loan countries	Interviews
<i>Payment delay</i>		
PayPD_1	Payment delay from partners or shippers	Seyoum, 2009
PayPD_2	Unrealized contract with partners	Tummala and Schoenherr, 2011
<i>Non-payment</i>		
PayNP_1	Shippers going into bankruptcy	Husdal and Bråthen, 2010; Tummala and Schoenherr, 2011
PayNP_2	Shippers abandoning cargos when cargos have already reached the port of destination	Interviews
PayNP_3	Shippers breaking the contract or reducing the container volume	Chen, 2008
PayNP_4	Having partners with bad credit	Tummala and Schoenherr, 2011

3.2 Characteristics of the respondents

In reference to the list of ROC National Association of Shipping Agencies, this study selected and invited the managers to participate in the questionnaire survey. This research sent out 342 questionnaires on 14th July 2011 and then got 88 replies, include 62 valid one and 26 invalid one, within a month. The valid return rate was 18.13% (Table 4).

Table 4. Questionnaires reply detail

Questionnaire	Return	Invalid reply	Valid reply	Valid reply rate
342	88	26	62	18.13%

Table 5 presents the 62 respondents' detail. In the work experience (year) aspect, approximately 75% of respondents have already worked within shipping industry for more than 16 years. This result shows that most of the respondents have very professional work experience within container shipping supply chain and the result of this questionnaire has a high reliability. In department aspect, the most respondents work in operation/shipping department (48.4%), information/document department has 12.9% and financial/accounting department occupies 19.4%. Although this study has already tried to distribute similar sample number between information, financial and operation departments, the replied respondents' department are uncontrollable. This unbalance sample might become a bias to the result of risk identification and risk mitigation strategies choice. In terms of professional role, the most type of respondent is manager/assistant manager (35.5%), and the second one is direct/vice direct (29%). There are 30 respondents' positions above

than manager, which shows 48.4% of respondents have the power to make decisions within shipping companies. More than 60% of respondents work in container shipping agency, and approximately 30% of respondents work in container shipping company. In ownership type sector, more than 70% of respondents work in local container shipping companies. In the company size aspect, 35.5% of respondents work in small companies (fewer than 50 employees), and around 45% of respondents work in companies which have more than 200 employees.

Table 5. Respondents' detail

	Groups	number	%
Work experience (year)	1 - 5 years	9	14.5
	6 - 10 years	4	6.5
	11 - 15 years	3	4.8
	16 - 20 years	12	19.4
	21 - 25 years	17	27.4
	Over 25 years	17	27.4
Department	President/ vice-president	7	11.3
	Information/ document	8	12.9
	Financial/ accounting	12	19.4
	Operation/ shipping	30	48.4
	Other	5	8.1
Job title	Vice president or above	8	12.9
	Manager/Assistant manager	22	35.5
	Director/Vice Director	18	29.0
	Clerk	10	16.1
	Sales representative	3	4.8
	Others	1	1.6
Type of business	Container shipping company	19	30.6
	Container shipping agency	38	61.3
	Others	5	8.1
Ownership pattern	Local firm	44	71.0
	Foreign-owned firm	10	16.1
	Foreign-local firm	7	11.3
	Others	1	1.6
Number of employees	1 - 50 people	22	35.5
	51 - 100 people	11	17.7
	101~200 people	1	1.6
	201~500 people	15	24.2
	over 500 people	13	21.0

3.3 Results from ANOVA

3.3.1 About work experience

Table 6 shows the results about different risk perceptions of employee with different work experiences. Four groups have been classified into 1-10 years of work experience (Group A), 11-20 years of work experience (Group B), 21-25 years of work experience (Group C), and over 25 years of work experience (Group D).

Under financial loss, in terms of element InfoD, Group A has significant difference with group B and group D from statistics view; moreover, from the mean value, Group A (11.33) is significant higher than Group B (6.05) and Group D (6.72). In terms of element InfoI, Group A (11.28) is significant higher than Group D (6.24). Regarding to InfoIT, the mean value of Group A (11.00) is significant higher than Group B (6.04) and Group D (5.78). In order to save the space, the following sections only present the elements that have significant groups. Group A is significant higher than Group B in PhTD and PayPD, whilst Group A is

significant higher than Group D in PhTD, PhCD, PayPD, and PayNP. The results indicate that Group A, the people who are junior (work experience between 1 and 10 years), has significant higher sense of risk in financial loss than other groups.

Under reputation loss, Group A is significant higher than Group D in InfoI, PhTD, PhCD, PayPD, and PayNP, whilst Group C is significant higher than Group D in PhTD. This result shows that Group D, the people whose work experience are over 25 years, has significant lower sense of risk in reputation loss.

Under safety and security related incident loss, Group A is significant higher than Group B in InfoIT, PhTD, and PayPD, whilst Group A is significant higher than Group D in InfoI, InfoIT, PhTD, and PayPD. Group C is significant higher than Group D in PhCD.

Notably, InfoIT in reputation loss (P value: 0.024) and InfoD in safety and security incident related loss (P value: 0.026) have significant P value (i.e. P value < 0.05); however, the results of their Tukey HSD show that no groups have significant different within these two risk elements.

Table 6. ANOVA result from different work experiences

	Category	Element	Work experience (Year)				P value	Tukey HSD
			1-10 (N = 13)	11-20 (N = 15)	21-25 (N = 17)	Over 25 (N = 17)		
Financial loss	Risks associated with information flow	InfoD	11.33	6.05	9.35	6.72	0.007*	(A,B) (A,D)
		InfoI	11.28	7.77	9.95	6.24	0.016*	(A,D)
		InfoIT	11.00	6.04	9.14	5.78	0.003*	(A,B) (A,D)
	Risks associated with physical flow	PhTD	12.16	8.08	11.26	7.88	0.006*	(A,B) (A,D)
		PhCD	13.03	8.98	10.87	7.22	0.004*	(A,D)
	Risks associated with payment flow	PayCE	11.31	7.00	10.71	7.79	0.095	N/A
		PayPD	12.54	7.23	10.24	6.41	0.004*	(A,B) (A,D)
		PayNP	11.92	7.47	8.85	6.18	0.017*	(A,D)
Reputation loss	Risks associated with information flow	InfoD	8.88	6.12	9.25	6.32	0.101	N/A
		InfoI	10.92	7.29	9.49	6.04	0.019*	(A,D)
		InfoIT	9.92	5.60	9.25	5.82	0.024*	N/A
	Risks associated with physical flow	PhTD	10.64	6.53	9.84	5.68	0.003*	(A,D) (C,D)
		PhCD	11.12	7.87	9.98	6.02	0.013*	(A,D)
	Risks associated with payment flow	PayCE	10.19	5.4	9.15	5.74	0.078	N/A
		PayPD	10.27	5.67	9.47	5.00	0.010*	(A,D)
		PayNP	10.04	5.85	8.16	4.72	0.026*	(A,D)
Safety and security incident related loss	Risks associated with information flow	InfoD	9.35	5.60	9.10	5.81	0.026*	N/A
		InfoI	11.55	7.77	10.84	6.86	0.014*	(A,D)
		InfoIT	11.03	6.47	10.08	5.88	0.000*	(A,B) (A,D)
	Risks associated with physical flow	PhTD	10.40	5.74	9.40	6.07	0.006*	(A,B) (A,D)
		PhCD	11.50	10.04	12.27	7.64	0.021*	(C,D)
	Risks associated with payment flow	PayCE	9.08	5.13	9.15	5.97	0.155	N/A
		PayPD	9.58	4.90	8.15	4.85	0.009*	(A,B) (A,D)
		PayNP	8.85	5.18	8.26	4.97	0.064	N/A

*means the p value is less than 0.05

3.3.2 About professional field

Table 7 shows that results about different risk perceptions of employee with different department. Five groups have been classified into president/vice-president (Group A), information/document (Group B), financial/accounting (Group C), operation/shipping (Group D), and other department (Group E).

In financial loss, there are two risk elements that have significant P value, including PhTD (P value: 0.015) and PhCD (P value: 0.038). In terms of PhTD, the result shows that Group B and Group D are significant different, which means that managers in operation/ shipping department (mean value: 11.39) have more risk perceptions than managers in information/ document department (mean value: 5.81). In terms of PhCD, the result also shows that Group B and Group D are significant different, which means that managers in operation/ shipping department (mean value: 11.54) have more risk perceptions than managers in information/ document department (mean value: 5.85).

In reputation loss, although PhTD does not have a significant P value (0.051), there are still two groups that have significant risk perceptions, including Group B and Group D. This means that the managers in operation/ shipping department (mean value: 9.65) have more risk perceptions on transportation delay than the managers in information/ document department (mean value: 4.64). In addition, PayPD has a significant P value (0.041); however, there are no significant different groups that address on this risk element.

Under safety and security incident related loss, two risk elements (PhTD and PhCD) have a set of groups that hold significant different risk perception, respectively. In terms of PhTD, whose P value is significant (P value: 0.030), and operation/ shipping department (Group D, mean value: 9.21) have more risk perceptions on transportation delay than the managers in information/ document department (Group B, mean value: 3.90). In terms of PhCD, whose P value is not significant (P value: 0.057), but there are still two groups (Group A and Group B) that have different risk perception. This means that president/ vice-president (Group A, mean value: 13.21) have more risk perceptions on cargo/asset loss or damage than the managers in information/ document department (Group B, mean value: 6.60). In addition, PayPD has a significant P value (0.048); however, there are no significant different groups that address on this risk element.

Table 7. ANOVA result from different professional field

	Category	Element	Department					P value	Tukey HSD
			A	B	C	D	E		
Financial loss	Risks associated with information flow	InfoD	10.79	6.31	6.50	8.84	8.54	0.252	N/A
		InfoI	10.17	6.30	7.70	9.47	8.46	0.428	N/A
		InfoIT	7.62	4.83	6.50	9.40	7.71	0.104	N/A
	Risks associated with physical flow	PhTD	10.14	5.81	9.12	11.39	8.43	0.015*	(B,D)
		PhCD	9.74	5.85	9.28	11.54	8.88	0.038*	(B,D)
	Risks associated with payment flow	PayCE	9.50	5.06	9.00	10.84	6.86	0.094	N/A
		PayPD	9.00	5.38	8.83	10.75	5.93	0.055	N/A
		PayNP	9.46	5.41	7.25	9.89	7.00	0.170	N/A
Reputation loss	Risks associated with information flow	InfoD	10.04	5.81	6.27	7.95	8.21	0.346	N/A
		InfoI	9.83	5.98	6.73	9.22	8.54	0.294	N/A
		InfoIT	8.57	4.17	6.03	9.01	7.33	0.112	N/A
	Risks associated with physical flow	PhTD	8.03	4.64	7.92	9.65	5.97	0.051	(B,D)
		PhCD	8.31	5.10	8.32	10.01	7.60	0.113	N/A
	Risks associated with payment flow	PayCE	8.07	3.19	7.58	9.27	4.86	0.110	N/A
		PayPD	8.21	3.81	6.50	9.45	4.86	0.047*	N/A
		PayNP	7.39	3.53	6.13	8.82	5.25	0.092	N/A
Safety and security incident related loss	Risks associated with information flow	InfoD	9.21	5.34	6.29	8.19	6.71	0.371	N/A
		InfoI	12.37	7.03	7.97	9.50	9.03	0.246	N/A
		InfoIT	8.24	6.17	7.03	9.29	8.62	0.320	N/A
	Risks associated with physical flow	PhTD	8.48	3.90	8.06	9.21	5.59	0.030*	(B,D)
		PhCD	13.21	6.60	9.44	11.11	9.86	0.057	(A,B)

	Risks associated with payment flow	PayCE	9.00	3.19	7.38	8.96	3.43	0.059	N/A
		PayPD	7.43	3.25	7.33	8.07	3.86	0.048*	N/A
		PayNP	9.04	3.09	6.69	7.81	4.39	0.080	N/A

A: president/vice-president (N = 7), B: information/document (N = 8), C: financial/accounting (N = 12), D: operation/shipping (N = 28), E: other (N = 7) and *means the p value is less than 0.05

3.3.3 About position in the company

Table 8 shows that results about different risk perceptions of employee with different positions. Three groups have been classified into president and manager (Group A), Director and clerk (Group B), and Sales and other (Group C).

The results show that no risk elements have significant P value, and all these three groups do not have significant different risk perceptions on these risk elements under different risk consequences.

Table 8. ANOVA result from different position

	Category	Element	Professional role			P value	Tukey HSD
			President & manager (N = 23)	Director & clerk (N = 28)	Sales & other (N = 11)		
Financial loss	Risks associated with information flow	InfoD	8.78	7.52	8.98	0.554	N/A
		InfoI	9.14	8.48	8.25	0.846	N/A
		InfoIT	7.80	7.40	9.15	0.577	N/A
	Risks associated with physical flow	PhTD	10.24	9.12	10.37	0.576	N/A
		PhCD	10.12	9.92	9.17	0.858	N/A
	Risks associated with payment flow	PayCE	10.33	7.71	10.27	0.203	N/A
		PayPD	9.41	8.13	10.05	0.529	N/A
		PayNP	9.17	7.65	8.84	0.563	N/A
Reputation loss	Risks associated with information flow	InfoD	8.60	6.54	8.27	0.245	N/A
		InfoI	8.78	7.66	8.98	0.627	N/A
		InfoIT	8.35	6.43	8.85	0.263	N/A
	Risks associated with physical flow	PhTD	8.82	7.19	8.74	0.400	N/A
		PhCD	9.10	8.38	8.23	0.833	N/A
	Risks associated with payment flow	PayCE	8.72	5.98	8.95	0.209	N/A
		PayPD	8.70	6.32	7.95	0.295	N/A
		PayNP	8.02	6.02	7.66	0.378	N/A
Safety and security incident related loss	Risks associated with information flow	InfoD	8.34	6.52	7.70	0.371	N/A
		InfoI	10.02	8.69	8.55	0.569	N/A
		InfoIT	8.38	7.86	9.00	0.741	N/A
	Risks associated with physical flow	PhTD	8.85	6.65	8.59	0.196	N/A
		PhCD	11.37	9.76	9.44	0.387	N/A
	Risks associated with payment flow	PayCE	8.98	5.41	8.55	0.091	N/A
		PayPD	7.80	5.88	6.82	0.364	N/A
		PayNP	8.46	5.37	6.64	0.099	N/A

3.3.4 About employer's main businesses

Table 9 shows that results about different risk perceptions of employee in different companies with different main business. Three groups have been classified into shipping company (Group A), shipping agency (Group B), and other (Group C).

The results show that only under reputation loss has a risk element with significant P value, this is PayPD and its P value is 0.032. Group A and Group B have significant different risk perceptions on this risk element, this

means that managers in shipping agencies (Group B, mean value: 8.92) have significant higher risk perception on PayPD than managers in shipping companies (Group A, mean value: 5.18). Moreover, although PhCD under reputation loss does not have significant P value, there are still two groups that have significant risk perceptions. They are Group A (mean value: 6.50) and Group B (mean value: 9.65), and this means managers in shipping agencies have higher risk perception on PhCD than managers in shipping companies. In addition, there are no risk elements that have significant P value under financial loss and safety and security incident related loss.

Table 9. ANOVA result from different main businesses

	Category	Element	Main business			P value	Tukey HSD
			Shipping company (N = 19)	Shipping agency (N = 38)	Other (N = 5)		
Financial loss	Risks associated with information flow	InfoD	7.24	8.80	7.85	0.502	N/A
		InfoI	7.43	9.18	9.68	0.392	N/A
		InfoIT	6.79	8.54	6.80	0.360	N/A
	Risks associated with physical flow	PhTD	8.78	10.20	10.07	0.506	N/A
		PhCD	8.56	10.29	11.60	0.300	N/A
	Risks associated with payment flow	PayCE	7.87	9.43	11.70	0.360	N/A
		PayPD	7.89	9.30	10.20	0.562	N/A
		PayNP	7.39	8.64	10.75	0.408	N/A
Reputation loss	Risks associated with information flow	InfoD	6.50	7.91	9.55	0.339	N/A
		InfoI	7.07	8.59	10.92	0.237	N/A
		InfoIT	6.16	8.04	9.33	0.298	N/A
	Risks associated with physical flow	PhTD	6.58	8.92	7.27	0.183	N/A
		PhCD	6.50	9.65	8.83	0.061	(A,B)
	Risks associated with payment flow	PayCE	4.79	8.83	8.00	0.066	N/A
		PayPD	5.18	8.92	5.40	0.032*	(A,B)
		PayNP	5.05	8.24	5.60	0.080	N/A
Safety and security incident related loss	Risks associated with information flow	InfoD	6.00	8.00	8.20	0.285	N/A
		InfoI	7.68	9.83	9.64	0.289	N/A
		InfoIT	7.16	8.90	7.47	0.309	N/A
	Risks associated with physical flow	PhTD	6.49	8.55	7.24	0.269	N/A
		PhCD	8.96	10.85	11.23	0.330	N/A
	Risks associated with payment flow	PayCE	4.79	8.39	8.40	0.105	N/A
		PayPD	5.21	7.76	5.00	0.113	N/A
		PayNP	4.49	7.74	7.65	0.069	N/A

*means the p value is less than 0.05

3.3.5 About company type

Table 10 shows that results about different risk perceptions of employee in different type of company: Taiwan local company (Group A), foreign company (Group B), and Taiwan with foreigner cooperation (Group C).

The results show that only Group A (mean value: 9.92) and Group B (mean value: 5.44) have significant different risk perception in InfoI under safety and security incident related loss. This means that managers in Taiwan local companies (Group A) feel that InfoI would cause serious risk impact compared to managers in foreign companies (Group B).

Table 10. ANOVA result from different company types

	Category	Element	Company type			P value	Tukey HSD
			Taiwan local company	Foreign company	Taiwan with foreigner cooperation		

			(N = 45)	(N = 10)	(N = 7)		
Financial loss	Risks associated with information flow	InfoD	8.34	6.38	10.32	0.238	N/A
		InfoI	8.98	6.36	10.09	0.214	N/A
		InfoIT	7.90	6.53	9.48	0.441	N/A
	Risks associated with physical flow	PhTD	10.18	6.89	11.14	0.059	N/A
		PhCD	10.20	7.37	11.29	0.160	N/A
	Risks associated with payment flow	PayCE	9.52	6.35	10.64	0.213	N/A
		PayPD	9.20	6.70	10.50	0.297	N/A
		PayNP	8.57	6.55	10.21	0.342	N/A
Reputation loss	Risks associated with information flow	InfoD	7.53	6.33	9.96	0.267	N/A
		InfoI	8.43	6.98	9.46	0.553	N/A
		InfoIT	7.64	5.90	9.48	0.353	N/A
	Risks associated with physical flow	PhTD	8.05	6.36	10.63	0.171	N/A
		PhCD	8.89	6.13	10.48	0.142	N/A
	Risks associated with payment flow	PayCE	7.53	5.30	10.64	0.221	N/A
		PayPD	7.49	5.10	10.93	0.095	N/A
		PayNP	7.02	5.55	9.43	0.337	N/A
Safety and security incident related loss	Risks associated with information flow	InfoD	7.52	5.13	9.93	0.101	N/A
		InfoI	9.92	5.44	9.57	0.028*	(A,B)
		InfoIT	8.60	6.37	8.71	0.304	N/A
	Risks associated with physical flow	PhTD	7.97	5.54	10.02	0.126	N/A
		PhCD	10.54	7.87	12.24	0.136	N/A
	Risks associated with payment flow	PayCE	7.42	4.60	10.29	0.170	N/A
		PayPD	7.02	4.60	8.14	0.255	N/A
		PayNP	6.88	4.28	9.36	0.123	N/A

*means the p value is less than 0.05

3.3.6 About company size

Table 11 shows that results about different risk perceptions of employee in different company size. Three groups have been classified into company that has less than 50 employees (Group A), company that has 51 to 500 employees (Group B), and company that has more than 500 employees (Group C).

The results show that only risks associated with payment flow has significant p value under reputation loss and under safety and security incident related loss. In terms of reputation loss, managers in company size which under 50 employees (Group A) have significant higher risk perception than managers in company size with 51-500 employees (Group B) and managers in company size with over 500 employees (Group C) in PayCE, PayPD, and PayNP. Moreover, in terms of safety and security incident related loss, managers in company size which under 50 employees (Group A) have significant higher risk perception than managers in company size with 51-500 employees (Group B) in PayCE, PayPD, and PayNP.

Table 11. ANOVA result from different company size

	Category	Element	Employee number			P value	Tukey HSD
			1-50 (N = 33)	51-500 (N = 16)	Over 500 (N = 13)		
Financial loss	Risks associated with information flow	InfoD	8.95	7.06	7.90	0.415	N/A
		InfoI	9.05	7.43	9.31	0.478	N/A
		InfoIT	8.60	7.02	7.03	0.419	N/A
	Risks associated with physical flow	PhTD	10.41	8.14	10.09	0.217	N/A
		PhCD	10.47	8.65	9.82	0.453	N/A
	Risks associated with payment flow	PayCE	10.14	7.13	9.08	0.222	N/A
		PayPD	9.71	7.41	8.88	0.373	N/A
		PayNP	9.13	7.50	7.79	0.525	N/A

Reputation loss	Risks associated with information flow	InfoD	8.07	6.69	7.60	0.618	N/A
		InfoI	8.45	7.90	8.48	0.925	N/A
		InfoIT	8.23	6.83	6.79	0.550	N/A
	Risks associated with physical flow	PhTD	9.37	6.50	6.70	0.058	N/A
		PhCD	9.65	7.22	7.73	0.188	N/A
	Risks associated with payment flow	PayCE	9.80	4.97	4.88	0.007 [*]	(A,B) (A,C)
		PayPD	9.47	5.41	5.04	0.008 [*]	(A,B) (A,C)
		PayNP	8.87	5.14	4.79	0.013 [*]	(A,B) (A,C)
	Safety and security incident related loss	Risks associated with information flow	InfoD	8.52	5.48	6.92	0.087
InfoI			9.75	7.04	10.25	0.123	N/A
InfoIT			9.10	7.08	7.54	0.230	N/A
Risks associated with physical flow		PhTD	9.09	6.00	6.79	0.055	N/A
		PhCD	11.17	8.64	10.14	0.208	N/A
Risks associated with payment flow		PayCE	9.33	4.88	5.08	0.018 [*]	(A,B)
		PayPD	8.26	4.81	5.35	0.027 [*]	(A,B)
		PayNP	8.45	4.83	4.73	0.016 [*]	(A,B)

*means the p value is less than 0.05

4. Discussion and Conclusion

This study explores the impact of employees' background on risk perceptions in container shipping. Taiwan container shipping is used as a case study and ANOVA is employed. A number of findings are obtained:

- (1) The respondents' year of work experience has obvious impact on risk perception. The new employees with a work experience of less than 10 years have higher value of risk perception on many risk elements compared to the employees with a work experience of between 11 and 20 years or over 25 years. This might be because that the new employees are not yet fully familiar with their job operations and thus take the risks more seriously. On the other hand, the employees who have had an extensive work experience might not be as alert as the junior staff since they are fully familiar with the operations.
- (2) The respondents' professional field has some impact on risk perception. The employees working in operation/shipping department have higher risk perception than the employees working in information/document department on transportation delay. This might be because that in container shipping companies employees from operation/shipping department have to take the responsibility of transporting cargoes and are likely to experience high occurrence on transportation delay caused by unstable weather and/or port congestion.
- (3) The respondents' company's main business area has some impacts on risk perception. The employees who work in shipping agencies have higher risk perception than the employees who work in shipping companies on "cargo/asset loss or damage" and "payment delay" in respect of "reputation loss". This might be because the shipping agencies do not have their own ship to transport cargo, so they tend to emphasize more on risks that may cause reputation loss.
- (4) The respondents' company type has some impacts on risk perception. The employees who work in Taiwan local companies have higher risk perception than the employees who work in foreign companies on "inaccurate information" in respect of "safety and security incident related loss". This might be because that the customers of Taiwan local companies are usually local; the shipping companies are thus under pressure of maintaining good relationship with the shippers who sometimes want to save transportation fee by hiding real cargo information, this may cause serious safety and security incident to shipping companies. On the other hand, foreigners' companies do not have such pressure of getting good relationship around the local shippers, so they have some strict policies that the local shippers have to

follow.

- (5) The respondent's company size has some impact on risk perception. The employees who work in small companies of less than 50 employees have higher risk perception than the employees who work in middle-sized companies (51 to 500 employees) and big company (over 500 employees) on risks associated with payment flow in respect of both "reputation loss" and "safety and security incident related loss". This might be because that the small companies usually do not have huge capital to run the business and they largely rely on their sales which in turn is dependent on their reputation. Thus they tend to emphasize more on risks associated with payment flow that may cause reputation loss. Furthermore, safety and security incident related loss, if occurred, are normally in large quantity, the damage caused by which will be more serious to smaller companies than large companies.
- (6) Quite different from the above, the respondents' position does not seem to impact on risk perceptions. Considering this with the above findings, this result perhaps suggests that the employees in different positions, be that junior or senior, so long as their work experience is similar and they work in same department, their risk perceptions will be similar.

From the point of view of improving risk management in container shipping companies, based on the above results, a number of recommendations may be made. (1) The shipping companies could consider holding regular trainings sessions about operation risks for their staff, especially those who have worked in the industry for more than 10 years to refresh and enhance their risk awareness. (2) The shipping company could arrange exchange of staff, or at least short term training, between different departments so that their risk perceptions with regard to different type of risk will not be too different. (3) It is perhaps more important for larger shipping companies to pay more attention to risk and risk management training for their staff as their risk perception is relatively low. (4) For Taiwan local container shipping companies, they could consider implementing stricter policies with regard to revealing cargo information even the cargo is from a local shipper.

The contributions of this study is that the paper, through conducting a questionnaire survey, is an empirical research and fills a research gap in the maritime field about the impact of employees' background on their risk perceptions. It is believed that this paper can provide some insights on academic and container shipping industry.

The paper has some limitations. Firstly, this paper only uses ANOVA as the main method to analyse risk perception in container shipping operations. There are other quantitative methods as well for analysing risk perceptions, e.g. willingness to pay (WTP) model (Weber and Hsee, 1998) and psychometric approach (Fischhoff et al., 1978; Slovic, 1992). It would have been better if more quantitative methods were used in the study so that the results from different methods could be compared and more accurate results could be achieved. Secondly, this paper only uses quantitative methods. It would have been better if qualitative methods were also used. According to Renn and Rohrman (2000), using only quantitative approach is insufficient to reflect the complex pattern of individual risk perception. They suggested that research on risk perceptions should also include qualitative methods to measure the consequences of risk activities as the qualitative methods can help to obtain a deeper and explainable results, e.g. the reasons why the respondents have higher risk perceptions on certain risk factors.

Nevertheless, as an exploratory study, we hope this paper can shed some light on the issue of risk perception in the shipping industry and help those who are interested in studying the risks in container shipping to understand better how the risks are perceived by people.

References

- Angulo A., Nachtmann, H. and Waller, M.A. (2004), Supply chain information sharing in a vendor managed inventory partnership, *Journal of Business Logistics* 25(1): 101-120.
- Bebbington, J., Larrinaga-González, C. and Moneva, J. (2008), Corporate social responsibility reporting and reputation risk management, *Accounting, Auditing and Accountability Journal* 21(3): 337-361.

- Chen, S.Y. (2005), *Multivariate Analysis* (in Chinese), HwaTai, Taipei.
- Chen, Y. (2008), Research on trust among supply chain partners, In: H. Zhang, R.M. Zhao and Z. Xie, (eds.), *Industry Cluster and Meta-studies: Proceedings of International Conference on Industry Cluster Development and Management*, June 27-30 2008, Orient Academic Forum, China 742-745.
- Cox, L.A. (2008), What's wrong with risk matrices? *Risk Analysis* 28(2): 497-512.
- Dake, K. (1991), Orienting dispositions in the perception of risk an analysis of contemporary worldviews and cultural biases, *Journal of Cross-Cultural Psychology* 22(1): 61-82.
- Darbra, R.M., Crawford, J.F.E., Haley, C.W. and Morrison, R.J. (2007), Safety culture and hazard risk perception of Australian and New Zealand maritime pilots, *Marine Policy* 31(6): 736-745.
- Davidson, D.J. and Freudenburg, W.R. (1996), Gender and environmental concerns: a review and analysis of available research, *Environment Behaviour* 28: 302-339.
- Drewry (2006), *Annual Container Market Review & Forecast 2006/07*, Drewry Shipping Consultants Ltd, London.
- Drewry (2009), *Risk Management in International Transport and Logistics*, Drewry Shipping Consultants Ltd, London.
- Elky, S. (2006), An introduction to information system risk management, www.sans.org/reading_room/white_papers/auditing/introduction-information-system-risk-management_1204 (Accessed in July 2013).
- Ellegaard, C. (2008), Supply risk management in a small company perspective, *Supply Chain Management: An International Journal* 13(6): 425-434.
- Finch, P. (2004), Supply chain risk management, *Supply Chain Management: An International Journal* 9(2): 183-196.
- Fischhoff, B., Slovic, P., Lichtenstein, S., Read, S. and Combs, B. (1978), How safe is safe enough? A psychometric study of attitudes towards technological risks and benefits, *Policy Sciences* 9(2): 127-152.
- Flynn, J., Slovic, P. and Mertz, C.K. (1994), Gender, race and perception of environmental health risks, *Risk Analysis* 14: 1101-1108.
- Forrester, J.W. (1961), *Industrial Dynamics*, MIT Press, Boston.
- Fu, X., Ng, A.K.Y. and Lau, Y.Y. (2010), The impacts of maritime piracy on global economic development: the case of Somalia, *Maritime Policy and Management* 37(7): 677-697.
- Gustafsson, P.E. (1998), Gender Differences in Risk Perception: theoretical and Methodological perspectives, *Risk Analysis* 18(6): 805-811.
- Hays, W.L. (1994), *Statistics*, Holt-Saunders, London.
- Husdal, J. and Bråthen, S. (2010), Bad locations, bad logistics? How Norwegian freight carriers handle transportation disruptions, In the *World Conference for Transportation Research 2010*, Lisbon, Portugal.
- IMO (2009), *IMO What It Is?*, International Maritime Organization, London.
- Kasperson, R.E., Renn, O., Slovic, P., Brown, H.S., Emel, J., Goble, R., Kasperson, J.X. and Ratick, S. (1988), The social amplification of risk: a conceptual framework, *Risk Analysis* 8(2): 177-187.
- Lee, H.L., Padmanabhan, V. and Whang, S. (1997), Information distortion in a supply chain: The bullwhip effect, *Management Science* 43(4): 546-558.
- Liwång, H., Ringsberg, J.W. and Norsell, M. (2013), Quantitative risk analysis: ship security analysis for effective risk control options, *Safety Science* 58: 98-112.
- Lu, C.S. and Shang, K.C. (2005), An empirical investigation of safety climate in container terminal operators, *Journal of Safety Research* 36(3): 297-308.
- Lu, C.S. and Tsai, C.L. (2008), The effects of safety climate on vessel accidents in the container shipping context, *Accident Analysis and Prevention* 40(2): 594-601.
- Metters, R. (1997), Quantifying the bullwhip effect in supply chains, *Journal of Operations Management* 15(2): 89-100.
- Millman, R. (2007), Human error biggest threat to computer security, ITPRO, 19th June, www.itpro.co.uk/115920/human-error-biggest-threat-to-computer-security (Accessed in May 2013).
- Mitchell, V.W. (1995), Organizational risk perception and reduction: a literature review, *British Journal of Management* 6(2): 115-133.
- Ministry of Transportation and Communications Taiwan (2011), www.motc.gov.tw/mocwebGIP/wSite/ct?xItem=4300&ctNode=553&mp=1 (Accessed in March 2013).
- Notteboom, T.E. (2006), The time factor in liner shipping services, *Maritime Economics and Logistics* 8(1): 19-39.
- Notteboom, T.E. and Vernimmen, B. (2009), The effect of high fuel costs on liner service configuration in

- container shipping, *Journal of Transport Geography* 17(5): 325-337.
- NPSA (National Patient Safety Agency) (2008), A risk matrix for risk managers. www.npsa.nhs.uk/nrls/improvingpatientsafety/patient-safety-tools-and-guidance/risk-assessment-guides/risk-matrix-for-risk-managers/ (Accessed in May 2013).
- Olstedal, H. and Wadsworth, E. (2010), Risk perception in the Norwegian shipping industry and identification of influencing factors, *Maritime Policy and Management* 37(6): 601-623.
- Qi, X.T. and Song, D.P. (2012), Minimizing fuel emissions by optimizing vessel schedules in liner shipping with uncertain port times, *Transportation Research Part E* 48(4): 863-880.
- Qi, Y. and Zhang, Q. (2008), Research on information sharing risk in supply chain management, *International Conference on Wireless Communications, Networking and Mobile Computing*, Dalian, China, 1-6.
- Renn, O. and Rohrman, B. (2000), *Cross-Cultural Risk Perception: A Survey of Empirical Studies*, Kluwer Academic Publishers, Netherlands.
- Saunders, M., Lewis, P. and Thornhill, A. (2007), *Research Methods for Business Students*, Pearson Education Limited, England.
- Seyoum, B. (2009), *Export-Import Theory, Practices, and Procedures*, Routledge, Oxon.
- Sharma, S. and Gupta, J.N.D. (2002), Securing information infrastructure from information warfare, *Logistics Information Management* 15(5): 414-422.
- Shen, L.Y., Wu, G.W. and Ng, C.S. (2001), Risk assessment for construction joint ventures in China, *Journal of Construction Engineering and Management* 127(1): 76-81.
- Slovic, P. (1992), Perception of risk: reflections on the psychometric paradigm, In: S. Krimsky and D. Golding, (Eds.), *Social Theories of Risk*, Praeger Publishers, Westport 117-152.
- Sjöberg, L. (1998), Risk perception: experts and the public, *European Psychologist* 3(1): 1.
- Song, D.P. and Dong, J.X. (2011), Flow balancing-based empty container repositioning in typical shipping service routes, *Maritime Economics and Logistics* 13(1): 61-77.
- Song, D.P., Zhang, J., Carter, J., Field, T., Marshall, J., Polak, J., Schumacher, K., Sinha-Ray, P. and Woods, J. (2005), On cost-efficiency of the global container shipping network, *Maritime Policy and Management*, 32(1): 15-30.
- Spekman, R.E. and Davis, E.W. (2004), Risky business: expanding the discussion on risk and the extended enterprise, *International Journal of Physical Distribution and Logistics Management* 34(5): 414-433.
- Swabey, P. (2009), European firms at risk of technological breakdown, *Information-age*, 10th December, www.information-age.com/channels/management-and-skills/perspectives-and-trends/1101952/european-firms-at-risk-of-technological-breakdown.html (Accessed in June 2013).
- Talley, W.K. (1996), Determinants of cargo damage risk and severity: the case of containership accidents, *Logistics and Transportation Review* 32(4): 377-388.
- Tummala, R. and Schoenherr, T. (2011), Assessing and managing risks using the supply chain risk management process (SCRMP), *Supply Chain Management: An International Journal* 16: 474-483.
- Tzannatos, E.S. (2003), A decision support system for the promotion of security in shipping, *Disaster Prevention and Management* 12: 222-229.
- Waters, D. (2007), *Supply Chain Risk Management: Vulnerability and Resilience in Logistics*, Kogan Page, UK.
- Weber, E.U. and Hsee, C. (1998), Cross-cultural differences in risk perception, but cross-cultural similarities in attitudes towards perceived risk, *Management Science* 44(9): 1205-1217.
- World Shipping Council (2011a), Shipping and World Trade, www.marisec.org/shippingfacts/worldtrade/number-of-ships.php (Accessed in July 2013).
- World Shipping Council (2011b), www.worldshipping.org (Accessed in June 2013).
- Yang, C.C., Marlow, P.B. and Lu, C.S. (2009), Assessing resources, logistics service capabilities, innovation capabilities and the performance of container shipping services in Taiwan, *International Journal of Production Economics* 122(1): 4-20.
- Yang, Y.C. (2010), Impact of the container security initiative on Taiwan's shipping industry, *Maritime Policy and Management* 37: 699-722.
- Yang, Y.C. (2011), Risk management of Taiwan's maritime supply chain security, *Safety Science* 49: 382-393.
- Zou, P.X.W., Zhang, G. and Wang, J. (2007), Understanding the key risks in construction projects in China, *International Journal of Project Management* 25: 601-614.

Service Preference and Short Sea Shipping

Yenming J. Chen¹, Mark Goh² and Jau-Wen Wang¹

¹Department of Logistics Management, National Kaohsiung University of Science & Technology, Kaohsiung, Taiwan. Email: yjjchen@ncku.edu.tw.

²The Logistics Institute-Asia Pacific & NUS Business School, National University of Singapore. E-mail: mark_goh@nus.edu.sg.

Abstract

While studies have addressed the importance of service quality and perceived value, the service preference of shippers and its relationship to perceived value and purchase intentions remain unexplored. This paper proposes a causal model in the context of coastal shipping services in Taiwan to investigate the influence of purchase intention through the shipper's service preference and perceived value. We use Partial Least Squares to assess the empirical strength of the relationships in the proposed model. Our results show that for short sea shipping, timing-related services, price-related services, warehousing services, sales services, door-to-door services, information services, and advertising services positively affect service preference. Specifically, the more functional and transactional service attributes tend to influence service preference positively, and hence lead to higher perceived value.

Keywords: Service preference, Perceived value, Purchase intention, Coastal Shipping, PLS

1. Introduction

Coastal Sea Shipping (SSS) is the transport of cargo around the coast of a country and is a cost effective alternative to road freight. In addition to bulk cargo, SSS includes the transport of international ISO containers (Brooks & Frost, 2004) through feeder and the re-positioning of empty containers between ports in a country by ocean-going vessels. The purpose of SSS includes a leg of transshipment or a replacement for road transport. SSS has advantages, such as the reduction of air pollution and overall cost savings for ship operators. For instance, short sea shipping accounts for 40 percent of the internal transport of goods in the European Union (EU) and is instrumental in reducing congestion, ensuring territorial cohesion, and promoting the sustainable development of Europe (Grama & Patache, 2011). In Japan, 7.9 percent of domestic freight transportation is carried by SSS (IOT, 2007); in the US, the figure is only 2 percent (Medda & Trujill, 2010). SSS is also particularly important for alleviating road congestion (Paixão & Marlow, 2002). In addition, the potential cost reduction by switching from road transport to SSS in the EU is 35 percent (Saldanha & Gray, 2002). As such, SSS is receiving considerable attention in the shipping industry and with shippers. In the EU, more than 400 studies on SSS have been undertaken since the 1990s (Brooks & Frost, 2004).

For Taiwan, an island, while using a maritime mode to move domestic cargo around the island is a potential option, SSS forms only 1.8 percent of the domestic freight transport (IOT, 2007). Government policy on promoting SSS to move cargo around Taiwan is not enforced. Thus, understanding the service preference of shippers and designing the SSS service according to such preferences can increase a shipper's perceived value of the SSS service and motivate them to use SSS to move freight around the island. Measuring the service preference is thus useful for informing policy and provides a mechanism for the optimal price setting of SSS services.

Service preference, pertaining to the preferred selection by an individual (O'Cass & Lim, 2001), is the preference perceived by customers and therefore also refers to customer preference. For example, everyone favours low price and good product quality, but not everyone needs a dedicated transport service. Prior research has identified several attributes of service in maritime firms (Paixão & Marlow, 2005), such as the reliability of sailing, availability of cargo space, and on-time pick-up, and their influence on carrier selection

(Lu, 2003). However, few studies have specifically explored the influence of service attributes on service preferences in the SSS context. While preferential decision making is an ongoing research topic in the social sciences (Muthitacharoen et al., 2006), little effort has been made to incorporate service preference decisions into shipping service research. In Taiwan, only one piece of policy research has been conducted by the Institute of Transportation (2000) to study the economic feasibility of the development of container SSS. The study found that the volume of container SSS can only be increased slightly in comparison with road haulage due to the poor service quality and high cost of SSS. Thus, our study attempts to determine the service attributes of coastal ocean container carriers that are preferred by shippers in Taiwan and suggests a strategy to attract more shippers to use SSS to replace road transport, especially in the context of the littoral states and environmental consciousness in Asia.

Studies have investigated the effect of the service quality of carriers, shipping agencies, and freight forwarders on the degree of satisfaction of their shippers (Lu & Marlow, 1999). Our study therefore aims to (1) investigate the importance of SSS service attributes from the perspective of shippers, (2) examine the relationship between the shippers' service preference and their perceived value, and (3) examine the association between shippers' perceived value and their purchase intentions. Hypotheses are proposed and tested to answer the following research questions: What service attributes influence the service preference of a shipper? Is perceived value a significant determinant of purchase intentions in the SSS context? Is service preference a significant determinant of perceived value and purchase intention in the SSS context?

2. Theoretical Background and Hypotheses Development

2.1 SSS and Service Attributes

The literature provides various definitions of SSS, hinting at the complexity of the concept. From the logistics and regulatory perspectives, SSS research can study different ships from conventional to innovative ones such as fast ships, with various cargo handling techniques (horizontal, vertical, or both), ports, networks, and information systems. Crilley and Dean (1993) defined coastal and short sea ships as ships used to move goods and passenger loads of between 100 and 5,000 gross tons. SSS can also be categorized based on the type of cargo transported, namely (1) the feeding of domestic and international containers with LOLO feeder vessels or container barges and (2) the transportation of domestic trailers with RORO ships (Perakis & Denisis, 2008). As SSS carriers can either own and operate several ships or own and run only one or a few ships, service providers of different types may offer various services to their clients (Paixão & Marlow, 2002). The relevant research on service attributes can be found in Brooks and Trifts (2008) who examined the determinants that affect a container carrier's choice of shippers, and Lu (2003) who identified how the service attributes of four generic carriers influence their service quality from a shipper's perspective. Table 1 which summarizes the literature on service attributes is available on request from the authors.

2.2 Service Preference

Preference is "the setting by an individual of one thing before or above another thing" (Cobb-Walgren et al., 1995). Consumers prefer services that are congruent with their self-concept and thereby reflect what they would really like to be (O'Cass & Lim, 2001). The importance of service preference in relation to the other psychological variables, such as beliefs and intentions, has been observed in previous studies (Anderson, 1982). According to Hsu and Lu (2007), service preference is the degree of positive feelings that users have toward the products and services of a vendor. Caplan (2003) found that individuals prefer online socialization over face-to-face socialization, indicating that social interaction plays an important role. The positive feelings of customers influence their service preferences, and such preferences can be measured by service accessibility and service variety, which include the ability to provide different services that satisfy the various needs of customers (Muthitacharoen et al., 2006).

However, few studies have empirically developed a framework to measure service preference. Research has not explored service attributes or service preference. Lu (2003) investigated the effect of the service attributes of carriers on the satisfaction of shippers within the shipper-carrier partnership. An evaluation of the aggregated perception of the shippers on the service attributes of carriers revealed all 30 attributes to be

satisfactory. Using exploratory factor analysis, Lu (2003) identified six service dimensions from the shipper's perspective: timing, price, warehousing services, sales service, door-to-door services, and information.

Table 2. Exploratory factor analysis of short sea shipping service attributes

Construct/ factor	Attribute	Measure	Factor Loading
Timing related services (TS)	TS1	On-time pick-up	0.92
	TS2	Short transit time	0.95
	TS3	High frequency of sailing	0.89
Pricing related services (PS)	PS1	Freight rates	0.88
	PS2	Price and discount structure	0.90
	PS3	Willingness to negotiate	0.86
Warehousing services (WS)	E1	Customs clearance service	0.75
	E2	Storage service	0.92
	E3	Packaging/labeling service	0.82
Sales service (SS)	S1	Frequency of sales representatives' calls to shippers	0.79
	S2	Knowledge ability of sales personnel	0.85
	S3	Ability of sales representatives to handle problems	0.83
Door-to-door services (DS)	DS1	One stop logistics service	0.78
	DS2	Seamless logistics service	0.80
Information services (IS)	IS1	Computer EDI interface	0.77
	IS2	Computer cargo tracing	0.91
Service Preference (SP)	SP 1	Transaction cost preference	0.94
	SP 2	Product preference	0.88
	SP 3	Social interaction preference	0.79
Perceived value (PV)	PV1	The service would be economical	0.80
	PV2	The service is value for money compared with that of major competitors	0.88
	PV3	The choice of transacting with the firm is a right decision when price and other expenses are considered	0.82
Purchase intentions (PI)	PI1	I intend to transact with the firm in the near future.	0.82
	PI2	I plan to purchase the service from the firm in the near future	0.89
	PI3	I predict that I would consider purchasing the service from the firm in the near future.	0.92

Sources: Lu (2003), Muthitacharoen et al. (2006), and Jiang et al. (1999)

Our study attempts to examine the relationship of service attributes with the preference of shippers to use SSS. Danielis et al. (2005) noted that the following service attributes influence the shippers' preference regarding the purchase of a shipping service and are normally used by the shippers in choosing transportation alternatives: (1) travel time (in days / hours), (2) freight cost and freight (in US monetary terms), (3) reliability (through an indicator, such as percent of on-time deliveries), (4) loss and damage to goods transported (number of occurrences or value of goods stolen or damaged), (5) frequency (number of shipments per day or week), and (6) flexibility (hours or days of notice required for a change in delivery condition). Jiang et al. (1999) studied the choice of freight transport mode and found that the logistics facilities of a firm (e.g., warehouses) are closely related to its transportation demand and significantly influence its modal choice. In addition, the information system of a firm strongly influences its logistics practices and plays an increasingly important role in its transportation decisions. Table 2 shows the service attributes that influence the preference of shippers regarding SSS based on the work of Lu (2003), Muthitacharoen et al. (2006), and Jiang et al. (1999). Through these attributes, we posit the following hypotheses:

- H1: All service attributes are positively related to service preference.
- H1a: Timing-related services are positively related to service preference.
- H1b: Price-related services are positively related to service preference.
- H1c: Warehousing services are positively related to service preference.

- H1d: Sales services are positively related to service preference.
- H1e: Door-to-door services are positively related to service preference.
- H1f: Information services are positively related to service preference.

2.3 *Perceived Value*

The service offered by a firm is only as good as how the customer perceives that service. Value indicates that customers believe that their choices are better than any substitute and that they have selected what is best for them (Solomon, 2006). Value is the perception of a tradeoff between benefits (including quality) and costs (Zeithaml, 1988). Bolton and Drew (1991) conceptualized value as a tradeoff between quality and price, though several studies claim that value is more complex and that other dimensions have to be included (Bolton & Drew, 1991). According to Christopher (1992), logistics services are explored to seek an advantageous position based on value advantage. Relative value can help a firm gain additional competitive advantage (Ernst, 1988). The perceived value construct has not received as much attention as other constructs in transportation literature. Unlike those of the other industries, the customers of SSS pay directly for the service rendered. SSS has third-party logistics service providers (3PLs) who pay for all or part of the service provided. Coverage by the 3PLs may affect a shipper's understanding of the price and perceived value offered by the SSS carriers. How the perceived value of the services of 3PLs is influenced in the SSS context is difficult to analyse. A shipper perceives high value if all service attributes (including service quality) of the provider meet his requirement (Kuo et al., 2009). In the SSS context, the role of perceived value should be examined as the shipper may not always consume the best service and may instead purchase a 3PL service according to their assessment of the value of a service (Cronin & Taylor, 1992). However, if the carrier provides services preferred by the shippers, the shippers may perceive more value from a psychological evaluation of the relative rewards and losses associated with the offering. This observation leads to the following hypothesis:

- H2: Service preference is positively related to perceived value.

2.4 *Purchase Intentions*

Most studies have focused on understanding the initial purchase behaviour or behavioral intention of customers, including their willingness to buy (Jarvenpaa et al., 1999), their purchase intention (e.g., McKnight et al., 2002), their willingness to transact (Bhattacharjee, 2001), and their behavioral intention to use (Suh & Han, 2003). Multiple behavioral intentions include customer loyalty, positive recommendation behaviour, and repurchase intentions (Zeithaml et al., 1996). In addition, Zeithaml et al. (1996) proposed a multidimensional measure of these indicators that includes purchase intentions, complaint behaviour, price sensitivity, and word-of-mouth communication. Perceived value is a direct antecedent of behavioral intentions and a significant factor in purchase intentions (Dodds et al., 1991). Further, as service is intangible, inseparable, heterogeneous, and perishable (Etzel et al., 2001), service preference stresses service accessibility and service variety, which involves the ability to provide different services to meet the various needs of customers (Muthitacharoen et al., 2006). According to Ajzen's (1991) theory of planned behavior, if shippers obtain information and perceive that the service of a vendor (e.g., a short sea carrier) has high quality, they generate a favourable attitude and preference toward the service and demonstrate behavioral control over it and thus develop a greater intent to purchase that service (Pavlou & Fygenson, 2006). Kuo et al. (2009) report that service quality influences the purchase intentions of consumers in the services industry. Table 3 summarizes the nine measures of the three constructs (service preference, perceived value, and purchase intention). Hence, the following hypotheses are proposed:

- H3: Perceived value is positively related to purchase intentions.
- H4: Service preference is positively related to purchase intentions.

On the basis of these hypotheses, we propose our research model, as shown in Figure 1.

Table 3. Nine measures of the three constructs in theory of planned behaviour

Construct	<div>Measures</div> <div>Source</div>															
		Hsu & Lu (2007)	Marcussi & Rotaris (2005)	Caplan (2003)	Zeithaml (1988)	Botanic (1996)	Bolton & Drew (1991)	Sheth et al. (1991)	Palmroth (1991)	Parasuraman & Grewal (2000)	Petrick (2004)	Jarvenpaa & et al (1999)	McKnight et al. (2002)	Bhattacharjee (2001)	Suh & Han (2003)	
Attitude: Service Preference (SP)	Transaction cost preference		✓													
	Product preference	✓														
	Social interaction preference			✓												
Norm: Perceived Value (PV)	The service would be economical				✓		✓	✓	✓							
	Value for money compared with that of major competitors				✓	✓	✓	✓		✓						
	The choice of transacting with the firm is a right decision				✓	✓	✓	✓		✓	✓					
Behaviour : Purchase Intention (PI)	I intend to transact with the firm in the near future															
	I plan to purchase the service from the firm in the near future															
	I consider purchasing service from the firm in the near future															

3. Research Method

A questionnaire comprising 25 items was generated, and the list of the items is shown in Tables 2 and 3. All the items were measured on a five-point Likert scale with anchors ranging from strongly disagree (=1) to strongly agree (=5). All the measurement items were developed either by adapting the measures validated by previous research or by converting the definitions of the constructs into a questionnaire format. The questionnaire was pretested with five industry experts to ensure content validity and reliability within the target context, in particular the wording clarity, task relevance, and the suitability of the question item sequence. All experts have over 25 years of work experience; two work for the government authorities, another two are forwarders while the fifth is a small ship-owner. As a result, several minor modifications of the wording and item sequence were made. Next, a pilot was conducted on 30 individuals with experience in carriers or shippers. Their comments and suggestions on the item content and structure of the instrument were solicited. A mail survey was used to collect data to investigate the research model. Candidate firms were randomly selected from the membership list of the International Ocean Freight Forwarders and Logistics Association in Taiwan. Subsequently, 200 firms were contacted through an introductory letter and a follow-up phone call describing the goal of the study and soliciting the support of the firm. All respondents were required to have knowledge of logistics and transportation. At the end of the screening, 130 questionnaires were sent to those firms willing to participate in the study. In an e-mail welcoming and thanking the respondents for participating in the survey, several statements were included to assure them of the confidentiality of their responses. From August to September 2011, 105 complete questionnaires were returned; 86 of these (81.9% response rate) provided usable data and were thus used in the analysis.

Three statistical analyses were used: (1) exploratory factor analysis to confirm the hypothesized nine-factor

model; (2) confirmatory factor analysis to test reliability and validity (a reliability test for each construct was applied to assess the internal consistency from composite reliability; (3) To investigate the objectives of this study and test the hypotheses, partial least squares (PLS) was employed to analyse the collected data. PLS facilitates the analysis of both the measurement and structural models and places minimal restrictions on the measurement scales, sample size, and residual distribution (Chin & Newsted, 1999).

4. Data Analysis and Results

Data on the measurement and structural models were analysed. The adequacy of the measurement model was evaluated according to reliability, convergent validity, and discriminant validity. Reliability was examined using composite reliability values, which should be greater than the benchmark of 0.7 to be considered adequate (Fornell & Larcker, 1981). Table 4 shows that all the values were above 0.7, indicating adequate construct reliability. Additionally, the convergent validity of the scales was verified by using the two criteria suggested by Fornell and Larcker (1981): (1) all service attributes' loadings should be significant and should exceed 0.7, and (2) the average variance extracted (AVE) by each construct should exceed the variance because of the measurement error for that construct (i.e., $AVE \geq 0.5$). Most items exhibited a loading higher than 0.7 on their respective constructs, providing evidence of acceptable item convergence on the intended constructs. Different fit indices (GFI, AGFI, CFI, RMSEA, and RMR) were all above the threshold as suggested by Hair et al. (2006). Construct reliability was between 0.85 and 0.92, and the AVE values were all above 0.69. Therefore, both conditions for convergent validity were met.

Table 4. Confirmatory factor analysis

Construct	Attribute	Factor Loading	Construct Reliability (CR)	AVE
Timing related services (TS)	TS1	0.92	0.91	0.75
	TS2	0.95		
	TS3	0.89		
Pricing related services (PS)	PS1	0.88	0.93	0.86
	PS2	0.89		
	PS3	0.86		
Warehousing services (WS)	WS1	0.75	0.82	0.71
	WS2	0.92		
	WS3	0.82		
Sales Service (SS)	SS1	0.79	0.87	0.79
	SS2	0.85		
	SS3	0.83		
Door-to-door services (DS)	DS1	0.78	0.91	0.75
	DS2	0.80		
Information service (IS)	IS1	0.77	0.94	0.83
	IS2	0.91		
Service Preference (SP)	SP1	0.94	0.85	0.80
	SP2	0.88		
	SP3	0.79		
Perceived value (PV)	PV1	0.80	0.91	0.85
	PV2	0.88		
	PV3	0.82		
Purchase Intentions (PI)	PI1	0.82	0.92	0.69
	PI2	0.89		
	PI3	0.92		

Discriminant validity was assessed by examining the factor loadings to determine if the questions were loaded more highly on their intended constructs than on the constructs (Fornell & Larcker, 1981). We considered both loadings and cross-loadings to establish discriminant validity, and all items had higher loading on their own construct than on the other constructs in the model (Table 5). In addition, the square root of the AVE from the construct is greater than the correlation between the construct and the other constructs in the model satisfying discriminant validity. Table 5 lists the correlations among the constructs, with the square root of the AVE on the diagonal. The diagonal values exceeded the inter-construct correlations; thus, discriminant validity was acceptable. Thus, the measures for each construct satisfied construct reliability and validity.

Table 5. Discriminant analysis between constructs

	TS	PS	WS	SS	DS	IS	SP	PV	PI
TS	0.87								
PS	0.92	0.93							
WS	0.35	0.15	0.84						
SS	0.24	0.44	-0.23	0.89					
DS	0.45	-0.35	-0.12	-0.65	0.87				
IS	0.16	-0.26	-0.19	0.72	-0.43	0.94			
SP	0.28	-0.17	-0.04	0.36	-0.23	0.28	0.89		
PV	0.60	-0.50	-0.34	0.38	-0.38	0.40	-0.08	0.92	
PI	0.29	-0.39	-0.20	0.78	-0.46	0.73	-0.26	-0.56	0.83

Structural Equation Modelling (SEM) was used to test the interrelationships among the research constructs of service attributes, perceived value, and purchase intentions and to compare the modelled relationships with the observed scores. Figure 2 shows the SEM results. On the effect of service attributes on customer preference, our empirical findings suggest that timing-related services, pricing-related services, warehousing services, sales service, door-to-door services, information services, and advertising services positively affect customer preference. In particular, among the service attributes examined, timing related services, pricing related services, and warehousing related services significantly influence customer preference ($p < 0.01$), as compared to sales and door-to-door services or information services. This has implications for developing an SSS strategy for Taiwan. In some ways, there is consensus for the results. For instance, Lu (2003) found that both door-to-door and information services were not significantly correlated with shipper satisfaction. However, our study found that door-to-door and information services positively affect service preference, although the significance of these two services is weaker than that of the other attributes. As our study mainly investigated the effects of the service attributes of the carriers on service preference from the shipper's perspective, it differs from Lu's (2003) study, which focused on the satisfaction of shippers within the shipper-carrier partnership. A possible reason is that shippers are concerned with door-to-door services, including the good condition of the containers, and the information services provided through cargo tracking. Service preference strongly affects perceived value ($p < 0.01$) and thus validates H2. The greater the shipper's preference, the greater the value perceived by the shipper regarding the carrier's service. Service preference also directly and significantly affects purchase intentions ($p < 0.1$) and thus validates H4. Further, H3 is validated as perceived value strongly affects purchase intentions ($p < 0.01$). This finding is consistent with prior research (Dodds et al., 1991). In short, shippers perceive that value significantly influences purchase intention.

5. Discussion

This paper has attempted to understand the important issues in the link between the service attributes and service preference which indirectly affects the intention to purchase that service. On SSS, we find that it is the more functional and transactions based service attributes which will continue to dominate and influence the service preference of the shippers. Specifically, shippers look for the reliability and frequency of the transport service provided, as indicated by the timing of the services provided. At the same time, shippers are very cost sensitive, due probably to the nature of the goods transported, to the services provided through SSS. In this regard, the offer price has to be seen as being competitive to road or rail transport in Taiwan, which may prove to be difficult given the lack of economies of scale in the interim. This is particularly important given that the lead time for SSS is often longer than the other modes of transport. Third, the need for seamless

connectivity to the other ground related services, as espoused in the literature, appears to drive service preference. In this regard, SSS should combine with other logistics services and providers to provide better or convenient storage locations for temporary cargo storage. In this study, it is clear that SSS is not particularly part and parcel of an integrated service offering in logistics such as door-to-door or even information updates and cargo visibility. In this regard, there is no imperative for the SSS carriers to consider combining their service suites (as in an end-to end service) to improve the prevailing perceived value nor provide better transport visibility through platforms such as information systems access for the shippers. Policy makers and business decision makers for both shippers and SSS service providers can benefit from this insight.

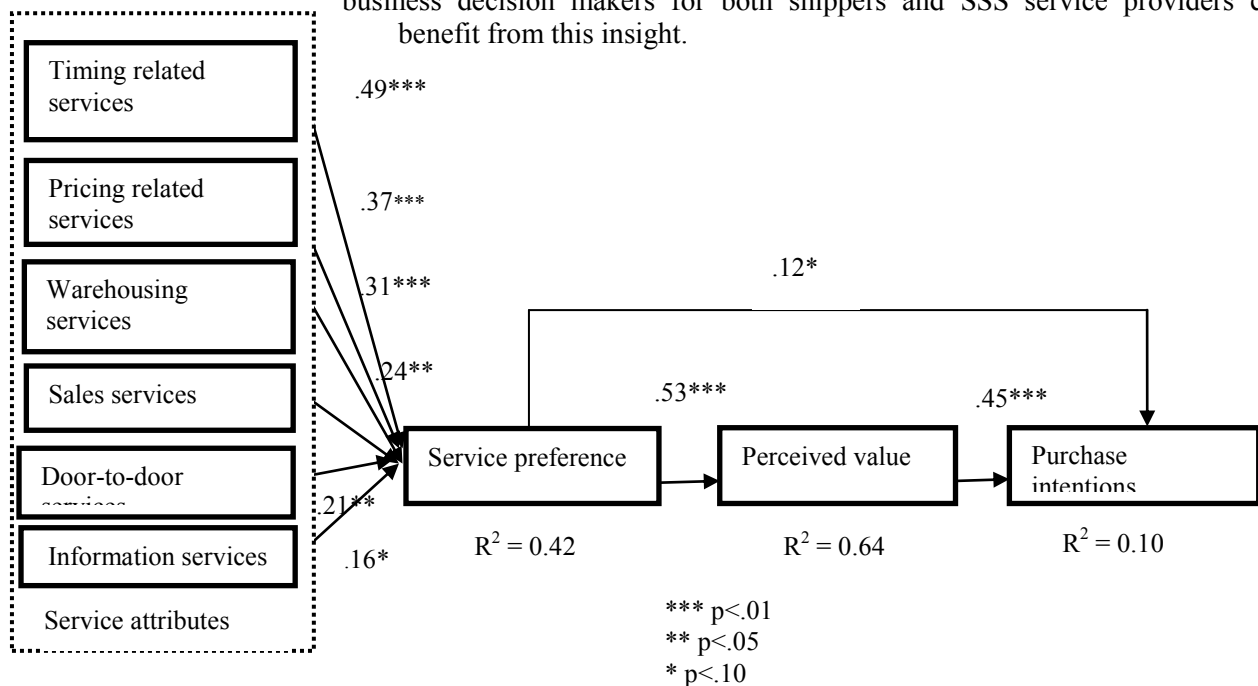


Fig 2. SEM Results

6. Conclusion

The development of SSS services offers a potential and environment-friendly market (Paixão and Marlow, 2002). However, research has paid minimal attention to this trend. Our study empirically examines the effects of perceived value on purchase intentions in the SSS context and identifies the relationship between service attributes and service preference. This study can help carriers to manage relationships with their shippers. Most carriers focus on providing excellent service quality, but they may ignore the link between service quality specification and shipper preference. Thus, carriers should provide proper service quality with each of the attributes and constructs to effectively increase the degree of customer preference toward their SSS service. Through our research, SSS service providers can identify the right factors that affect the purchase intentions of shippers as well as the factors that increase customer loyalty. This research also has managerial implications as the managers of carriers can now assess and then increase the degree of service preference of their shippers by providing appropriate freight service in necessary attributes. Future research can extend the context to a regional study.

References

- Ajzen, I. (1991), The theory of planned behavior, *Organizational Behavior & Human Decision Processes* 50: 179-211.
- Anderson, P.F. (1982), Marketing, strategic planning, and the theory of firm, *Journal of Marketing*, 46: 15-26.
- Bhattacharjee, A. (2001), An empirical analysis of the antecedents of electronic commerce service continuance, *Decision Support Systems* 32: 201-214.
- Bolton, R.N. and Drew, J.H. (1991), A multistage model of customers' assessment of service quality and value, *Journal of Consumer Research* 17: 375-384.

- Brooks, M.R. and Frost, J.D. (2004), Short sea shipping: a Canadian perspective, *Maritime Policy & Management* 31(4): 93-407.
- Brooks M.R. and Trifts V. (2008), Short sea shipping in North America: understanding the requirements of Atlantic Canadian shippers, *Maritime Policy & Management* 35(2): 145-158.
- Caplan S.E. (2003), Preference for online social interaction: a theory of problematic internet use and psychosocial well-being, *Communication Research* 30(6): 625-648.
- Chin, W.W. and Newsted, P.R. (1999), Structural equation modeling analysis with small samples using partial least squares, In: R. Hoyle (ed.), *Statistical Strategies for Small Sample Research*, Sage: Thousand Oaks 307-341.
- Christopher, M. (1992), *Logistics and supply chain management strategies for reducing costs and improving services*, Pitman, London.
- Cobb-Walgren, C.J., Ruble C.A. and Donthu N. (1995), Brand equity, brand preference, and purchase intent, *Journal of Advertising* 24(3): 25-40.
- Crilley, J. and Dean, C.J. (1993), Shortsea shipping and the world cargo-carrying fleet - a statistical summary, Lloyd's of London Press Pubs: European Shortsea Shipping, 1st European Research Roundtable Conference, 26-27 Nov 1992, Delft, the Netherlands, Procs.
- Cronin, J.J. and Taylor, S.A. (1992), Measuring service quality: a reexamination and extension, *Journal of Marketing* 56(3): 55-68.
- Danielis, R, Marcucci E. and Rotaris L. (2005), Logistics managers' stated preferences for freight service attributes, *Transportation Research Part E* 41(3): 201-215.
- Dodds, W.B., Mornore, K.B. and Grewal, D. (1991), Effects of price, brand and store information on buyers' product evaluations, *Journal of Marketing Research* 28(3): 307-319.
- Douet, M. and Cappuccilli, J.F. (2011) A review of short sea shipping policy in the European Union, *Journal of Transport Geography* 19: 968-976.
- Ernst, K.R. (1988), Visioning: key to effective strategic planning, In: *Annual Conference Proceedings. Council of Logistics Management*, Oak Brook, Ill: 53-165.
- Etzet, M.J., Bruce J.W. and William, J.S. (2001), *Marketing Management* (12ed.) McGraw-Hill: New York.
- Fornell, C. and Larcker, D.F. (1981), Evaluating structural equation models with unobservable variables and measurement error, *Journal of Marketing Research* 18: 39-50.
- Grama, I.G. and Patache, L. (2011), The importance of improvements in short sea shipping for European transport system, *Economics, Management, and Financial Markets* 6(1): 650-660.
- Hair, J.F.Jr., Anderson, R.E., Tatham, R.L. and Black, W.C. (2006), *Multivariate Data Analysis* (6ed.), Prentice Hall, New Jersey.
- Hsu, C.L. and Lu, H.P. (2007), Consumer behavior in online game communities: a motivational factor perspective, *Computers in Human Behavior* 23(3): 1642-1659.
- IOT (2007), The investigation & evaluation of Blue Highway (II) - the feasibility study on the development of container coastal shipping, Institute of Transportation, Ministry of Transportation and Communication, Taipei, Taiwan.
- Jarvenpaa, S.L., Tractinsky, N. and Saarinen, L. (1999), Consumer trust in an internet store: a cross-cultural validation, *Journal of Computer-Mediated Communication* 5(2): 1-5.
- Jiang, F., Johnson, P. and Calzada C. (1999), Freight demand characteristics and mode choice: an analysis of the results of modeling with disaggregate revealed preference data, *Journal of Transportation and Statistics* 2(2): 149-158.
- Kuo, Y.-F., Wu, C.-M. and Deng, W.-J. (2009), The relationships among service quality, perceived value, customer satisfaction, and post-purchase intention in mobile value-added services, *Computers in Human Behavior* 25(4): 887-896.
- Lu, C.S. and Marlow, P. (1999), Strategic groups in Taiwanese liner shipping, *Maritime Policy & Management* 26(1): 1-26.
- Lu, C.S. (2000), Logistics services in Taiwanese maritime firms, *Transportation Research Part E* 36(2): 79-96.
- Lu, C.S. (2003), The impact of carrier service attributes on shipper-carrier partnering relationships: a shipper's perspective, *Transportation Research Part E* 39: 399-415.
- McKnight, D.H., Choudhur, Y.V. and Kacmar, C. (2002), The impact of initial consumer trust on intentions to transact with a web site: a trust building model, *Journal of Strategic Information Systems* 11(3/4): 297-323.

- Medda, F. and Trujillo, L. (2010), Short-sea shipping: an analysis of its determinants, *Maritime Policy & Management* 37(3): 285-303.
- Muthitacharoen, A., Gillenson, M.L. and Suwan, N. (2006), Segmenting online customers to manage business resources: A study of the impacts of sales channel strategies on consumer preferences, *Information and Management* 43: 678-695.
- Ng, A.K.Y. (2009) Competitiveness of short sea shipping and the role of port: the case of North Europe, *Maritime Policy & Management* 36(4): 337-352.
- O'Cass, A. and Lim, K. (2001), The influence of brand associations on brand preference and purchase intention, *International Journal of Consumer Marketing* 14(2/3): 41-71.
- Paixão, A.C. and Marlow, P.B. (2002), Strengths and weaknesses of short sea shipping, *Marine Policy* 26: 167-178.
- Paixão, A.C. and Marlow, P.B. (2005), The competitiveness of short sea shipping in multimodal logistics supply chains: service attributes, *Maritime Policy & Management* 32(4): 363-382.
- Paixão A.C. and Marlow, P.B. (2009), Logistics strategies for short sea shipping operating as part of multimodal transport chains, *Maritime Policy & Management* 36(1): 1-19.
- Palmroth, W. (1991), Always remember the six buyer benefits: qualities buyers look for in a product, *American Salesman* 36(9): 12-18.
- Pavlou, P.A. and Fygenon, M. (2006), Understanding and predicting electronic commerce adoption: an extension of the theory of planned behavior, *MIS Quarterly* 30(1): 115-143.
- Perakis, A.N. and Denisis, A. (2008), A survey of short sea shipping and its prospects in the USA, *Maritime Policy & Management* 35(6): 591-614.
- Petrick, J.F. (2004), The roles of quality, value, and satisfaction in predicting cruise passengers' behavioral intentions, *Journal of Travel Research* 42(4): 397-407.
- Saldanha, J. and Gray, R. (2002), The potential for British coastal shipping in a multimodal chain, *Maritime Policy & Management* 29(1): 77-92.
- Sheth, J.N. (1991), Why we buy what we buy: a theory of consumption values, *Journal of Business Research* 22(2): 159-170.
- Solomon, M. (2006), *Consumer Behavior*, Prentice Hall, New Jersey.
- Suh, B. and Han, I. (2003), The impact of customer trust and perception of security control on the acceptance of electronic commerce, *International Journal of Electronic Commerce* 73: 135-161.
- Zeithaml, V.A. (1988), Customers' perceptions of price, quality, and value: a means-end model and synthesis of evidence, *Journal of Marketing* 52(3): 2-22.
- Zeithaml, V.A., Berry, L.L. and Parasuraman, A. (1996), The behavioral consequences of service quality, *Journal of Marketing* 60(2): 31-46.

IFSPA 2014
ifspa.2014@polyu.edu.hk
<http://www.icms.polyu.edu.hk>

ISSN 2312-6388



9 772312 638004

