IFSPA 2017

The International Forum on Shipping, Ports and Airports (IFSPA) 2017

Innovative Transport Logistics in Shaping the Future of Supply Chains

22 - 25 May 2017
The Hong Kong Polytechnic University
Hong Kong

PolyU
The Hong Kong Polytechnic University
香港理工大學

PolyU 理大商學院
Business School
Innovation-driven Education and Scholarship

Department of Logistics & Maritime Studies
物流及航運學系

CY TUNG International Centre for Maritime Studies
董浩雲國際海事研究中心

Proceedings of the

International Forum on Shipping, Ports and Airports (IFSPA) 2017

Innovative Transport Logistics in Shaping the Future of Supply Chains

22 – 25 May 2017

Hong Kong

Edited By:

Tsz Leung Yip

Achim I. Czerny

Chin-Shan Lu

Proceedings of the International Forum on Shipping, Ports and Airports (IFSPA) 2017

22 – 25 May 2017

ISBN: 978-962-367-811-7

September 2017

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.

Carrying the core message “Proud of PolyU · Proud of Hong Kong”, a series of events held on 25 November 2016 marked the beginning of the year-long celebrations, and IFSPA 2017 is one of the highlights of the PolyU 80th Anniversary events in 2017.

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 800 participants from different countries and regions of the world.

Preface

The 9th International Forum on Shipping, Ports and Airports (IFSPA) 2017 was successfully held from 22 – 25 May 2017, in Hong Kong. The proceedings contained a collection of 20 full papers out of 83 presentations 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 2017 was "Innovative Transport Logistics in Shaping the Future of Supply Chains". 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 innovation management and technology 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, 1 Industrial Session, 2 Special Sessions and 19 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 100 delegates came from different parts of the world including Belgium, Canada, Chile, Germany, Japan, Norway, Shi Lanka, South Korea, Sweden, Taiwan, Thailand, The Netherlands, 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 IFSPA 2017 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 Violette Wong and Tsz-him Chan.

The Editors

Tsz Leung Yip
Achim I. Czerny
Chin-Shan Lu

Hong Kong, September 2017

IFSPA 2017 Organizing Committee

Conference Chairman	Tsz Leung Yip
Co-Chairs	Achim I. Czerny Chin-Shan Lu
Committee Members	Y.H. Venus Lun Hong Yan Mike Kee-Hung Lai Petrus W.C. Choy Meifeng Luo Chi To Daniel Ng Shuaian Hans Wang Zhou Xu Ling Zhu Yulai Sarah Wan Dong Yang Kelvin Pang C. L. Johnny Wan Sik Kwan Tai
Secretariat	Violette Wong Tsz-him Chan

IFSPA 2017 International Steering Committee

List of Keynote Speakers

IFSPA 2017 is proud to have invited the following worldwide prestigious scholars and practitioners as Keynote Speakers for this event:

- Mr Peter Huijbers
  CALS Financial Leasing (Shanghai), Co., Ltd.

- Dr Leonardo J. Basso
  Universidad de Chile, Chile

- Professor Gilbert Laporte
  HEC Montreal, Canada

- Professor Robin Lindsey
  University of British Columbia, Canada

- Professor Amedeo Odoni
  Massachusetts Institute of Technology, USA

- Mr Raymond TC Wong
  TCWong Average Consulting Ltd., Hong Kong

- Mr CH Wong
  Five Oceans Maritime Ltd., 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 2017.

Aminuddin Md Arof	Universiti Kuala Lumpur Malaysian, Malaysia
Sven Buyle	University in Antwerp, Belgium
Stephen Cahoon	University of Tasmania, Australia
Eve Chan	Technological and Higher Education Institute of Hong Kong, Hong Kong
Kee-Hung Lai	The Hong Kong Polytechnic University, Hong Kong
Joseph Yui Yip Lau	The Hong Kong Polytechnic University, Hong Kong
Meifeng Luo	The Hong Kong Polytechnic University, Hong Kong
Yong An Park	University College London, UK
Yulai Wan	The Hong Kong Polytechnic University, Hong Kong
Grace W.Y. Wang	Texas A&M University Galveston, USA
Shuaian Wang	The Hong Kong Polytechnic University, Hong Kong
Ka Io Wong	National ChiaoTung University, Taiwan
Liping Jiang	Copenhagen Business School, Denmark
Zaili Yang	Liverpool John Moores University, UK
Tsz Leung Yip	The Hong Kong Polytechnic University, Hong Kong
Simon Yuen	The Hong Kong Polytechnic University, Hong Kong

Contents

Optimization Model to Identify the Benefits of Developing an Inventory Model to Reduce the Dummy Items Flown in an Aircraft in Airline Catering Industry

Aravinda Dissanayake and W. W. Anuja Shamini Fernando

Department of Transport and Logistics Management, Faculty of Engineering
University of Moratuwa, Sri Lanka
Email: ara20451@gmail.com

Abstract

Airline catering is a dynamic industry which evolves rapidly. Different airlines use different set up in their catering process. The meals are served on tray set up called rotables including trays, bowls and cutlery etc. which weight approximately 0.5kgs. At the destination these rotables are removed, washed, sanitized and prepared for a return leg flight.

To balance the inventories at each destination the flights fly with rotables equal to seat capacity. The empty rotables are known as dead heads or dummy items. Currently most of the airlines in the world use this dead heads to balance the supply. It creates unwanted weights onboard in the aircraft which are not really required for the given flight and ultimately cause extra cleaning, drying and handling by the catering suppliers.

Through this research inventory management process will be developed to optimize the unwanted movement of catering equipment on board. The savings through inventory management process will ultimately reduce waste in the process and deliver benefits to the airline as well as the catering service providers at the destination.

The research includes the current process identification of ABC airlines and ABC Catering limited through the case study method. According to the developed model the dummy items will be reduced and an inventory will be maintained at the destination. The optimum number to maintain at the destination that will incur the minimum cost will be calculated by Excel Solver by giving the cost variables of new model. The minimum total cost can be also identified using the sensitivity analysis where the inventory level is the independent variable. The replenishment is done if the inventory level exceeds the optimum number or it reaches the zero level. To identify the total cost the calculation can be done for a period of one year. Where,

Total Cost = $\alpha + \beta + \gamma + \delta + \varepsilon$

α = Purchasing cost
β = Cost of placing the inventory
γ = Holding cost at the destination
δ = Replenishing cost
ε = Extra cleaning and handling

The total cost of the new modal have to be compared with the current cost of dummy items movement and the comparison will show the feasibility of the model. The calculation is for one route and an airline with several hundred routes may have a considerable cost saving.

Keywords: Dummy items, Dead heads, Rotables, Replenish, Sensitivity Analysis

1. Introduction

Airline industry is one of the most dynamic and changing industry with 24 hours operation. Except for several airports with night curfew most of the airports operate 24x7 and the based Airlines do too operate accordingly.

Therefore the catering services which provide meal services to those airlines have to operate throughout the day. When an aircraft is landed at any airport there are items removed from the aircraft. This includes catering items, pillows, blankets, bottles, magazines papers and earphones. When considering the catering disposable items which are removed as garbage and other reusable items such as used trays, folks, knives and glasses are there. This part should be returned to catering service providers for re use. This is where the balancing of inventory part gets involved in airline catering services.

The meal items are loaded into trolleys or carts and they are placed in the aircraft galley. Once the aircraft lands at the destination the trolleys are unloaded if the double sector catering is not done from the origin or base airport. These rotables refer to non-disposable items used in catering where they can be used again after proper cleaning. Then the waste is removed and reusable items are washed, dried and stored. Fresh supplies are loaded to the aircraft with meals. Normally the aircraft do not fly always with filled passengers adhering to the configuration and there are empty seats flying. These empty seats do not need catering supplies. But due to imbalance in demand and breaking the flights into sectors can lead to heap up the trays and reusable items in several places. To avoid this airlines use a concept called "equipment balancing" through sending the rotable equipment to match the aircraft configuration. Therefore these rotables are only loaded with food items to match the number on board. But few or maybe large number equivalent to empty seats go as "dead heads" to balance the inventory levels in the system. Also they are known as "dummy" items where empty set travels. Hereafter as generic terms ABC Catering Limited will be used as the catering service provider and ABC Airline as the main supplier of this hypothetical catering provider. When ABC Airlines operate a flight to its destination the catering supplies are loaded from hub airport and remaining is unloaded at the destination. Then some of the items are disposed and reusable items are taken by the catering provider of ABC Airlines at the given destination. Re using and developing a conceptual model to these re-usable items become vital in the catering industry. Since there are demand fluctuations the development of this model can help the catering suppliers to maintain an optimal level of inventories with the usage of inventory management.

1.1 Research Objectives

- Identify current practices related to airline catering supply and logistics
- Compare best practices with the current practice and evaluate the potential of practicing
- Develop a conceptual model to be practiced in equipment balancing process of the Airline Catering
- Identify and highlight the savings of resources through optimization of the process.

Therefore the research objectives need to identify the current practices, bottlenecks faced and how to overcome them through developing a new model to balance the inventory in the supply chain partners in airline catering. This includes the parties involved in managing the reusable inventories

2. Research Methodology

2.1. Case Study

In this chapter the current process of ABC Catering Ltd and other airlines practices will be discussed. Normally commercial airlines have two or three classes and economy class carry more passengers compared to others. Therefore large number of items carried to accommodate economy class and in this research economy class catering supply is considered. Due to several reasons and airlines practices the process of buying catering supplies at the destination will be determined. However airlines normally have several destinations where they have to buy catering supplies from a destination supplier. Current practice is the aircraft will be loaded with rotables equal to seat number and these rotables will be filled with meals equal to the actual passengers on board. This prevents stacking of rotables at anywhere in the system. The decision making on dummy item loading is shown in the figure 1.

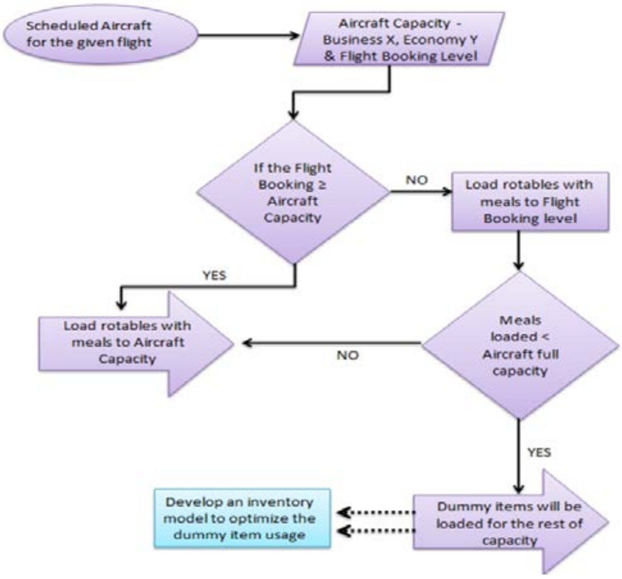


Figure 1: Dummy item loading decision

The economy class rotables are made with a special plastic called melamine, glass and cutlery is made from steel or plastic. The items in a rotable set of economy class consists of tray, salad bowl, tea cup, side plate, meal plate, water tumbler and cutlery pack which weights around 500-600g without the meal depending on the airline. An empty cart will be 15-25kg in weight. The weight can be different according to the cart type used by the airline and facilities available with the cart. One rotable set is used to serve one meal and depending on the duration two to three meals can be served. Unloaded rotables and carts will go through a cleaning process.

2.2. Data Collection

Different types of data are required to analyze the problem and develop solutions depending on the study area. Therefore quantitative and qualitative data will be required to be gathered from various sources using different techniques. For the research quantitative data will be required mainly but there are some places qualitative data will be also useful to identify some of the issues which are not visible from the numbers. There are several methods available to collect the primary data and during the research to identify the current processes personal interviews, visits to the catering facility, visit to airline departments, telephone conversations information gathering were used. The data gathered was mainly focusing the current airline and catering service practices in the industry. The secondary data refers to data collected by some other person or organization to obtain their objectives. Therefore these data can be not directly related to the purpose of the research. The secondary data related to the research was collected using the system generated reports of airline, website information, journal articles and research papers.

2.3. Research Design

The current airline and catering service practices was observed through several visits to ABC Airline and ABC Catering limited. Identification of current process included several email and telephone conversations with the industrial personnel. The industry best practices were identified through the catering plant visit and through personal interviews of airline related personnel. The process of identifying the best practices and comparing them with the current practices were done through gathering data. Identification of the current practices and industry practices will highlight the importance of the process and the issues in the current process. Therefore developing a method to optimize the usage of dummy items has to be supported with the savings and other benefits possible to achieve through this practice. Once the passenger flow is identified one destination is selected with single meal offered on board to reduce the complexity of the model explanation. Identification of all the cost variables associated with the new model will be used to clarify and research all the cost variables that can affect the developing model. The model will be developed using the data collected and the explanation will be done through entering the values to the selected example destination statistics.

Once the data is entered and the ultimate calculations will explain the possible savings gained through the model.

3. Analysis and Results

3.1. Identification of Dummy Items Flow

ABC airlines operate to 30 destinations from the base and 99 destinations including codeshare agreements. This includes short, medium and long haul flights operated directly and with one stops. From these 30 destinations there are 18 destinations where the airline does not carry double sector catering. These are the destinations which need to be used as the sample for analysis. For these 18 destinations ABC catering service provides catering supplies for one way and from that destination another catering supplier provides provisions for the return leg. The usage of dummy items happens in these destinations.

3.2. Costs Associated With Dummy Movements

In the airline industry there is several cost factors associated with the dummy item movements. Some of these costs are not directly visible to any party. Since airline catering is a collaborative outcome of the airline and catering supplier some of the points kept hidden from both parties due to lack of information sharing. The following costs were identified as directly involved costs in dummy items movement.

1. Cost of moving the dummy items between the origin and destination
2. Cost of washing, sanitizing and drying the dummy items
3. Labour cost and time spent on preparing and re arranging dummy items
4. Cost associated with replacing damage and broken dummy items during movements and cleaning

Above 1 and 2 can be identified and given with a value by measuring them in a way that they can be useful. 3 and 4 is directly not measurable but occurs in directly immeasurable way.

3.3. Inventory Model to Reduce the Dummy Items Flow

Developing the model to reduce the flow of dummy items and possible gains through the model will be discussed.

i. Identification of passenger flow statistics

The passenger movement statistics plays the major role in developing the inventory model. Since the meals served on board will be the actual passenger number travelled and the left over seats is the number will show the dummy items on board. Initial stage of developing model will be identifying the passenger flow consequences on the inventory if the dummy items are removed.

ii. Dummy items stack or lag at the destination

Without using the dummy items there is a possibility of stacking and lagging of the rotables at the destination. To identify the impact of removing dummy items the possibility of stack or stock out situation need to be identified. Therefore the impact is identified using the passenger movement for one year. The first operating onward flight will carry rotables to match the passengers on board and for the return flight there can be less, equal or more passengers compared to onward flight. If it is equal there will be no need of rotables at the destination hypothetically. The identification of above requirement is explained in the Table 1. If the value is plus it means there will be items stacking at the destination.

Table 1: Calculation method used to identify stacking and lagging of rotables

Flight Leg	Date	Economy Capacity	Actual Pax.	Scenario	Stack or lag of rotables
Base - Destination Destination- Base	1-Jan-14 1-Jan-14	296 296	238 257	Onward < Return	-19
Base - Destination Destination- Base	7-Jan-14 7-Jan-14	236 236	228 193	Onward > Return	35
Base - Destination Destination- Base	5-Jan-14 5-Jan-14	256 256	226 226	Onward = Return	0

3.4. Developing the Model

After identifying the variables associated to the inventory model the next step is developing the model. Therefore developing the model and identifying of the variables will be explained using a destination of ABC airlines and the related data of ABC catering limited and destination catering provider. Assumptions as follows,

- Cleaning and handling per rotable set is same in both catering service providers
- Inventory holding cost is not applicable for the base catering service provider
- Holding cost will be charged for the inventory level maintained since the variation is not predictable.
- The purchasing cost of new rotables will be dispersed into 5 years

Developing the model is done using the route of Colombo (CMB)–Mumbai (BOM) which is operated using a narrow bodied A320. The route is operated daily with one frequency. For this operation the average operating cost per kg is LKR.44.81. Weight of one set of rotable is 0.575kg and it costs LKR.600.00 for a new set. The cleaning cost per rotable set is LKR.20.00 and holding cost per set per year is LKR.60.00. There were 12,619 movements of dummy items for the considered one year in both ways.

i. Purchasing cost of new rotable items

To maintain an inventory at destination there should be new items added to the current flow. Current practice is to maintain 3 times of rotable sets at the destination. Therefore with the current practice there are 140 x 3 = 420 sets of rotables at the destination. This inventory is not changed with the new model and it will be kept as a safe stock at the destination. And this inventory do not cost any amount since it is in the service agreement to keep 3 times or 5 times inventory at the destination. The cost will be dispersed into 5 years as assumed.

Purchasing cost (α) = (Number of new items x Purchasing cost of new set of rotables) / 5 (1)

ii. Placing the inventory

The new rotables need to be placed. For that average route operating cost per kilogram will be used.

Cost of placing the inventory (β) = Weight of the rotables x Average operating cost per kilo (2)

iii. Cost of holding inventory at the destination

New inventory will create a holding cost depending on the agreement with the catering provider.

Holding cost at the destination (γ) = Number of inventory stored x Holding cost per set of rotables per year (3) *iv. Replenishing the inventory*

After placing the inventory, this has to be replenished by monitoring daily inventory level. If the inventory level is 500 it should be monitored and once it is more than 500 balance need to be returned to base. Also when the level goes below 0 the number need to be replenished from base. Since there is a requirement of sending the rotables in the aircraft as dummy items it will incur a cost.

$$\textit{Replenishing cost } (\delta) = \textit{Annual number of rotables replenished x Weight of single rotable set x Average operating cost per kilo} \quad (4)$$

v. Extra cleaning and handling

This is due to replenishment. Since the replenishment is as dummy items it needs to be cleaned.

$$\textit{Extra cleaning and handling } (\varepsilon) = \textit{Annual number of rotables replenished x Cleaning cost per set of rotables} \quad (5)$$

vi. Total cost calculation

Sum of these 5 cost variables will give the total cost incurred at each inventory level. Past data can be utilized to identify the trend and replenishment numbers which will vary with the inventory level.

$$\textit{Total cost} = \textit{Purchasing cost} + \textit{Cost of placing the inventory} + \textit{Holding cost at the destination} + \textit{Replenishing cost} + \textit{Extra cleaning and handling} \quad (6)$$

$$\textit{Total cost} = \alpha + \beta + \gamma + \delta + \varepsilon \quad (7)$$

3.5. Sensitivity Analysis to Identify the Optimum Inventory Level

The inventory level which creates the least total cost will be identified as the optimum inventory level. The total cost can be calculated for several figures and drawing the total cost can derive the best inventory level through sensitivity analysis. In the given example the 300 can be identified as the best level that creates least total cost. According to the sensitivity analysis graph the total cost cannot fall in any other location in the curve with the given conditions and assumptions. Figure 2 shows the graph of total cost.

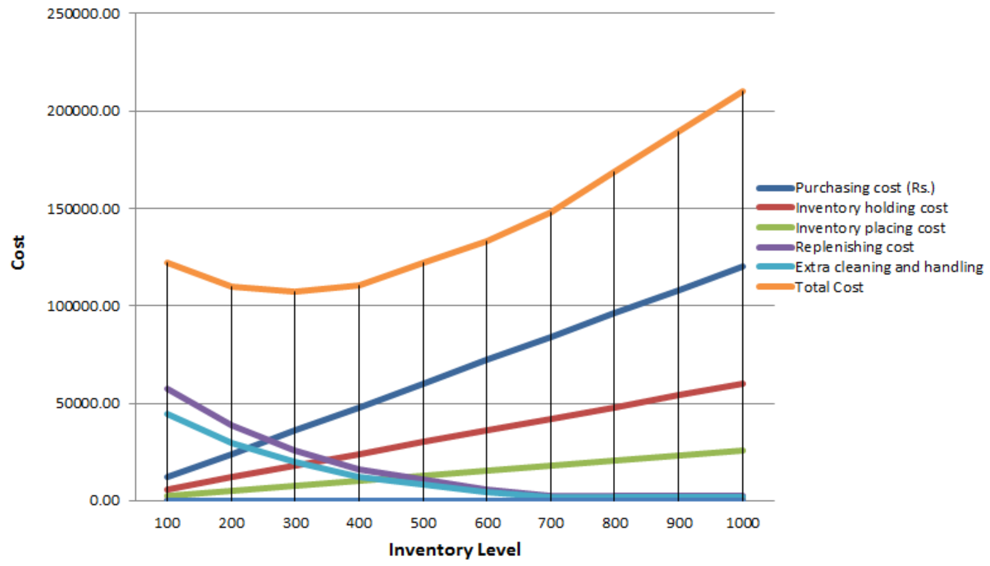


Figure 2: Total cost curve

3.6. Optimum Inventory Level Using Excel Solver

The total cost variable to be minimized and giving other cost variables and allow the inventory level to vary. The result will give the best inventory level. With the 5 years purchase cost dispersion the result is given as 316 (figure 15) which is the most accurate inventory level. The Figure 3 shows the excel solver output.

Solution Time: 1.5 Seconds.
Iterations: 9 Subproblems: 0

Solver Options

Max Time Unlimited, Iterations Unlimited, Precision 0.000001, Use Automatic Scaling
Convergence 0.0001, Population Size 100, Random Seed 0, Derivatives Forward, Require Bounds
Max Subproblems Unlimited, Max Integer Sols Unlimited, Integer Tolerance 1%, Assume NonNegative

Objective Cell (Min)

Cell	Name	Original Value	Final Value
V28	Total Cost Number of Rotables	122063.00	106894.50

Variable Cells

Cell	Name	Original Value	Final Value	Integer
V2	Inventory Level	100	316	Integer

Constraints

Cell	Name	Cell Value	Formula	Status	Slack
V23	Purchasing cost (Rs.) Number of Rotables	37920.00	V23>=0	Not Binding	37920.00
V24	Inventory holding cost Number of Rotables	18960.00	V24>=0	Not Binding	18960.00
V25	Inventory placing cost Number of Rotables	8176.50	V25>=0	Not Binding	8176.50
V26	Replenishing cost Number of Rotables	23598.00	V26>=0	Not Binding	23598.00
V27	Extra cleaning and handling Number of Rotables	18240.00	V27>=0	Not Binding	18240.00
V28	Total Cost Number of Rotables	106894.50	V28>=0	Not Binding	106894.50
V2	Inventory Level	316	V2>=0	Not Binding	316

V2=Integer

Figure 3: Excel solver result sheet

3.7. Feasibility of the Model

Airlines and Catering service providers can collaboratively use their data and analyze the possibility of implementing the above model in their operational process. For each destination with third party catering at the destination, the optimal inventory number can be calculated by identifying the total cost that will occur. By comparing the current cost figures that the dummy items cause the feasibility of the model can be revealed. The operating cost of the airline per kilo is used to identify the cost associated with dummy items moved annually and cleaning cost accordingly. Finally the comparison of current cost with the total cost of new model can contrast the model feasibility.

Current costs associated with dummy items movement = (Annual dummy items movement x weight of rotable set x operating cost per kilo) + (Annual dummy items moved x Cleaning and handling cost) (8)

Feasibility of the model = Current costs associated with dummy items movement - Total cost of new model (9)

3.8. Calculation of the Considered Route

The calculation for the above mentioned route of ABC Airline is as follows according to the Excel Solver considering the time of one year with the inventory level of 316.

- Total Cost - LKR.106,894.50
- Current operating cost for dummy items - LKR.578,896.62

Feasibility of the model = LKR. (578,896.62 – 106,894.50) (10)
= LKR. 470, 002.12

According to the calculation feasibility gives a positive value where there will be LKR. 470,002.12 savings from the model for one year to both airline and catering service provider from this route. This will be approximately 3133.34 US $ per year (1US $=LKR.150.00).

4. Conclusion

The developed model can be used for any airline or catering service provider by replacing the cost values according to the airlines cost variables. But the analysis can be developed using the data relevant to the airline and identify the best inventory level to maintain at the destination by calculating the total cost by changing the inventory number in the equation. There are some parts to be calculated manually and other calculations by the equations directly. For example the replenish inventory level at each inventory level can be calculated through Excel and ultimately the total cost can be also calculated by developing the equation variables in a single Excel sheet. The minimum total cost have to be identified through and sensitivity analysis. The best inventory level need to be maintained to attain the lowest total cost have to be calculated and it should be compared with the cost that the dummy item movement process will occur to identify the feasibility of the model. The feasibility of using the model cannot be identified until the final cost comparison is calculated. Therefore by just looking at the passenger statistics and dummy movement cannot highlight the feasibility and possible cost savings to the airline and catering service provider.

5. Recommendations

Airlines and catering service providers can analyze their data and identify the gains possible through reducing dummy item movement. Accurate data relevant to the operations can improve the output of the model. The total cost calculation will provide the final cost that the inventory model will cause for a period of one year. If it is less than the extra costs incurred when the normal procedure of dummy items inventory balancing is used it can be taken as a feasible route to implement the model. The purchase cost should be dispersed for few years to identify the real benefits of the model. It will improve the results if it is dispersed for several years. Availability of accurate data related to these cost factors refers that it can be used to calculation and check the feasibility. To improve the accuracy of the model passenger information for several consecutive years can be taken into analysis. And the future movements can change due to the dynamic nature in airline industry. The benefits of reducing dummy items do impact the airline as well as the catering service providers at the destination. Therefore identifying and implementing this model will be beneficial to both parties.

References

Catering, E.F. (2016) Emirates flight catering. Available at: http://www.ekfc.com/about-us/ (Accessed: 10 January 2016).

El-Namrouty, K.A. (2013) ‘Seven wastes elimination targeted by lean manufacturing case study ″Gaza strip manufacturing Firms″’, International Journal of Economics, Finance and Management Sciences, 1(2), p. 68. doi: 10.11648/j.ijefm.20130102.12.

Jones, P. (2004) Flight catering. 2nd edn. Amsterdam: Elsevier Butterworth-Heinemann

SriLankan Airlines (2015) Available at: http://www.srilankan.com/environment/ (Accessed: 1 December 2015).

SriLankan Catering (2014) Our Environment. Available at: http://www.srilankancatering.com/index.php/our-environment/customer-service (Accessed: 20 December 2015).

Analysis of the Competitiveness of the Second International Airport in Sri Lanka

H. K. Sameera Prasani and W.W. Anuja Shamini Fernando

Department of Transport and Logistics Management, University of Moratuwa, Sri Lanka

Abstract

Airports act as the gateways to enter countries. Until 2013, there was only one international airport operating in Sri Lanka to facilitate air transport in and out of the country. In 2013 a second international airport-Mattala Rajapakse International Airport (MRIA), which was constructed in a less lucrative area in the country, commenced its operations. Although this airport is equipped with the necessary facilities for an international airport and operating for almost two years, the airport was unable to achieve its target as anticipated. The main purpose of this study was to identify whether there was a demand for another international airport in Sri Lanka, why the airport was unable to achieve its target as indicated in the master plan and identify viable options. The requirement of another international airport was to serve as an alternative airport to the Bandaranaike International Airport. However, the location of the second international airport was not suitable due to lack of infrastructure and accommodation facilities, industrial activities and demand for air traffic in the region. The location of the airport has played a critical role for the current status of MRIA. Converting the airport to a Maintenance, Repair and Overhaul facility and promoting low cost carriers are the viable options to achieve a competitive edge.

Keywords: Second International Airport, Alternative Airport, Competitive Edge

1. Introduction

There was only one international airport operating in Sri Lanka to facilitate air transport in and out of the country, until 2013. Mattala Rajapakse International Airport (MRIA), the second international airport was constructed in Hambantota District which is a less lucrative area in the country. The objective of MRIA was to serve as an alternative aerodrome to the solitary international airport (Bandaranaike International Airport) in Sri Lanka and to aid the rapid development of the southern region of the country (Airport and Aviation Services (Sri Lanka) Limited, 2012).

The airport was declared open on 18th March 2013 with a capacity to handle 1 million passengers and 45,000 tonnes of cargo per annum. However, the airport was not able to utilize its facilities since the commencement of operations. The master plan of the airport has forecasted a total passenger demand of 160, 873 for the year 2013 (Airport and Aviation Services (Sri Lanka) Limited, 2012). But the total arrivals and departures for the year 2013 was reported as 13, 284 and 22,853 (National Transport Commission, 2014) respectively.

The situation did not improve rather deteriorated with the stoppage of the operation of the national carriers to the airport. Sri Lankan Airlines and Mihin Lanka Airlines suspended its operation to MRIA in January 2015 (Civil Aviation Authority Sri Lanka, 2015). Therefore, the ability of the airport to sustain in the industry and recover the investment of US $250 million is questionable with the current trend.

2. Research Objectives

The aim of this study is to identify why the airport (MRIA) was unable to achieve its target as indicated in the master plan. To achieve the aim, the research is based on the following objectives;

- Identifying whether there was a demand for another international airport in Sri Lanka
- Identifying the reasons why the airport was unable to achieve the target
- Identifying the benefits and viable options for the airport to succeed

3. Literature Review

Airport is a complex industrial enterprise which act as the medium where disparate elements and activities are brought together in order to facilitate both passengers and freight. Airport consists of one or more runways for aircrafts along with terminals and buildings where the passengers or freight transported by the aircraft is processed (Doganis, 2005). Moreover, (Wiltshire, 2013) mention airports as the gateway to aviation and the key link in the air transport chain. Airports facilitate air transport by offering the accessibility to essential infrastructure and services.

An international airport is "any airport designated by the Contracting State in whose territory it is situated as an airport of entry and departure for international air traffic" (ICAO Definitions- UVS International, 1944,p. 21).ICAO has defined alternative aerodrome as "An aerodrome to which an aircraft may proceed when it becomes either impossible or inadvisable to proceed to or to land at the aerodrome of intended landing" (ICAO Definitions-UVS International, 1944,p. 8).

Today airports are not just infrastructure providers, airports are operating in a competitive environment (European Commission, 2002). Present day an airport faces seven areas of competition. They are provision of services to airlines, traffic: outbound, traffic: transfer, traffic: inbound (destination), global competition, competition for funding and competition with other modes (Jimenez, et al., 2014). Competition between airports exists when two or more airports have the same catchment area or when two or more airports are sharing a common part of the catchment area (Barbot, 2009).

4. Research Methodology

Objectives of the study could not be achieved from a single method, hence a methodological approach including both quantitative and qualitative studies were adopted as shown in Figure 1.

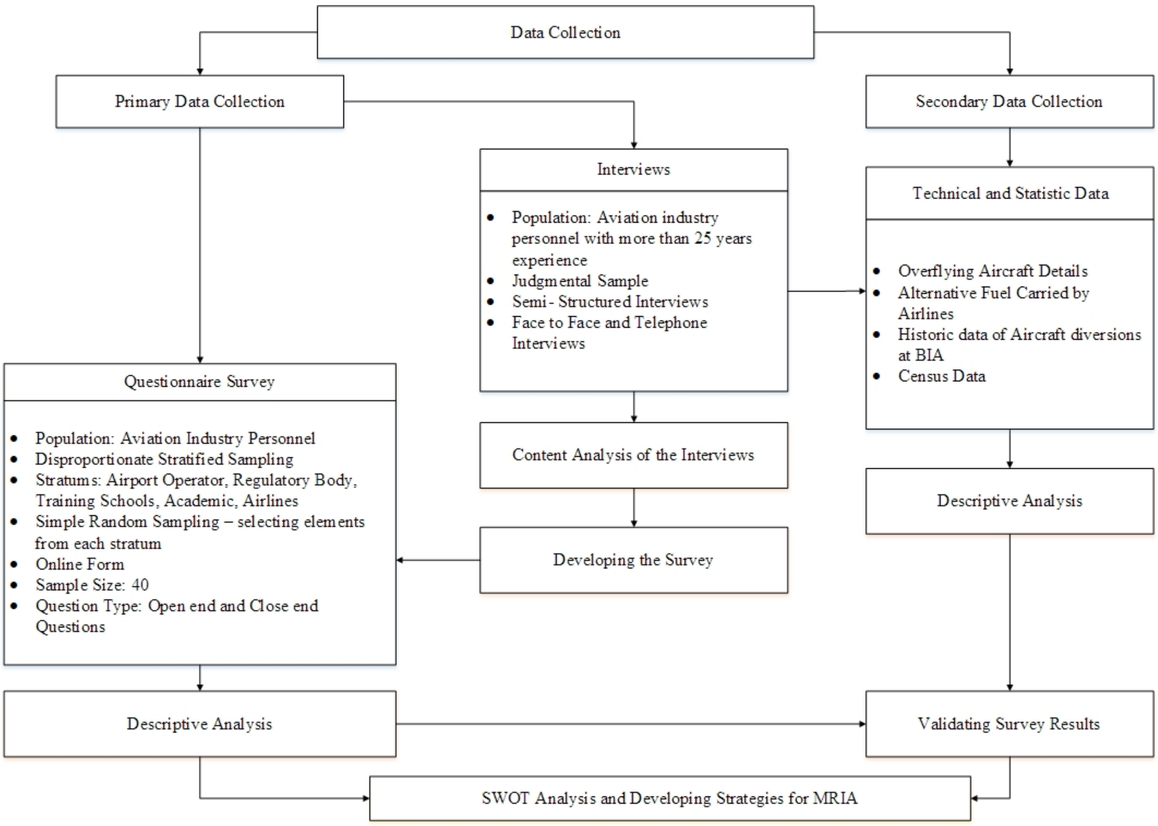


Figure 1: Research Methodology

4.1. Primary Data Collection

Interviews were carried out first with the aim of obtaining the background knowledge relating to the study. Judgmental sampling was used to select data from interviews. Based on the researcher's judgment, the researcher interviewed personnel in the aviation industry who were having sound knowledge regarding the study area. The interviewed sample consisted of personnel in the aviation industry having more than 25 years of experience in the industry.

Then the questionnaire was developed based on the findings of the interviews. Disproportionate stratified sampling method was used to select the respondents, to obtain a better representation of each sector in the sample. The perception of the study area among each sector in the aviation industry could be different; hence it was imperative to have the representation of all the sectors in the sample. 40 samples were collected.

4.2. Secondary Data Collection

From the findings from the interviews, the technical data and statistical data needed to validate the questionnaire findings was identified first. Secondary data of overflying aircraft in Colombo Flight Information Region (FIR), alternative fuel carried by airlines arriving at BIA and foreign employment departures from Sri Lanka were collected.

4.3. Analysis Method

Data were analyzed via descriptive methods. Finally, a SWOT analysis was performed to develop strategies for the airport to have a competitive edge.

5. Analysis

5.1. Composition of the Sample

All the sectors of the aviation industry were represented in the sample as shown in Fig. 2. When the airline sector is considered, 70% of airline sector was represented by international airlines and remaining 30% by domestic airlines. Moreover, 25% of the sample had more than 25 years of experience in the aviation industry, which further validates the questionnaire findings.

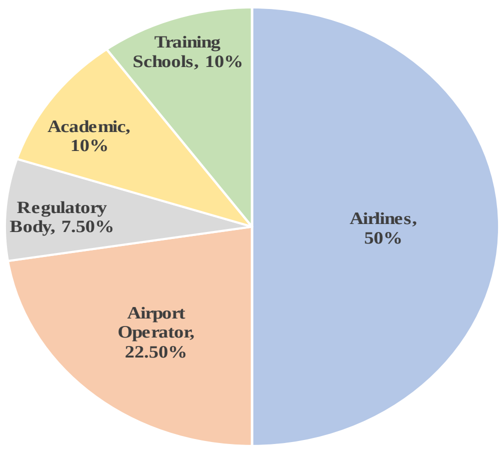


Figure 2: Composition of the Sample

5.2. Requirement for another International Airport in Sri Lanka

According to the study, 75% of the sample stated that unavailability of another airport in Sri Lanka to use in emergency situations as the prominent issue faced when having only the Bandaranaike International Airport (BIA), whereas 57.5% of the sample also stated lack of an airport to divert in bad weather conditions at BIA as the issue. But according to the historical data of aircraft diversions at BIA from 1996-2006, there were only 14 instances where an aircraft was diverted due to bad weather. Hence, aircraft diversions at BIA due to bad weather conditions seems to be a rare occurrence.

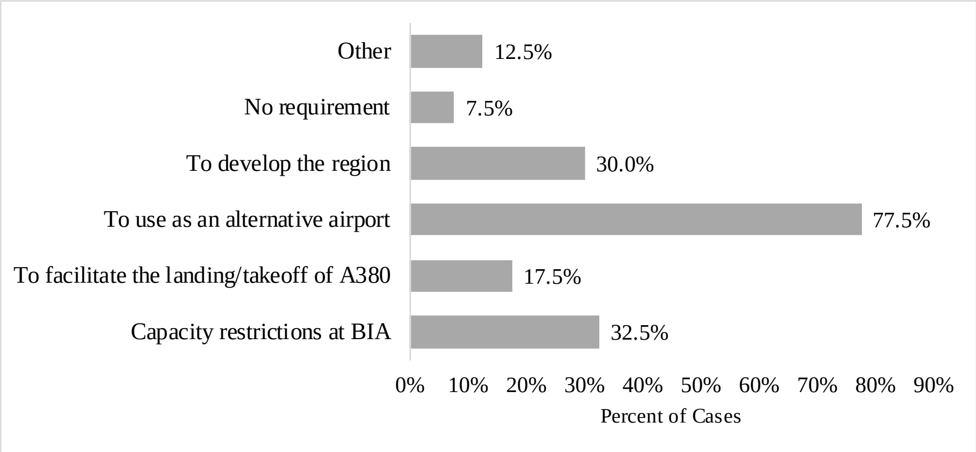


Figure 3: Requirement to have another International Airport in Sri Lanka

As Figure 3 depicts, 77.5% of the respondents stated the requirement of another international airport was to use as an alternative airport to BIA. However, as shown in the Figure 4, 75% of the industry experts questioned did not agree with the location of the second international airport due to lack of infrastructure facilities, lack of industrial activities, lack of demand for air traffic and less accommodation facilities in the region.

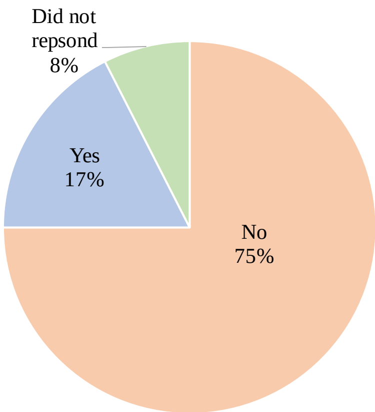


Figure 4: Suitability of Hambantota as the location for the Second International Airport in Sri Lanka

52.2% of those who did not agree with Hambantota as the location for the airport, suggested either Kandy or Dambulla in Central province would have been the most suitable location for the second international airport. Reasons were accessibility, proximity to tourist attractions, good road network with other regions in the country, large catchment area and contrast weather condition compared to BIA.

5.3. Reasons for the underutilization of the airport

Respondents were asked to rate the reasons for underutilization of the airport according to its degree of influence for the underutilization. Rates were given from 5 to 1, representing to ‘a great extent’, ‘somewhat’, ‘neutral’, ‘very little’ and ‘not at all’ respectively. Of the reasons mentioned in Table 1, the lack of demand in the region (both passenger and cargo) was the reason which contributed mostly for the underutilization of the airport, with a mean of 4.05. 60% of the respondents consider that lack of demand in the region has contributed for the underutilization of the airport to a great extent.

Table 1: Reasons for the Underutilization of the Airport

	Not at all	Very Little	Neutral	Somewhat	To a great extent	Mean
Technical Reasons	60.0%	5.0%	5.0%	20.0%	10.0%	2.15
Operational Reasons (Lack of airport marketing)	30.0%	5.0%	5.0%	22.5%	37.5%	3.33
Lack of demand in the region	17.5%	0.0%	2.5%	20.0%	60.0%	4.05
Lack of tourism marketing	52.5%	7.5%	5.0%	15.0%	20.0%	2.43
Lack of accommodation facilities near the airport	32.5%	12.5%	5.0%	15.0%	35.0%	3.08
Lack of utility facilities within the airport	55.0%	10.0%	2.5%	17.5%	15.0%	2.28
Lack of support from the government	65.0%	7.5%	5.0%	12.5%	10.0%	1.95
Other	92.5%	0.0%	0.0%	0.0%	7.5%	

Secondary data was analyzed to identify whether MRIA has a demand or not. Distance to BIA and MRIA from each district and its population was analyzed. According to the distance analysis (Table 2) ,9 districts are close to MRIA compared to BIA. These districts are Ampare, Badulla, Batticaloa, Galle, Hambantota, Matara, Monaragala, Nuwaraeliya and Ratnapura. Galle and Ratnapura is having similar distances to MRIA and BIA. However, the population of these districts are considerably less, which makes the catchment area of the airport small. This also confirms the finding where industry experts did not agree with Hambantota as the location for the international airport. It is evident that the location of the airport has played a critical role for the current status of the airport.

Table 2: Distance Analysis

District	**Population * (‘000)**	**Distance to BIA (km)**	**Distance to MRIA (km)**	**District**	**Population (‘000)**	**Distance to BIA (km)**	**Distance to MRIA (km)**
Ampare	648.3	306	176	Kegalle	836.7	66.5	213
Anuradhapura	856.4	274	344	Kilinochchi	113.0	304	465
Badulla	815.3	230	118	Kurunegala	1,611.0	74	251
Batticaloa	525.4	292	237	Mannar	99.1	216	421
Colombo	2,310.1	35.7	257	Matale	482.4	128	258
Galle	1,059.1	154	148	Matara	809.6	184	106
Gampaha	2,294.8	19.3	208	Monaragala	448.2	271	92
Hambantota	596.8	289	27.7	Mullaitivu	90.8	282	441
Jaffna	583.6	370	525	Nuwaraeliya	706.7	161	154
Kalutara	1,217.6	96.9	213	Polonnaruwa	403.8	204	260
Kandy	1,370.2	104	233	Puttalam	760.1	107	324
Vavniya	171.4	225	388	Rathnapura	1,082.8	100	117
				Trincomalee	378.3	277	352

Source: Economic and Social Statistics of Sri Lanka 2014, Central Bank of Sri Lanka

62.5% of the experts surveyed stated, action available to mitigate the underutilization of the airport was to develop the region in terms of infrastructure, accommodation facilities and utility facilities. Implementing a proper marketing plan was voted by 55% responses as the second highest factor.

5.4. Benefits of the Airport since its Commencement and Viable Options to achieve a Competitive Edge

When considering the benefits from MRIA since its opening, only 82.5% of the sample considered that there is a benefit. Nevertheless, as shown in Figure 5, 70% of the respondents indicated the availability of another international airport to use as an alternative airport as the benefit. Carrying of less fuel by the aircraft arriving at BIA and increase in aircraft flying over Colombo FIR (Flight Information Region) were considered as benefits obtained from the airport by the respondents. This is supported by the findings of secondary data analysis based on the number of overflying aircraft and alternate fuel carried by aircraft before and after the opening of MRIA. Certain assumptions were undertaken in arriving at these calculations due to unavailability of data.

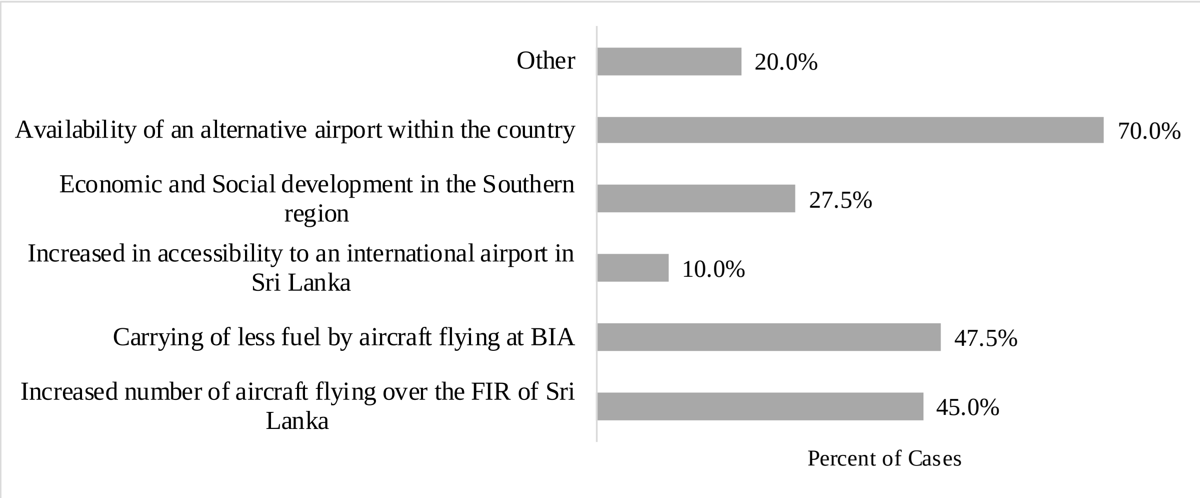


Figure 5: Benefits of MRIA since its opening

As per Table 3, mean value of the number of overflying aircraft after the opening of MRIA is greater than that of the number of over flying aircrafts before MRIA. Hence, there is an increase in overflying aircraft after the opening of MRIA.

Table 3: Comparison of Overflying Aircraft Before/After MRIA

Overflying Aircraft in Colombo FIR	**Mean**
Number of over Flying Aircraft before MRIA	1973.16
Number of over Flying Aircraft after MRIA	2575.48

As per the findings in Table 4, there is a fuel saving of 15 minutes. Due to carrying less fuel, an aircraft can save on fuel consumption which is the saving for the airline. On average an aircraft saves about $ 2000 per trip due to naming MRIA as the alternative airport.

Table 4: Comparison of Fuel Carried by Airlines Arriving at BIA, Before and After MRIA

	Before MRIA	**After MRIA**
Alternative Airport when arriving to BIA	Trivendrum	MRIA
Flying time from BIA to the Alternative Airport	45 minutes	20 minutes
Amount of alternative fuel carried	Fuel sufficient for 45 minutes	Fuel sufficient for 30 minutes
Average Saving per trip		$ 2000

Remarkably, the majority of the sample does not feel there is an economic and social development in the region due to the airport. MRIA did not have the required air service to help the development of Hambantota area, which was a necessary requirement for an airport to assist the development of a region as per the studies conducted by (Robertson, 1998).

Respondents were asked to select and rank the options according to its preference and suitability from 1-6, rank 1 being the most suitable and preferred option. According to the ranking as shown in Table 5, Maintenance, Repair and Overhaul (MRO) obtained the lowest mean value of 1.38 compared to 1.52 for Cargo Hub option. This indicates in terms of suitability and preference MRO option is ranked first.

Table 5: Viable Options for The Airport

	Tourist Hub	Cargo Hub	Training School	LCC passenger Hub	MRO facility
No of Responses	12	23	20	7	24
Mean	2.75	1.52	2.30	3.43	**1.38**

5.5. SWOT Analysis

Strengths

- Availability of bare lands adjacent the airport to expand
- Runway category of the airport allows to land/take off any aircraft type, including the largest aircraft A380.
- Equipped with facilities to handle 1 million passengers and 45000 ton of cargo per annum. The terminal building can accommodate 325 international passengers and 75 domestic passengers two ways at peak hour (Airport and Aviation Services (Sri Lanka) Limited, 2012).
- Ability to serve as a hub for Westbound and Eastbound airlines due to its strategic location
- Favorable weather and climatic condition of the location
- Availability of skilled labour force for the operational activities of the airport
- A higher percentage of departures originating from the districts in the catchment are for clerical, skilled, semi-skilled, unskilled and housemaid employment. Hence, there is a demand for budget carriers within the region.

Weaknesses

- Constant crosswinds due to the wrong alignment of the runway, and which has resulted in difficulty in maneuvering the aircraft
- Lack of parallel taxiway
- Hazards of bird strikes for flying aircraft
- Destruction to wildlife due to the operations of the airport because the airport is constructed in a wildlife sanctuary

Opportunities

- Close proximity to the sea port, where opportunities can emerge for transshipment cargo.
- Proximity to tourist attractions in Sri Lanka which in addition is a booming industry in the country.
- Airspace above the airport is not congested as in other countries, therefore favourable environment to establish a training school.
- MRO industry is a growing industry in the Asian region as many western companies are out sourcing their aircraft maintenance work to Asian firms or setting up centres in Asia.
- Commencement of industrial activities in the region, which can boost the development of the region.

Threats

- Lack of demand for air traffic in the catchment area
- Only a limited number of districts can access MRIA easily compared to BIA. The catchment area of the airport is not lucrative. Unavailability of a good road network to access the airport.
- Close proximity to the Bandaranaike International Airport. The flying time between the airports is approximately 20 minutes.
- Lack of infrastructure, accommodation, utility facilities in the region.
- Development and expansion of the second runway at BIA

According to the analysis, the following strategies are developed to achieve a competitive edge for the airport.

- Build a Maintenance, Repair and Overhaul (MRO) facility in the airport and develop a MRO hub for the South Asia
- Promoting low cost carriers from the airport since there is a demand for low cost carriers in the catchment area as per the SWOT analysis.

6. Conclusion

Unavailability of another international airport in Sri Lanka to use in emergency situations was the key issue faced when having only the Bandaranaike International Airport (BIA) in Sri Lanka. Accordingly, the main requirement to build another international airport was to use as an alternative airport to the BIA.

However, the majority of the experts did not agree with the location of the second international airport. According to the study, the most significant reason for the underutilization and the current status of the airport is the lack of demand in the catchment area. The catchment area of the airport only consists of 9 districts (out of 25) of the country. This confirms that the location has played a critical role in affecting the performance of the airport. Course of action to overcome the current status of the airport is to develop the region with the required infrastructure, accommodation and utility facilities. Then, an implementation of a proper marketing plan is essential to improve the performance of the airport.

Yet there is a benefit from the opening of the airport. Main benefit obtained from operating MRIA is the availability of an alternative airport in the country. Increase in the number of overflying aircraft over Colombo FIR and reduction in the fuel carried due to naming MRIA as the alternative airport are the other benefits. As per the analysis, viable options for the airport to succeed are to convert MRIA as a Maintenance, Repair and Overhaul (MRO) facility. Strategies were developed based on the SWOT analysis and strategies were to develop MRIA as MRO and low cost carrier airport.

7. Limitations of the Study

Secondary data obtained was not available as required, hence certain assumptions were made during the analysis which is a limitation of the study.

References

Airport and Aviation Services (Sri Lanka) Limited, 2012. Master Plan - Mattala Rajapakse International Airport, s.l.: s.n.

Civil Aviation Authority Sri Lanka, 2015. Civil Aviation Authority Sri Lanka. [Online] Available at: http://www.caa.lk/index.php?option=com_content&view=featured&Itemid=793&lang=en [Accessed 21 June 2015].

Jimenez, E., Claro, J. & Sousa, J. P. d., 2014. The airport business in a competitive environment. Procedia - Social and Behavioral Sciences, pp. 947-954.

National Transport Commission, 2014. National Transport Commission Statistics 2014, s.l.: National Transport Commission.

Robertson, J. A. W., 1998. Airports and Economic Regenaration. Journal of Air Transport Management, p. 88.

Yao, S. & Yang, X., 2008. Airport Development and Regional Economic Growth in China. Research Paper Series - China and the world economy, p. 33.

Key Factor Analysis to be an Airport City (Aerotropolis) in Sri Lankan Context

W.W.A.S. Fernando and J.M.S.J. Bandara

Department of Civil Engineering, University of Moratuwa, Sri Lanka
Email: anujatlm@yahoo.com

Abstract

Airport City is a new concept to Sri Lanka and this paper identifies the key factors to be an airport city in Sri Lankan context. Initially, a broader set of factors applicable to anywhere in the world, were identified through comprehensive literature survey. Inductive approach was used to collect data through studies and industry experts. After interviewing a group of industry experts, seven factors were finalized namely geographic location, demand, technology, nature of the airport, non-aeronautical activity centers, business management and access modes. A stratified sampling technique was used to select industry experts to define and rank factors. The AHP technique was used for factor analysis and seven criteria were compared with the purpose of ranking based on importance. It is identified that Non Aeronautical activities, Geographic Location, Demand, Nature of the Airport, are the more important to achieve airport city status. Access Modes, Business Management and Technology are the other factors that must be considered to be an airport city in Sri Lankan context. This approach can be used for identification and ranking of relevant factors for any airport city to be developed.

Keywords: Airport City, AHP, Ranking

1. Introduction

The world has become smaller due to the globalization and time has become expensive in day today life. Globalization integrates people internationally and airports play a critical role in facilitating the tourism, business travel and global supply chains. Airports are considered as a key link in air transportation. Airport provides gateway to the people and goods which are moving internationally. Modern gateways are facilitating the trend through the airport city concept. It is not only the shopping malls within the terminal but also the myriad businesses that congregate in airport environs, keen to exploit its convenient connectivity (IATA, 2012).

Airport city has become the 21st century way forward to many airports (Kasarda, 2008). Although this is quite a new concept for Sri Lanka, Seoul Incheon International Airport in South Korea and Amsterdam Schiphol International Airport in Netherlands are already well advanced in the concept. There is no any research work had done for investigating airport city concept in Sri Lanka and therefore this research is aimed to fill the gap for identifying critical factors for being an airport city. Basically it is focused on to identify the factors which influence to be an airport city in Sri Lankan context and it investigates the relative importance of those factors. Accordingly, the study presents key factors to be an airport city in Sri Lankan Context.

1.1 Research Objectives:

The objectives of this research are:

- Identify the important factors to be an airport city
- Perform an assessment of importance of each factor to evaluate Airport and its' environment to be an Aerotropolis
- Rank the identified factors in the order of importance in Sri Lankan context

This paper organized as follows; a literature review on airport city (Aerotropolis) concept, methodology and the methods used for identifying factors, aligning those factors for Sri Lankan context and ranking the importance, results and findings followed by the conclusions.

2. Literature Review

2.1 Airport City Concept

Historically, an airport is considered as a place where aircraft operate, including runways, control towers, terminals, hangers and other facilities which directly serve aircraft, passengers and cargo. Airport city concept is grounded in the fact that in addition to their core aeronautical infrastructure and services, focusing on development of non aeronautical facilities, services and revenue streams (Kasarda, 2006).

Major gateway airports are generating spatial concentrations of commercial activities that are leading to a new aviation linked urban form: the aerotropolis (Stevens, 2006). Many airports today receive greater percentages of their revenues from non-aeronautical sources (hotels, retail complexes, conference and exhibition centers…) than from aeronautical sources (landing fees, gate leases, passenger service charges) (Kasarda, 2006).

Boeing's long term forecast shows global passenger traffic increasing at about 5% per annum to 2024 with the Asia Pacific region growing faster at nearly 6% (Current Market Outlook 2005, Boeing). Some aspects of the Airport city concept clearly hold benefits like integrate multimodal transport and connectivity of passengers and businesses. Schiphol International Airport is one of the well-established, well developed and it has state art of technology to be an airport city.

2.2 Bandaranaike International Airport

When considering Sri Lankan context, Bandaranaike International Airport (BIA) is the main International Airport and it is in a blooming stage. There is a positive sign for international traffic for BIA and it is medium size airport with compared to passenger movements. In 2013, BIA has handled 7.3 million of passenger movements which is a 3.2% growth when compared to 2012. Further, the number of transit passengers who were at BIA has increased and is recorded as 1,231,903 (CAASL, 2013). BIA has a single runway (04/22) with 3350m length and 60m width. In year 2014, 28 scheduled airlines have used BIA, flying to and from and it covers 45 cities around the world (AASL, 2014). International Flight movements of BIA for the year 2014 recorded a total of 54,960.

2.3 Identification of order of importance

There are many Multi Criterion Analysis Techniques such as ANP (Analytical Network Process), Analytical Hierarchy Process (AHP), Data Envelopment Analysis, ELECTRE (outranking), Relative Merit Method (RMM) and the Evidential Reasoning Approach to identify the importance of factors affecting to decision making. When compared with other techniques, Analytical Hierarchy Process (AHP) enables decision makers to have a practical decision making with the knowledge about criteria and also Judgment on one criterion can be made effectively relative to another criterion. The input can be obtained from subjective opinion such as satisfaction, feelings and preference. AHP can be considered as an effective tool since it can handle numbers of alternatives at once even some other method like Relative Merit Method can handle only two alternatives at once (Bahurmoz, 2006). In this research, decision making is crucial with experts' perceptions in number of alternatives. Therefore AHP model is used for this study and it is selected for ranking the importance.

3. Research Methodology

Methodological approaches including both quantitative and qualitative studies were adopted as shown in figure 1.

Secondary Data Collection	Comprehensive Literature Survey Sample : 25 Research Articles *18 key factors to be an airport city were identified*

↓ ↓

Primary Data Collection	Personal Interviews & Brain Storming Sessions Sample Size : 15

	Sampling Method : Convenient Sampling Population : Experienced Personal in Aviation Industry *Seven Factors were defined for this study* Questionnaire Survey Sample Size : 50 Sampling Method : Random Sampling Population : Airport Operators ,Regulatory body , Airline Service Providers *Pair wise comparison was done*
Data Analysis	Analytical Hierarchy Process (AHP) *Ranked Factors to be an airport city*
Conclusion	

Figure 1: Research Methodology

4. Research Results and Findings

4.1 Identify key factors to be an Airport City (Aerotropolis)

Inductive approach is used to start with the data collection through literature. The identification of all relevant key factors was done through a comprehensive literature survey. Nearly 25 research articles were referred to identify the factors to be an airport city and a summary table is given in Appendix 1. When selecting the factors for the analysis, the number of citation were taken into account. When developing the summary table (Appendix 1), the methodology followed can be applicable to any airport in worldwide and Bandaranaike International Airport is the case study based airport. The 18 factors which required being an airport city were extracted from the literature are listed below.

1. Geographic Location
2. Attractiveness
3. Aviation policy of the country
4. Nature of the airport
5. Traffic
6. Infrastructure
7. Level of Service
8. Logistics and Just in time Manufacturing
9. Free trade zones
10. Flexible and advanced technology
11. Intermodal freight hub
12. Related and supporting industries
13. Mixed use residential areas
14. Local and global interest
15. Airport access modes
16. Land supply
17. Land availability
18. Performance of the airport

The detailed summary of these factors are in Appendix 1 and it is provides extracted information, title of the paper, authors and year of publication.

4.2 Aligning to Sri Lankan Context

According to the Western Region Megapolis Mater Plan under the Ministry of Megapolis and Western Development established in 2015 have identified aero city zone as one of the major development areas around the present Bandaranaike International Airport (BIA). This is an opportunity to develop BIA as an airport city and this is the best time for identification of key factors for being an airport city.

Industry experts were involved to identify and prioritize key criteria to be an Airport City in Sri Lanka. As mentioned above, literature summary table was developed by referring published research articles. The factors which are listed in Appendix 1 are general and it is necessary to align them in to Sri Lankan context. To align those factors, aviation industry experts' views were solicited. A stratified sampling technique was used to select industry experts. Airport Managers, Aviation Policy Makers, Regulators, Executives in aviation industry are included in the sample. They were asked to screen the factor identified from the literature and come up with important factors to be considered when Bandaranaike International Airport (BIA) is planning to become an airport city.

Table 1: Summary of defined Factors for the study

No.	Criteria	Relevance in to Research (Sri Lankan Context)
1	Geographic Location	This refers the location where particular airport is located. Approachability to the airport, Air routes around the area, neighbor countries, airway distance, overflying are the most important aspects in geographic location. Different land uses of the nearby areas are also can be identified as geographic location.
2	Demand	This refers all airport users like passengers (arrival, departure and transfers), employees, visitors and government agencies representatives, concessionaires. Space and the infrastructure must be adequate for facilitating all the needs of the users.
3	Technology	This explains flexibility and advancement of the technology that airport is using. Air Transportation relies much on high technology support. Therefore technology plays a key role for passenger handling, cargo floe, functions of airport facilities and the environment. Real time information is also depended on technology.
4	Nature of the Airport	This refers current status of the airport. Its current capacity & the maximum capacity, infrastructure availability & future development. Performance of the airport also considered here, because when converting to an airport city, airport performances are very important.
5	Non Aeronautical activity Centers	This is the key element to fulfill to be an airport city. To encourage customers, it should be given priorities to Logistic parks, conference centers, Free Trade Zones, Office parks and office corridors, Exhibition & conference centers, Hotels , entertainment, retail clusters , academic and research clusters.
6	Business Management	This refers the relevant laws and regulation about airport city development. Aviation policy of the country should be catering airport city concept. Management concept of the airport should be innovative, profitable and flexible. Air traffic right, investment opportunities and international image will generate more traffic towards airport city.
7	Access Modes	This explains the multimodal connectivity from and to airport. Dedicated expressway links (Aerolanes) and high speed rail (Aerotrains) should be there to provide accessibility with mobility.

Face to face interview was carried out with experts. The sample of expert resource persons selected are having more than 15 years of experience in the aviation industry. Therefore, with having clear background, resource persons were asked to align the identified factors to Sri Lankan context. Initially they were asked to categorize the factors identified in appendix I, to different groups according to similarity and the relationship. Majority of the resource persons identified that some factors were highly depended on each other about their judgments. First individual perception on each factor was well noted and then asked them to discuss with each other. Resource persons had given their inputs towards identified factors and also regrouping was done. By considering relationship and interconnection all factors were pooled in to sub criterion by having brain storming session. After completion of brain storming sessions, 18 factors were regrouped to seven factors based on Sri Lankan Context and it is summarized in Table 1.

4.3 Rank the order of importance of factors to be an Airport City

After grouping important factors to be an airport city in to seven factors for BIA, next step is to rank the importance of those factors. When BIA is planning to become an airport city, action plan can be developed according to the importance of each factor. To assess the importance of each factor, Analytical Hierarchy Process (AHP) was used.

To evaluate the importance of the factor, AHP uses a pair wise comparison technique. For the pair wise comparison, 1-9 point scale is commonly used (Saaty, 1980). This scale is very important for AHP analysis since it can derive well defined results due to meaningful explanations associated with each numerical value in scale. Pair wise comparison of seven factors was done by industry experts. Integrated value for entire sample had been taken as the input for the matrix.

Questionnaire form (Appendix 2) is used for the pair wise comparison. For this, new sample was used because this is highly focused on this study. Respondent were informed in advanced about the intention of this study and all seven factors were discussed before responding to questionnaire. 50 respondents were evaluated and sample of the respondents consists of airport operators, regulatory body, and service providers.

After constructing the matrix, relative weights for each factor can be obtained. First matrix must be converted to a normalized matrix and then Standardized Eigen vector must be extracted from the normalized matrix. The calculated Eigen vector can be interpreted as the weight, or importance of specific criteria relative to all other criteria. If cell value is C_{ij} (i-row, j- column) and derived weight is denoted by W_{ij}, Equation 1 can be applied for calculating weights.

$$W_{ij} = \frac{\sum_{j=1}^{n} \frac{c_{ij}}{\sum_{i=1}^{n} c_{ij}}}{n} \quad (1)$$

The Consistency check is an important part of the study in order to verify the consistency of data. To do that Principle Eigen value (λ max) is needed. First Consistency Vector (CV) for each individual row is calculated by multiplying pair-wise matrix with the weight matrix. λ max is obtained as the average of CV values. Consistency Index (CI) must be computed by using Equation 2.

$$\text{Consistency Index } (CI) = \frac{\lambda \max - n}{(n-1)} \quad (2)$$

The consistency Ratio (CR) is calculated in a systematic approach by using Equation 3.

$$\text{Consistency Ratio (CR)} = \frac{\text{Consistency Index (CI)}}{\text{Random Consistency Index (RI)}} \quad (3)$$

Following results were obtained when calculating consistency check.

Principle Eigen Value = 7.64, Consistency Index (CI) = 1.08, Random Consistency Index (RI) = 1.32, The Consistency Ratio (CR) =0.08

If the value of CR is smaller than 10% or equal 10%, the consistency is acceptable. If value is greater than 10%, it is needed to revise the subjective judgment. Calculated CR value is 0.082, which is smaller than 10% or equal 10%. That meant data is consistent and results can be accepted from this study.

Table 2: Normalised Matrix

Criteria	**Geographic Location**	**Demand**	**Technology**	**Nature of the Airport**	**Non Aeronautical activity Centers**	**Business Management**	**Access Modes**	**Total**	**Average**	**%**
Geographic Location	0.11	0.56	0.22	0.41	0.04	0.12	0.15	1.61	0.23	**22.9**
Demand	0.01	0.07	0.19	0.46	0.29	0.24	0.01	1.27	0.18	**18.1**
Technology	0.01	0.01	0.02	0.01	0.04	0.01	0.004	0.11	0.02	1.6
Nature of the Airport	0.01	0.01	0.09	0.05	0.29	0.24	0.27	0.96	0.14	13.7
Non-Aeronautical activity Centers	0.79	0.07	0.17	0.05	0.29	0.36	0.27	1.98	0.28	**28.4**
Business Management	0.04	0.01	0.10	0.01	0.03	0.04	0.27	0.50	0.07	7.1
Access Modes	0.02	0.28	0.19	0.01	0.03	0.004	0.03	0.57	0.08	8.1
Total	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	100.0

Table 3 represents the summary of the results which is used for ranking the factors.

Table 3: Summary of the AHP results

Non Aeronautical activity Centers	Geographic Location	Demand	Nature of the Airport	Access Modes	Business Management	Technology
28.4	22.9	18.1	13.7	8.1	7.1	1.6

According to the Table 3, "Non Aeronautical Activity Centers" has highest priority vector. Airport city concept is highly concentrated on non-aeronautical activities. Especially duty free shops, logistic arks, shopping complexes, restaurants, hotels and conference room for their passengers are the main target of having aerotropolis. Therefore, airport must give priority for its non-aeronautical activities and it will be a good advantage for being a competitive airport city. The result of the analysis shows that "Non Aeronautical Activity Centers" is the most important factor for being airport city for BIA. Decision makers must give highest priority of this factor when developing their action plan.

"Geographic Location" is the second important factor for being airport city. Being a sea locked country, air transportation is very much important to Sri Lanka. Geographic location is very much important to attract passengers. Approachability to the airport, Air routes around the area, neighbor countries, airway distance, overflying are added value to the airport city. Third highest factor for being aerotropolis is Demand. As explained by interviewer, demand is dependent on geographic location and non-aeronautical activities. Destination choice (which airport should be selected to land) is based on the country passenger is flying. Not only arrival and departure passengers, transfer passengers also consider facilities and geographic location before their choice. Facilities must be adequate for fulfilling all passenger expectation.

"Nature of the Airport" is the fourth factor to be considered. Investigation of current capacity of the airport and its performances is highly depended to be an airport city. Not only current capacity, evaluating potential or productivity of the airport must be concerned. Then it is easy to build up achievable targets. "Access modes" is fifth factor to be considered and it will affect for the passenger perception of the airport and the country. If passenger had negative impression towards airport accessibility, they will think twice before placing tickets. Passenger values his or her time because time is very expensive in modern world.

"Business Management" is a sixth factor and it refers the laws and regulation about city airport. After identify the feasibility for being an airport city it should be developed management concept. Investment opportunities are highly affected for the non-aeronautical activities and there should be free trade zones to encourage suppliers. Reducing taxes will be a positive strategy to attract customers. The lease important criterion is "Technology". Although technology is influenced to all the operations, respondent of the pair wise comparison selected it as a lease factor with compared to others. Technology must be advanced and flexible to any user to operate.

4. Conclusion

Selection of key factors to be an airport city is very much applicable in Sri Lankan context since it is the new market concept of aviation industry. Identify the criteria from literature was the foundation for this research and it is identified eighteen factors by using comprehensive literature survey. Aviation industry experts helped to grouping these criteria and decision makers had to deal with subjective perceptions. Then eighteen factors were reduced to seven and finally there were only seven factors for this research.

Multi criteria decision making with AHP approach was effective and helpful to reduce uncertainty in the assigning relative weight for different criteria. Key finding of the research can be summarized as follows.

- Non aeronautical activities have been identified as the most important criteria through AHP analysis. Therefore BIA must provide facilities to increase airport non aeronautical revenue to become airport city. In year 2014, non aeronautical revenue accounts 75% of company revenue structure (AASL , 2014) and also Number one Duty Free sales in South Asian Market (Airport Economics Manual, 2013). It is necessary to take prioritized actions to develop non aeronautical revenue sources like logistics park, hotels, conference buildings and so on.

- Geographic location and Demand were second and third criteria respectively. Those two are depended since both affect to customers destination choice. BIA is situated in growing South Asian markets like China and India. Tourist travel packages are important to attract passengers and compete with the market as an aerotropolis.

- Nature of the airport is fourth factor and it is essential to evaluate airport performances to introduce airport city concept to Sri Lanka. BIA is medium size airport and it has 10 million terminal capacity. Level of service should be increased up to the standard levels to facilitate the best service.

- Access modes, Business management and Technology are the other factors to be considered. In Airport city fast movements of passenger, cargo and the information are crucial. By giving priorities to access modes, business management and technology, it could be well facilitate fast movements.

References

Airport and Aviation Services (Sri Lanka) Ltd (2013), Annual Report, Airport and Aviation Services (Sri Lanka) Ltd, Sri Lanka.

Airport and Aviation Services (Sri Lanka) Ltd (2014), Annual Report, Airport and Aviation Services (Sri Lanka) Ltd, Sri Lanka.

Airport cities have the potential to deliver value to all aviation stakeholders, Available at: http://www.iata.org [Accessed: 08 December 2015].

Bahurmoz, A.M.A. (2006), 'The Analytical Hierarchy process: A methodology for win management', *JKAU: Economic and Administration*, Volume. 20, No.1, pp.3-16.

Chang, Y., Cheng, C. H., (2003) Performance evaluation of International Airports in the region of East Asia, pp 213- 230.

Derudder, B., Devriendt, L., Witlox, F., (2010) Ghent University, SEG Social and Economic Geography, Krijgslaan 281 (S8) , 9000 Ghent, Belgium.

Drob, M., De Jong, B., (2007) Planning airports in an era of glocalisation : A spatial economic and institutional comparison between Amsterdam Airport Shiphol (AMS) and Munich Airport International (MUC).

Gi T. Y., Wang, Y., Chou, C.C. (2003) Evaluating the competitiveness of the aerotropolises in East Asia. Department of Shipping Technology, National Kaohsung Marine University, Kaohiung 80543, Taiwan.

Haq , R., (2010) The Far East's Top ten Air Cargo Hubs, Available at : http://www.arabiansupplychain.com [Accessed : 13 December 2015].

Hygo, H., Braga, F., Silva, J., Moreira, T., (2010) A logistics study of the Brazilian airport Model and Its Employment at the Tancredo Neves International Airport. African Journal of Business Management Vol. 5, pp 7165-7170.

Kasarda, D. (2006) Airport Cities and the Aerotropolis, Available at: http:// www.aerotropolis.com [Accessed: 10 December 2015].

Kasarda, D. (2008) Shopping in the Airport City and Aerotropolis, Research Review, Vol, 15. p50, 56.

Kasarda, D. (2008) The Evolution of Airport Cities and the Aerotropolis, London.

Kasarda, S. J. and Appold, D. J. (2011) Seeding growth at airports and airport cities: Insights from the two-sided market literature. Research in Transportation Business & Management. p91, 100, Available at: http://www.elsevier.com [Accessed: 16 December 2013].

Kevin, B., (2008) How Airlines work, Available at : http:// www.awpagesociety.com [Accessed : 24 December 2015].

Kong, F., and Liu, H., (2005) Applying Fuzzy Analytic Hierarchy process to evaluate success factors of e commerce

TAM, M. L., TAM, M. L., William, H.K. L., (2005). An analysis of airport access mode choice – A case study in Hong Kong.

Tobias G., Rothlauf, F., Heinzl, A., (2007) Gravity models for airline passenger volume estimation.

Doganis, R., (1992) Airport Business. Ed.1. Routledge. P.204.

Saaty, R. W., (1980) The analytic hierarchy process. Vol.9. McGraw Hill. New York, p 161-176.
Stevens, N. J. (2006) City Airports to Airport Cities, Available at: http:// www. eprints.qut.edu.au [Accessed: 10 December 2015].
Vahidnia, M.H., Alesheikh, A., Alimohammadi, A. B., (2008) Fuzzy Analytical Hierarchy Process in GIS Application.
Wang, K. J. and Hong, W. C. (2010) Competitive advantage analysis and strategy formulation of airport city development – The case of Taiwan. Available at: http://www.elsevier.com [Accessed: 16 December 2015].
Witlox, F. and Devriendt (2009) A spatial analysis of multiple airport cities, Journal of Transport Geography, p345, 353.
Xia, Z. Y., and Li, P., (2011) Strategic development trend and key factors analysis of Airport City in Taiwan. Journal of Transport Geography.

Appendix 1 : Literature Table

No	Criteria	Description	Research Title	Author (Year)
01	Geographic Location	Land Use – Competition between airport and surrounding airport areas	City Airports to Airport Cities	Steve, Nicholas J. (2006)
		Air Routes Regional Planning	A spatial analysis of multiple airport cities	Ben Derudder, Lomme Devriendt, Frank Witlox (2010)
		Global Accessibility: The global network of air transportation overcome geographic barriers, and accessibility to such is most preferred by multi-national corporations (MCNs)	Competitive advantages analysis and Strategy formulation of Airport city development – the case of Taiwan	Kung Jeng Wang, Wang Chung Hong (2011)
02	Attractiveness	Spatial economic position	Planning airports in an era of glocalisation : A spatial economic and institutional comparison between Amsterdam Airport Shiphol (AMS) and Munich Airport International (MUC)	Michael Drob, Bart de Jong (2007)
		Business model of the airport (Aeronautical and non-aeronautical revenue sources)	Seeding growth at airports and airport cities : Insights from the two sided market literature	Stephen J. Appold, John D. Kasarda (2011)
		Trend for developing multi-functional airport (Tourist Destinations, Commercial Destinations, Industrial activities) & Market efficiency	Competitive advantages analysis and Strategy formulation of Airport city development – the case of Taiwan	Kung Jeng Wang, Wang Chung Hong (2011)
03	Aviation Policy of the country	Decision making and Jurisdictions	City Airports to Airport Cities	Steve, Nicholas J. (2006)
		Create new non-aeronautical revenue sources	Shopping in the Airport City and Aerotropolis New Retail Destinations in the Aviation Century	John D. Kasarda (2008)
04	Nature of the Airport	Spatial economic position as transfer passengers	Planning airports in an era of glocalisation : A spatial economic and institutional comparison between Amsterdam Airport Shiphol (AMS) and Munich Airport International (MUC)	Michael Drob, Bart de Jong (2007)
		New management and Investment opportunities	Shopping in the Airport City and Aerotropolis New Retail Destinations in the Aviation Century	John D. Kasarda (2008)
		Airport Services and Its Ownership	Airport Business	Rigas Doganis (1992)

05	Traffic	OD Pax/ Airport Users/ Airlines (International, Flag Carrier, Full Service/ LCC/ Efficient and Regular Services/ Competitive Prices/ More Frequencies) Identify the niche market by considering Income, frequency of service, travel time ratio, employment, economy fare	A spatial analysis of multiple airport cities Gravity models for airline passenger volume estimation	Ben Derudder, Lomme Devriendt, Frank Witlox (2010) Tobias Grosche, Franz Rothlauf, Armin Heinzl (2007)
06	Infrastructure (Air side & Land Side)/ Land Use and Cost & Facilities available at airport	The Competitive advantage of any city rests on a well-planned physical and commercial infrastructure Complete local infrastructure and Transport network	City Airports to Airport Cities Competitive advantages analysis and Strategy formulation of Airport city development – the case of Taiwan	Steve, Nicholas J. (2006) Kung Jeng Wang, Wang Chung Hong (2011)
07	Level of Service	Efficiency of Services	Airport Business	Rigas Doganis (1992)
08	Logistics and JIT Manufacturing	With the airport itself serving as a region wide multimodal transportation and commercial nexus, strings, and clusters of airport linked shopping centers, business parks, information and communication technology complexes, industrial parks, logistics parks, wholesale merchandise marts and mixed used developments are forming along airport arteries up to 20 miles outward.	Shopping in the Airport City and Aerotropolis New Retail Destinations in the Aviation Century	John D. Kasarda (2008)
09	Free Trade Zones (FTZ)	Commercial Investments/ Reduce Taxes, cut red tape, boost exports/ Country Economy Patterns of ownership of operations To attract companies, to have tax free incentives when importing the components, FTZ is themechanism	City Airports to Airport Cities Airport Business A logistics study of the Brazilian airport Model and Its Employment at the Tancredo Neves International Airport	Steve, Nicholas J. (2006) Rigas Doganis (1992) Tadeu Hygo Ferreira Braga , Silva Jersone Tasso Moreira (2010)
10	Flexible & Advanced Technology	Technological preeminence : air transportation relies much on hi-technology support, which play key role in passenger and cargo flow, airport facilities and the environment	Competitive advantages analysis and Strategy formulation of Airport city development – the case of Taiwan	Kung Jeng Wang, Wang Chung Hong (2011)
11	Intermodal Freight Hub	Brings together air, rail, highways, ports	Airport Business	Rigas Doganis (1992)
12	Related and supporting industries	Industrial Cluster: Industries oriented towards, related to or dependent on airport operation and air transportation tend to cluster within the airport city	Competitive advantages analysis and Strategy formulation of Airport city development – the case of Taiwan Study on Airport Economy	Kung Jeng Wang, Wang Chung Hong (2011)

	Office Parks and Office Corridors Exhibition and Conference Centers Hotels , entertainment, retail clusters Medical and wellness cluster Academic and Research Cluster	Connect air travel-intensive executives and professionals quickly to distant markets Trade and knowledge exchange magnets Serve long distance travelers and local needs Medical Tourism and healthcare provision Executive's education and research centers Airport Revenue Sources The formation of urban centers around the airports, offering multivariable services and increasing the creation of jobs in the airport region. These centers can be expanded in a ratio of up to 20km around the airport.	Airport Business A logistics study of the Brazilian airport Model and Its Employment at the Tancredo Neves International Airport	Z. Y. Xia and P. Li (2006) Rigas Doganis (1992) Tadeu Hygo Ferreira Braga , Silva Jersone Tasso Moreira (2010)
13	Mixed Used Residential Areas	Airport employee needs incidental service like housing, recreation, food services, retail, health, child day care and so on.	Shopping in the Airport City and Aerotropolis New Retail Destinations in the Aviation Century	John D. Kasarda (2008)
14	Local and Global Interests	Regional Planning Evolving airport edge cities, together with substantial other airport centric commercial development are giving rise to a new urban form.	A spatial analysis of multiple airport cities Shopping in the Airport City and Aerotropolis New Retail Destinations in the Aviation Century	Ben Derudder, Lomme Devriendt, Frank Witlox (2010) John D. Kasarda (2008)
15	Airport Access Modes	Clustering of developments at the airport territory Transport network (Trains, expressways, busses, taxis) Airport expressways serving as a catalyst and magnet for airport linked business development Dedicated expressway links (Aerolanes) and high speed rail (Aerotrains)	Planning airports in an era of glocalisation : A spatial economic and institutional comparison between Amsterdam Airport Shiphol (AMS) and Munich Airport International (MUC) Competitive advantages analysis and Strategy formulation of Airport city development – the case of Taiwan Shopping in the Airport City and Aerotropolis New Retail Destinations in the Aviation Century Airport Cities and the Aerotropolis	Michael Drob, Bart de Jong (2007) Kung Jeng Wang, Wang Chung Hong (2011) John D. Kasarda (2008) John D. Kasarda (2006)

		Expectation and perception of the passenger matters for the choice of access mode	An analysis of airport access mode choice – A case study in Hong Kong	Mei Ling TAM, Mei Lam TAM, William H.K. LAM (2005)
16	Land Supply	Land owner and municipalities play a controlling rule when it comes to land policy. Space for Future development	Planning airports in an era of glocalisation : A spatial economic and institutional comparison between Amsterdam Airport Shiphol (AMS) and Munich Airport International (MUC)	Michael Drob, Bart de Jong (2007)
17	Land Availability	Commercial sector pursuit of affordable, accessible land	Shopping in the Airport City and Aerotropolis New Retail Destinations in the Aviation Century	John D. Kasarda (2008)
18	Performance of the airport	Evaluation is based on supply, Airline demand, passenger demand, management side	Performance evaluation of International Airports in the region of East Asia	Daniel L. Stuffle Beam (2000)

Appendix 2: Questionnaire Form

		Extremely Important		Very Important		Important		Slightly Important		Equally Important		Slightly Important		Important		Very Important		Extremely Important	
	Criteria	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	**Criteria**
1	Geographic Location		x																Demand
2	Geographic Location	x																	Technology
3	Geographic Location		x																Nature of the Airport
4	Geographic Location															x			Non Aeronautical activity Centers
5	Geographic Location							x											Business Management
6	Geographic Location					x													Access Modes
7	Demand		x																Technology
8	Demand	x																	Nature of the Airport
9	Demand									x									Non Aeronautical activity Centers
10	Demand				x														Business Management
11	Demand													x					Access Modes
12	Technology												x						Nature of the Airport
13	Technology															x			Non Aeronautical activity Centers
14	Technology												x						Business Management
15	Technology																x		Access Modes
16	Nature of the Airport									x									Non Aeronautical activity Centers
17	Nature of the Airport				x														Business Management
18	Nature of the Airport	x																	Access Modes
19	Non Aeronautical activity Centers	x																	Business Management
20	Non Aeronautical activity Centers	x																	Access Modes
21	Business Management	x																	Access Modes

How LCC Affects the Market Structure of Taiwan International Air Transportation

*Tien-Chun Ho and Jin-Ru Yen**

Department of Shipping and Transportation Management, National Taiwan Ocean University, Keelung, Taiwan. Email: jinruyen@gmail.com

**Corresponding author*

Abstract

In 2015, the volume of passengers reached about forty million at Taoyuan International Airport (TPE). All of them are international passengers, and this makes TPE's international air transport position more important. Additionally, low-cost carriers (LCCs) have been actively built aviation network in surrounding countries such as Malaysia, Thailand, Vietnam, Japan, South Korea and Philippines. The rapid development of LCCs has changed airline industries and market structure significantly worldwide. The market share of LCCs at TPE is about 7% in 2014, compared to an average of above 20% in North America, Europe, and Southeast Asia. It is, however, interesting to know whether or not LCCs affect Taiwan's market structure of air transportation. This study uses Concentration Ratio and Herfindahl-Hirschman Index to investigate the international air transport market concentration and competition at TPE. The research shows that Tokyo route has the lowest market concentration and the highest market competition in 2014. In general, though the market penetration rate is less than 10%, the rapid development of LCCs has reduced market concentration and enhanced competition in Taiwan's international air transportation market.

Keywords: international air transport, market structure, concentration ratio, Herfindahl-Hirschman Index

1. Introduction

As an island nation, Taiwan must rely on sea and air transportation for her international transport. This paper focuses on air passenger transportation and investigates the market structure of the Taiwan Taoyuan International Airport (TPE). As the major international airport, TPE dominates the international air transportation of Taiwan, with about 85% of passengers from/to Taiwan using TPE. Additionally, all passengers using TPE are international travelers. According to the 2014 statistics of Airport Council International (ACI), in addition to an increase in flight movements and cargo growth of 7.53% and 6.18% respectively, TPE's passenger growth rate (11.15%) is the greatest in Asia, surpassing Narita, Incheon, Hong Kong, and Changi. TPE's latest statistics show that in 2015 the number of entry, exit, and transit passengers increased to about 38,473,333 people, and the forecast for 2016 is more than forty million.

The statistics of international passengers at TPE include passengers in direct cross-strait flights that have taken place since December 15, 2008. Since the cross-strait routes are an oligopoly market under a bilateral cross-strait economic cooperation framework agreement signed by the governments of China and Taiwan, they are therefore highly regulated, subject to political factors. The direct cross-strait air services only open to national airlines from both sides. Due to lack of competitiveness, these routes are therefore not within the scope of this study. Based on various criteria such as the number of airlines, flights, seats, and passengers on each route, the top ten international air transport routes of TPE are chosen. The two commonly used indices, Concentration Ratio (CR) and Herfindahl-Hisrschman Index (HHI), are employed to define the competition in each route. Data from 2010 to 2014 are used to investigate the impact of LCC developments on the market structure of TPE international route.

The remainder of this paper is organized as follows. Section 2 reviews the related literature on air transport market structure and provides a comprehensive appraisal of each. Section 3 describes the research methods.

Section 4 is an empirical analysis of the air transport market structure of TPE. Finally, some conclusions and recommendations are presented in section 5.

2. Literature Review

Market structure, also called industrial structure, describes the specific characteristics of a specific market, especially the level of competition. In general, because of the relative high entry threshold of the air transport industry, it is difficult to break an oligopoly market or to expect the market to develop a self-correcting repair mechanism. Before the entry of the LCCs into the air transport industry, traditional airline could instead avoid a bloody fare war, preserving the value of its own scarce resources by transferring its own capacity on those routes that cannot be served by LCCs (Jarach, 2004). It is difficult to expect them to develop competitive mechanisms to enhance market efficiency and the interests of travelers. Subsequently, Alderighi *et al*. (2012) found that competition with LCCs reduced both the business and leisure fares of traditional airlines. Zhang *et al.* (2013) suggested that an airport's position in carriers' hub hierarchies, competition from LCCs, and other market structure variables influence average airfares. Thus, when the market is perfectly competitive, airfares will only cover the airlines' operating costs, leaving airlines with zero profit. However, if airlines have market power, they enjoy positive profits (Ha *et al*., 2013).

Passengers consider many factors when they select an airline. The number of seats available, brand, and corporate reputation are considered the critical determining factors (Pearson *et al*., 2015). In practice, when passengers make boarding and ticketing decisions, the airline's low fares and the availability of frequent flier programs are major considerations (Proussaloglou and Koppleman, 1995). However, in terms of the flight punctuality, flight frequency and flexibility in using tickets, there is no significant difference between LCCs and traditional airlines (Mason, 2001). Therefore, when traditional airlines and LCCs coexist in an aviation market, LCC may gradually replace the traditional airlines because of their economic fares.

This study employs the Market Concentration Ration (CR) and the Herfindahl-Hirschman Index (HHI) to investigate the influence of LCCs on the market structure of various routes associated with TPE. The market concentration index (Concentration Ratio, CR) is used as a basis to define the degree of market competition. From the level of competition, we can effectively evaluate the operator's monopoly power in the industry. CR can only consider the small number of airlines with a high market share, while ignoring other airlines on the route. The Herfindahl-Hirschman Index (HHI) can divide the market structure based on the degree of concentration into a high, moderate or low degree of competition, and thus can effectively differentiate the degree of competition in the international air transport market of TPE.

CR and HHI have been used in numerous studies related to air transport industry in recent years. Lijesen *et al*. (2002) applied CR to assess the degree of market competition on routes between London and Paris, London and New York as well as other international routes. Pitfield (2007) used relevant operational data from members of the Airlines Alliance from 1990 to 2003 for market structure analysis and volume forecasts on routes from major international airports in the United States to Frankfurt and Paris to assess the future development of the Alliance. Detzen *et al*. (2012) applied HHI to assess the impact of the rise of LCCs on the existing structure of the aviation market. Németh and Niemeier (2012) analyzed the level of supply and demand as the European Aeronautic merger progressed from 1996 to 2009, and used HHI to assess the differences in the structure of the aviation market before and after the merger. Obermeyer *et al*. (2013) used HHI to verify the relationship of airfares and market structure.

3. Research Methods

3.1 Concentration Ratio (CR)

In industrial economics, the level of industrial concentration represents the magnitude of monopoly power of large enterprises and their impact on the industry and even on overall economy (Chen and Lin, 1997). CR calculates the total market share of some enterprises with the higher ranking of market share. In aviation industry, for example, greater CR in a specific route, defined as a market, means greater ability that top airlines can use to manipulate airfares in the specific route. The formulation of calculating CR is shown in equation (1).

$$CR_n = \sum_{i=1}^{n} Si \qquad (1)$$

where n : the number of airlines with higher market share,
Si : the market share of the i-th airline.

Samuelson and Nordhaus (1985) divided CR into four groups: a CR greater than or equal to 0.79 is highly concentrated; a CR greater than or equal to 0.33 but less than 0.79 is moderately concentrated; a CR greater than or equal to 0.18 but less than 0.33 is considered low concentration; a CR greater than 0.01 but less than 0.18 is a perfectly competitive market. In this study, for each selected route CR_1, CR_2, CR_3, and CR_4 are used to investigate the level of market concentration on each route.

3.2 Herfindahl-Hirschman Index

The Herfindahl-Hirschman Index (HHI) refers to the sum of the individual market share of all the participants in a particular market. Miller (1982) considers the Herfindahl Index the most important and most common measure of the degree of market competition — the lower the index, the higher the degree of market competition. In a perfectly competitive market, the HHI would be close to zero. It is calculated using formula (2).

$$HHI = \sum_{i=1}^{N} (S_i)^2 \qquad (2)$$

where: i the i-th airline in the market,
N: the number of airlines in the market,
S_i: the market share of the i-th airline.

The Department of Justice and Federal Trade Commission of US have used HHI to represent the degree of market competition. HHI has also been used as a criterion to assess whether or not to use Anti-Trust Law to intervene in the market (Austin, 1988). If HHI is equal to 0.1 or less, the market is considered as highly competitive. With an HHI between 0.1 and 0.18, the market concentration is considered as average. If HHI is greater than 0.18, the market is considered as highly concentrated with low degree of competition.

4. Empirical Analysis

4.1 Current international air transportation market at TPE

International flight movements at TPE reached 180,160 in 2014, with the total number of seats being about 46,042,958, and carrying 35,804,465 passengers (CAA, 2015). The statistics of TPE’s top ten international air passenger routes is shown in Table 1, including the number of airlines serving each route, number of flights, number of seats, and number of passengers. As listed in Table 1, in terms of available seats and passengers, the top three international routes were Hong Kong, Tokyo and Osaka, with the number of available seats being 9,091,064, 2,770,384 and 2,563,153, respectively, and carrying 6,722,957, 2,231,370 and 1,985,095 passengers. This was followed by Incheon, Singapore, Bangkok, Macau, Kuala Lumpur, Manila and Ho Chi Minh City. The annual number of flights on the top ten routes is 92,893, providing 24,538,253 seats, and carrying 18,701,411 passengers, which accounts for 51.56% of TPE’s flights, 53.29% available seats, and 52.23% passengers.

Table 1: Statistics of TPE’s top ten routes in 2014

Routes	Airlines (%)	Flights (%)	Seats (%)	Passenger (%)
Hong Kong	5 (8.62)	29,867 (32.15)	9,091,064 (37.05)	6,722,957 (35.95)

Tokyo (NRT)	9 (15.51)	10,538 (11.34)	2,770,384 (11.29)	2,231,370 (11.93)
Osaka	7 (12.07)	12,958 (13.95)	2,563,153 (10.45)	1,985,095 (10.61)
Incheon	7 (12.07)	6,592 (7.10)	1,818,532 (7.41)	1,587,075 (8.49)
Singapore	7 (12.07)	7,177 (7.73)	1,925,737 (7.85)	1,578,425 (8.44)
Bangkok	6 (10.34)	5,980 (6.44)	1,742,645 (7.10)	1,178,742 (6.30)
Macao	4 (6.90)	7,558 (8.14)	1,407,873 (5.74)	1,019,253 (5.45)
Kuala Lumpur	4 (6.90)	4,268 (4.59)	1,157,156 (4.71)	895,763 (4.79)
Manila	5 (8.62)	4,372 (4.70)	1,067,371 (4.35)	772,131 (4.13)
Ho Chi Minh	4 (6.90)	3,583 (3.86)	994,338 (4.05)	730,600 (3.91)
Total	58 (100.00)	92,893 (100.00)	24,538,253 (100.00)	18,701,411 (100.00)

Notes: The number of flights, seats and passenger are indicated by year.

The load factors of TPE's top ten routes in 2014 are shown in Table 2. As apparent from Table 2, the average load factor of the Incheon route was the greatest (87.27%), followed sequentially by Singapore (81.48%), Tokyo (80.54%), Osaka (77.45%), Kuala Lumpur (77.41%), Hong Kong (73.95%), Ho Chi Minh City (73.48%), Manila (72.34%), Macau (72.28%), and Bangkok (67.64%). All airlines serving TPE-Incheon have a load factor greater than 80%, with China Airlines being 90.59%, Eva Airways (90.94%), Cathay Pacific (81.83%), Scoot Airlines (93.18%), Korean Air (82.74%), and Asiana Airways (82.72%). In aspect of load factor by airline, most of LCCs serving among all top ten routes had been exceed the average load factor of their respective route, with Vanilla Air (87.63%) on Tokyo route (80.54%), Jetstar Asia (82.38%) and Peach Aviation (83.91%) on Osaka route (77.45%), Scoot Airlines (93.18%) on Incheon route (87.27%), Jetstar Asia (83.90%), Scoot Airlines (83.08%), Tiger Airways (89.32%) and TigerAir (82.68%) on Singapore route (81.48%), TigerAir (82.70%) on Macao route (72.28%) and AirAsia Airlines (81.32%) on Kuala Lumpur (77.41%). As Vowles (2006) stated the route structure and competition between carriers (especially from LCCs) play prominent roles in determining airfares in hub-to-hub markets, the market structure and the level of competition of TPE has become increasingly competitive due to the entry of LCCs into the air transport industry.

Table 2: Load factors of top ten routes from TPE in 2014

Routes	Airlines	Load factor by airline (%)	Average load factor (%)
Hong Kong	Eva Airways (BR)	82.03	73.95
	Hong Kong Airlines (HX)	79.75	
	China Airlines (CI)	77.51	
	Cathay Pacific Airways (CX)	73.01	
	Dragon Airlines (KA)	67.45	
Tokyo (NRT)	All Nippon Airways (NH)	89.36	80.54
	Japan Airlines (JL)	87.86	
	Vanilla Air (JW)	87.63	
	Eva Airways (BR)	85.64	
	Scoot Airlines (TZ)	80.40	
	China Airlines (CI)	79.63	
	Cathay Pacific Airways (CX)	77.75	
	TransAsia Airways (GE)	68.65	
	Delta Airlines (DL)	64.59	
Osaka	Eva Airways (BR)	84.78	77.45
	Peach Aviation (MM)	83.91	
	Jetstar Asia (3K)	82.38	
	Japan Airlines (JL)	77.75	
	Cathay Pacific Airways (CX)	75.65	
	China Airlines (CI)	73.83	
	TransAsia Airways (GE)	71.52	
Incheon	Scoot Airlines (TZ)	93.18	87.27
	Eva Airways (BR)	90.94	
	China Airlines (CI)	90.59	

	Thai Airways (TG)	84.67	
	Korean Air (KE)	82.74	
	Asiana Airways (OZ)	82.72	
	Cathay Pacific Airways (CX)	81.83	
Singapore	Tiger Airways (TR)	89.32	81.48
	Eva Airways (BR)	84.45	
	Jetstar Asia (3K)	83.90	
	Scoot Airlines (TZ)	83.08	
	TigerAir (IT)	82.68	
	Singapore Airlines (SQ)	79.73	
	China Airlines (CI)	76.67	
Bangkok	China Airlines (CI)	74.81	67.64
	V Air (ZV)	73.10	
	Thai Airways (TG)	69.29	
	TransAsia Airways (GE)	61.82	
	TigerAir (IT)	60.95	
	Eva Airways (BR)	56.38	
Macao	TigerAir (IT)	82.70	72.28
	Eva Airways (BR)	76.26	
	Air Macao (NX)	72.43	
	TransAsia Airways (GE)	64.19	
Kuala Lumpur	AirAsia Airlines (AK)	81.32	77.41
	Eva Airways (BR)	78.51	
	Malaysian Airlines (MH)	73.62	
	China Airlines (CI)	70.28	
Manila	Eva Airways (BR)	84.49	72.34
	Cebu Pacific Air (5J)	79.57	
	KLM Royal Dutch Airlines (KL)	78.53	
	Philippine Airlines (PR)	71.74	
	China Airlines (CI)	71.29	
Ho Chi Minh	Vietnam Airlines (VN)	78.08	73.48
	Eva Airways (BR)	74.27	
	China Airlines (CI)	71.44	
	Vietjet Air (VJ)	63.20	

Notes: The gray underlay represents LCC.

4.2 Concentration and competition of international air transport

The present research employs CR and HHI to investigate the market competition, or concentration, of TPE's top ten international passenger routes. The index of market concentration is usually based on the sum of the market share of the top four (CR4), top eight (CR8), or top ten (CR10) players, owing to CR being the most commonly used measurement of market competition in the theory of traditional industrial economics (Lin *et al*., 2002). CR1, CR2, CR3, and CR4 are used in this study since the greatest number of airlines among the top ten routes is nine on Tokyo route, which is followed by seven on Osaka, Singapore and Incheon routes, as well as four to six in other routes. The market concentration ration of TPE's main international passenger airline routes are shown in Table 3.

In terms of passengers, Table 3 indicates that Tokyo route has the lowest CR4 (.606), which is followed by Incheon (.678), Osaka (.697), Singapore (.743), Manila (.903), and Bangkok (.990). This order is in inverse to the order based on the number of airlines providing services on each route. That is, more airlines on each route tend to reduce market concentration of the route. Additionally, the present result is comparable to research by Samuelson and Nordhaus (1985), where Tokyo, Osaka, Incheon and Singapore represent a moderate market concentration while the remaining routes are highly concentrated markets.

Table 3: The concentration of main international air transport market in 2014

Route	Airlines	CR1		CR2		CR3		CR4	
		Flight	Passenger	Flight	Passenger	Flight	Passenger	Flight	Passenger
Hong Kong	5	.376	.400	.645	.692	.854	.862	.952	.966
Tokyo	9	.229	.290	.371	.415	.510	.518	.648	.606
Osaka	7	.327	.155	.531	.478	.644	.587	.756	.697
Incheon	7	.224	.168	.405	.345	.583	.518	.731	.678
Singapore	7	.207	.197	.410	.407	.579	.523	.724	.743
Bangkok	6	.365	.422	.616	.633	.865	.894	.985	.990
Macao	4	.376	.462	.746	.787	.996	.996	1.00	1.00
Kuala Lumpur	4	.343	.498	.653	.672	.829	.843	1.00	1.00
Manila	5	.333	.310	.515	.474	.682	.694	.849	.903
Ho Chi Minh	4	.407	.424	.785	.838	.992	.995	1.00	1.00

To further investigate the level of competition in Taiwan's air market, this research also calculates the market share on the ten routes over years 2010 to 2014 to determine the HHI for each route. Market shares are defined on the basis of the number of annual flights and passengers. The results of the analysis are listed in Tables 4 and 5, respectively, which are used to get more information about the impact of LCCs on market structure.

Table 4: 2010-2014 HHI of the top ten routes from TPE by flights

Routes	Airlines	Flights (thousands)					Market share					HHI				
		2010	2011	2012	2013	2014	2010	2011	2012	2013	2014	2010	2011	2012	2013	2014
	CI	8.33	8.86	8.23	8.03	8.03	.330	.332	.284	.264	.269					
	BR	4.73	4.92	5.60	6.23	6.24	.187	.184	.194	.205	.209					
	CX	9.26	10.70	11.31	11.26	11.23	.367	.401	.391	.371	.376					
Hong Kong	KA	2.72	2.22	2.04	1.68	1.44	.108	.083	.070	.055	.048	.29	.31	.28	.26	.27
	HX	--	--	1.77	2.71	2.92	--	--	.061	.089	.098					
	TG	.17	--	--	.48	--	.007	--	--	.016	--					
	VN	.00	--	--	--	--	.000	--	--	--	--					
	CI	2.28	1.90	2.12	2.22	2.42	.247	.270	.267	.262	.229					
	BR	1.38	.94	1.44	1.48	1.49	.150	.133	.182	.175	.142					
	CX	.73	.73	.73	.73	.73	.079	.104	.092	.086	.069					
	GE	--	--	--	.19	.84	--	--	--	.023	.080					
	TZ	--	--	.13	.71	.73	--	--	.016	.084	.069					
Tokyo (NRT)	JL	2.07	1.31	1.46	1.46	1.46	.225	.186	.184	.172	.138	.17	.17	.17	.16	.14
	NH	1.34	.73	.73	.73	.73	.145	.103	.092	.086	.069					
	JW	--	--	--	.02	1.47	--	--	--	.002	.139					
	DL	.64	.73	.73	.71	.68	.070	.103	.092	.084	.065					
	UA	.73	.71	.59	--	--	.079	.101	.075	--	--					
	EG	--	--	--	.22	--	--	--	--	.026	--					
	NW	.05	--	----	--	--	.005	--	--	--	--					
	CI	.80	.97	1.70	1.93	2.65	.196	.216	.263	.202	.204					
	BR	.74	.73	.73	1.10	4.23	.181	.163	.113	.116	.327					
	CX	.73	.73	.73	1.46	.73	.178	.163	.113	.154	.056					
Osaka	3K	.36	.73	1.28	1.33	1.20	.088	.163	.206	.140	.093	.24	.21	.19	.15	.20
	GE	--	--	.37	.76	1.23	--	--	.057	.080	.095					
	JL	1.46	1.32	1.46	1.46	1.46	.357	.295	.226	.154	.113					
	MM	--	--	.19	1.46	1.45	--	--	.029	.154	.112					
	KE	.95	.98	1.22	1.46	1.48	.194	.188	.214	.229	.224					
	CI	.79	.98	1.09	1.18	1.19	.162	.188	.190	.185	.180					
	BR	.75	.82	.91	.94	.98	.154	158	.159	148	.149					
Incheon	TG	.73	.73	.73	.73	.73	.150	.140	.127	.114	.111	.17	.17	.17	.17	.16
	CX	.73	.73	.73	.73	.73	.150	.140	.127	.115	.111					
	TZ	--	--	--	.17	.31	--	--	--	.027	.047					
	OZ	.93	.97	1.05	1.16	1.17	.190	.186	.183	.182	.178					
	CI	.81	1.31	1.51	1.48	1.48	.207	.220	.218	.198	.206					
	BR	.70	.75	.74	.75	.78	.179	.126	.106	.100	.109					
Singapore	3K	.73	.94	1.39	1.35	1.21	.187	.158	.200	.181	.169	.29	.20	.16	.16	.17
	SQ	1.67	1.78	1.56	1.46	1.46	.427	.299	.225	.196	.204					
	TZ	--	--	.18	.88	1.04	--	--	.026	.118	.145					

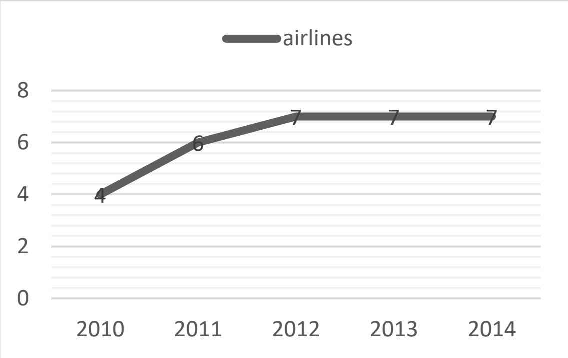
	TR	--	.79	.77	.99	1.01	--	.132	.111	.133	.141					
	IT	--	--	--	--	.19	--	--	--	--	.026					
	GE	--	.39	.79	.55	--	--	.065	.114	.074	--					
Bangkok	CI	2.01	2.03	2.02	2.72	2.18	.323	.357	.413	.414	.365	.24	.28	.33	.30	.27
	BR	1.48	1.47	1.24	1.71	1.50	238	.259	.253	.260	.251					
	TG	1.46	1.45	1.46	1.55	1.49	.235	.255	.299	.236	.249					
	GE	--	--	--	.59	.72	--	--	--	.090	.120					
	IT	--	--	--	--	.06	--	--	--	--	.010					
	ZV	--	--	--	--	.03	--	--	--	--	.005					
	KL	.71	.73	.17	--	--	.114	.129	.035	--	--					
	AK	.00	--	--	--	--	.000	--	--	--	--					
	FD	.55	--	--	--	--	.089	--	--	--	--					
Macao	BR	2.88	2.80	2.63	2.77	2.84	.343	.356	.354	.365	.376	.34	.33	.34	.34	.34
	GE	2.32	2.37	2.10	2.06	1.89	.277	.302	.283	.271	.250					
	NX	3.19	2.69	2.69	2.76	2.79	.380	.342	.363	.364	.370					
	IT	--	--	--	--	.03	--	--	--	--	.004					
Kuala Lumpur	CI	.76	.75	.76	.97	.75	.279	.279	.265	.249	.176	.26	.26	.27	.26	.27
	BR	.49	.45	.44	.62	.73	.179	.167	.153	.159	.171					
	MH	.63	.70	.73	1.11	1.33	.231	.260	.254	.285	.311					
	AK	.85	.79	.94	1.20	1.46	.311	.294	.328	.307	.342					
Manila	CI	1.36	1.45	1.46	1.34	1.45	.401	.393	.344	.309	.332	.20	.28	.23	.22	.22
	BR	.74	.72	.73	.73	.73	.218	.195	.172	.168	.167					
	5J	.56	.73	.76	.74	.80	.165	.198	.179	.171	.183					
	KL	--	--	.56	.73	.73	--	--	.132	.168	.167					
	PR	.73	.79	.74	.80	.66	.216	.214	.173	.184	.151					
Ho Chi Minh	CI	1.44	1.45	1.46	1.46	1.46	.459	.462	.459	.439	.407	.36	.36	.36	.35	.35
	BR	.97	.96	.99	1.06	1.36	.309	.306	.311	.318	.379					
	VN	.73	.73	.73	.81	.74	.232	.232	.230	.243	.206					
	VJ	--	--	--	--	.03	--	--	--	--	.008					

Notes: The Data of AirAsia Japan (EG), Thai AirAsia (FD), Northwest Airways (NW) and United Airlines (UA) do not appear in Table 2.

As indicated in Table 4, the HHIs of seven out of the top ten routes decreased from 2010 to 2014, an indication of increase in market competition. It is worth noting that there was at least one LCC entering each of the seven routes in the period from 2010 to 2014. The HHIs of the other three routes, Bangkok, Macao, Kuala Lumpur, did not decrease. Taking a close look at the data reveals that the number of airlines serving TPE to Bangkok is the same in 2010 and 2014. In the Kuala Lumpur route, the number of airlines is also the same. In addition to the flights, this study used seats and passengers to assess the degree of market competition and found similar results. Therefore, we apply flights to assess the market share and present the results in this paper.

In terms of the airline flights market share, there are seven traditional airlines operating on the Tokyo route, with 79.2% of a total market share, while there are two LCCs, with 20.8% of a total market share. Among these airlines, China Airlines has the highest market share (.229), followed by Eva Airways (.142), Vanilla Air (.139), Japan Airlines (.138), TransAsia (.080), Scoot Airlines (.069), All Nippon Airways (.069), Cathay Pacific (.069), Delta Airlines (.065), and in order. There are 6 traditional airlines operating on the Incheon route, with 95.3% of a total market share, while there is one LCC with 4.7% of a total market share. The Korean Air has the highest market share (.224), followed by Chinese Airlines (.180), Asiana Airways (.178), Eva Airways (.149), Cathay Pacific (.111), Thai Airways (.111), and Scoot Airlines (.047) in order. There are three traditional airlines operating on the Singapore route, with 51.9% of a total market share, while there are four LCCs, with 48.1% of a total share. Among these airlines, China Airlines has the highest market share (.206), followed by Singapore Airlines (.204), Jetstar Asia (.169), Scoot Airlines (.145), Tiger Airways (.141), Eva Airways (.109), and TigerAir (.026) in order. What is worth mentioning is that the last place just began operating in September 2014.

Taking Singapore, Kuala Lumpur and Manila for example, there was only one airline of LCCs for each route in 2010, and their HHI was .29, .26 and .20 respectively. In 2014, there were four airlines of LCCs for Singapore and still one for Kuala Lumpur and Manila, and their HHI was .17 , .27 and .22 respectively. That is, the LCC airlines of Singapore rise from 1 to 4, and the HHI of Singapore drops from .29 to .17, a decrease of approximately 41.38%. On the other hand, the LCC airlines and HHI of Kuala Lumpur and Manila did not change from 2010 to 2014. However, the traditional airlines of Manila rise from 3 to 4, and the HHI of Manila rises from .20 to .22, an increase of approximately 10.00%. This shows that an increase in LCCs has enhanced the competition in Taiwan’s international air transportation market. The changes in the LCC airlines and HHI of Singapore and Kuala Lumpur are shown in Figure 1 to 6.



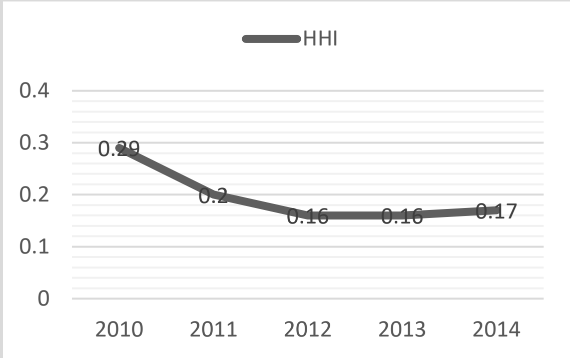
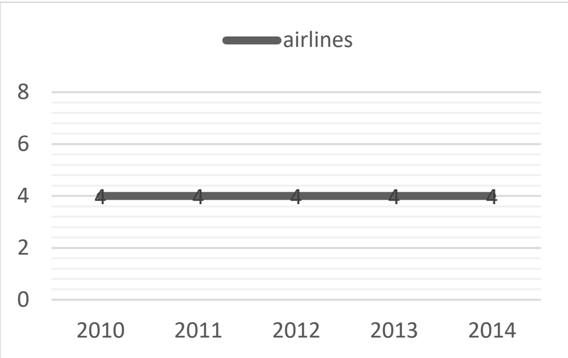


Figure 1: The Airlines of Singapore **Figure 2: The HHI of Singapore**



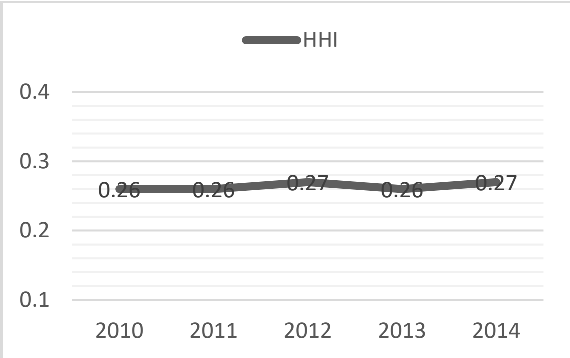


Figure 3: Number of airlines in Kuala Lumpur route **Figure 4: The HHI of Kuala Lumpur route**

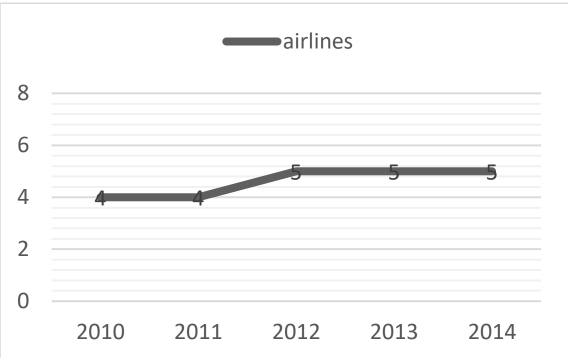


Figure 5: Number of airlines in Manila route **Figure 6: The HHI of Manila route**

In summary, according to the assessment standards of the US Department of Justice and Federal Trade Commission, the Tokyo and Incheon route have shown a moderate level of market concentration for the last five years. For Osaka and Singapore, there are some years of moderate market concentration, while the remaining routes are highly concentrated markets. Relative to Tokyo, the degree of competition on the Incheon, Singapore and Osaka routes is low.

4.3 Management implications

Based on the analysis presented in section 4.2, as for TPE’s international aviation market concentration and competition in 2014, the top three competitive routes are Tokyo, Incheon and Singapore in order. In addition to Taiwanese, Japanese, Singaporean, and South Korean airlines, there are some other countries operating traditional airlines and LCCs at the same time. When it comes to each airline's passenger load factor, Taiwanese airlines provide more choices of flight times on the Osaka, Hong Kong, Manila, and Bangkok routes, so they are the first choice of more passengers due to the higher frequency of flights. On the Incheon, Singapore, Macau and Kuala Lumpur routes, the passenger load rates of the LCCs are higher. Except the Kuala Lumpur route, although the LCCs’ frequency of flights is not as high as the traditional airlines’, their flight fares are 50% to 60% as cheap as the traditional airlines. The LCCs are popular with travelers because of their lower fares and no transferring required. On the Ho Chi Minh City route, since VietJet Air just began operating in December 2014, its impact on the market is not clear based on the current data, despite its advantage of lower flight fares.

Vietnam Airline's load factor is currently higher on this route mainly because it offers Vietnam natives a more competitive fare than Taiwan’s airlines. As to the Tokyo route, because there is little difference in flight fares between LCCs and traditional airlines, along with other factors such as flight safety, the company's reputation, better service quality, and no transferring required travelers from and to the two places still prefer to take Japan’s airlines. As to those traditional airlines not from Taiwan nor from the destination country, since their flight fares are not as competitive as LCCs’, their frequency of flights is not as high as Taiwan’s airlines, and they require travelers to transfer in a third place, their passenger load rates are lower in general. In terms of the market structure from 2010 to 2014, the number of traditional airlines operating on the top ten international routes at TPE dropped from 19 to 18, while that of LCCs increased from 4 to 10. This study find that the operation of LCCs in Taiwan’s international passenger market will change the oligopoly led by traditional airlines and effectively reduce the degree of market concentration, while enhancing the degree of market competition. Furthermore, because of the addition of LCCs to the airline market, the market share of all traditional airlines also tends to decline.

5. Conclusions

As passengers receive an image of different types and nationalities of airline companies, as well as the influence of reputation and fares, their ticket purchase decisions will be different from before. In the aviation market, a route is a market (Jiang *et al*., 2005), and the data above show that most LCCs operating at TPE serve a some number of passengers, which increases the degree of market competition, while decreasing the degree of market concentration at TPE, the results show that Taiwan's market structure has become more competitive. Since no relevant laws and regulations have restricted the development of LCCs, Taiwanese have started two LCCs that began operating in TPE’s aviation market in 2014. If the industry can adopt the LCCs industry business model, its growth potential must not be underestimated. As for the traditional airlines, since the market share of Taiwan’s traditional airlines is falling, this shows the existing situation deserve traditional airlines attention.

References

Alderighi, A. Cento, A. Nijkamp, P., Rietveld. P., 2012. Competition in the European aviation market: the entry of low-cost airlines. J. Air Transp. Manag. 24, 223-233.

Austin, D. V., 1988. The herfindahl-hirschman index: analyzing its effectiveness. Issue in Bank Regulation. 12(1), 28-32.

Chen, J. C., Lin, H. L., 1997. Concentration and its changes in Taiwan industries. Taiwan Economic Review. 25(3), 335-367.

Civil Aeronautics Administration, http://www.caa.gov.tw/big5/content/index01.Asp?sno=1855, retrieved on 07/24/2015.

Detzen, D., Jain, P. K., Likitapiwat, T., Rubin, R. M., 2012. The impact of low cost airline entry on competition, network expansion, and stock valuations. J. Air Transp. Manag. 18(1), 59-63.

Executive Information System, http://recreation.tbroc.bog.tw/asp1/statistics/year/INIT.ASP, retrieved on 07/24/2015.

Ha, H. K., Wan, Y., Yoshida, Y., Zhang, A., 2013. Airline market structure and airport efficiency: evidence from major northeast Asian airports. J. Air Transp. Manag. 33, 32-42.

Jarach, D., 2004. Future scenarios for the European airline industry: a marketing-based perspective,” J. Air Transp. Manag. 9(2), 23-39.

Lin, H. L., Chen, J. C., Chuang, W. B, 2002. Entry, Exit and Market Contestability Evidence from Taiwan's Manufacturing Sector. Taiwan Economic Review. 30(4), 491-530.
Lijesen, M. G., Nijkamp, P., Rietveld, P., 2002. Measuring competition in Civil Aviation. J. Air Transp. Manag. 8(3), 189-197.
Mason, K. J., 2001. Marketing low cost airline services to business travelers. J Air Transp. Manag. 7(1), 47-68.
Miller, R. A., 1982. The herfindahl-hirschman index as a market structure variable and exposition for antitrust practitioners. The Antitrust Bulletin. 27(3), 593-618.
Németh, A., Niemeier, H. M., 2012. Airline mergers in Europe – an overview on the market definition of the EU commission. J. Air Transp. Manag. 22(14), 45-52.
Obermeyer, A., Evangelinos, C., Püschel, R., 2013. Price dispersion and competition in European airline markets. J. Air Transp. Manag. 26, 31-34.
Pearson, J., Pitfield, J., Ryley, T., 2015. Intangible resources of competitive advantage: analysis of 49 Asian airlines across three business models. J. Air Transp. Manag. 47, 179-189.
Pitfield, D. E., 2007. The impact on traffic market shaves and concentration of airline alliances on selected European – US routes. J. Air Transp. Manag. 13(4), 192-202.
Proussaloglou, K., Koppleman, F., 1995. Air carrier demand: analysis of market share determinants, Transportation. 22(4), 371-388.
Samuelson P. A., Nordhaus, W. D., 1985. Economics. McGrw-Hill, INC.
Taiwan Taoyuan International Airport Information, http://www.taoyuan–airport.com/company_ch/NewPassengerQuery, retrieved on 10/12/2015.
Vowles, T. M., 2006. Airfare pricing determinants in hub-to-hub markets. J. Transp Geography. 14 (1), 15-22.
Zhang, S., Derudder, B., Witlox, F., 2013. The impact of hub hierarchy and market competition on airfare pricing in US hub-to-hub markets. J. Air Transp. Manag. 32, 65-70.

Regional Air Transport in Germany and Europe: Scope for Revitalization after Years of Decline?

Sven Maertens

Institute of Air Transport and Airport Research, German Aerospace Center (DLR), Germany
Email: sven.maertens@dlr.de

Abstract

Unlike e.g. low cost air travel, regional aviation is only scarcely featured in the transportation research literature. This paper reflects and discusses the development, connectivity impact, and potential outlook of intra-European regional air services from Germany. First, we employ air transport supply data to illustrate the general decline of this market segment in the past 15 years and resulting connectivity losses for selected airports and regions. Second, we discuss potential drivers behind the observed trend, as well as possible starting points for a revitalization of regional air links, which could – at the same time – also help improving regional connectivity and the utilization (and financials) of small airports. We close the paper with a simple but straightforward exercise to quantify the demand potential for new, nonstop regional air services from Germany based on empirical indirect passenger flow data. From today's perspective, we identify a potential for 313 new routes with a potential for 2.2 million passengers.

Keywords: small regional air transport, regional airports, regional air traffic, air transport demand

1. Introduction

Unlike e.g. long haul or low cost air services, regional air transport is hardly tackled in the transport research literature (Gillen and Hazledine, 2015). This is somehow remarkable as this air transport segment has had to continuously reinvent itself over the past years in response to competitive pressure from e.g. fast-growing low cost carriers (LCC) – and a resulting higher price awareness of the passengers – and new high-speed train links. As a result, many regional airlines have either ceased operations or transformed into cheaper operating platforms for network carriers (Graham, 1997). Average aircraft size has increased, and many of those thinner routes that used to be served at relatively high frequencies by aircraft with less than +/- 50 seats have disappeared. As a result, many regions have lost air transport supply, especially since the odd, low-frequency low cost service, if available at all, does not always make a good substitute in terms of connectivity for business travellers and regional economies.

Against this background, a revitalization of regional air services, if economically feasible, could potentially help enhancing the connectivity of certain regions (and hence serve the cohesion goals and the EC Flightpath 2050 connectivity goal that 90% of journeys within Europe shall be completed, door to door, within 4 hours; see European Commission, 2011) and - at the same time - improve the utilization and regional impact of smaller airports.

The objectives of this paper are three-fold: First, we aim at illustrating the decline of regional air traffic in Germany and Europe and resulting connectivity impacts on selected airports and regions. Second, we discuss potential drivers behind this trend as well as operational and technological pillars that may help overcome this issue. Third, in a case-study approach for the German market, we present a simple but transparent approach to quantify the demand potential for new, nonstop regional air services based on empirical data for indirect passenger flows and on certain assumptions regarding e.g. supply-induced demand generation.

By this, we aim at adding new aspects to the relatively small literature on regional air transport. Previous papers on this market segment dealt e.g. with issues like network types, route choice and/or pricing issues (e.g. Hanlon, 1992; Gillen and Hazledine, 2015), or with the impacts of new (jet) aircraft technologies (Dresner et al, 2002; Brueckner and Pai, 2009, and Fageda and Flores-Fillol, 2012). The latter also assessed the implementation and impact of low cost carrier supply in regional markets. Another string of papers tackled forms of external financing of regional, e.g. under the EU "Public Service Obligation" (PSO) or the US "Essential Air Service" (EAS) schemes. Recent examples are Grubesic and Wei (2013) and Merkert and O'Fee (2016).

2. Development of regional air links in Europe and resulting connectivity impacts

Passenger air transport in Europe, as in most other world regions, is split over four main, archetypal business models (see e.g. Ehmer et al, 2008; Bieger and Wittmer, 2002): scheduled continental and long haul flights by network carriers; holiday flights offered by dedicated leisure carriers on behalf of tour operators; regional air services, usually connecting small(er) airports with the main ones, or providing connections between regions; and low cost services which evoked towards the end of the 20th century following from market deregulation, and which are now aimed both at business, holiday and VFE (visiting friends and relative) travellers.

In pre-deregulation times, most regional flights were served by specialized "niche" carriers, holding permissions for routes that were e.g. not of interest to major carriers. Examples include both independent operators like Eurowings and Crossair (before being sold to Lufthansa and Swiss, respectively), or the likes of Air Anglia, Manx Airlines, Air UK or Proteus Airlines, and subsidiaries of national carriers, such as Lufthansa Cityline, Eurowings (after its sale to Lufthansa), Crossair (after partly taken over by Swissair), Regional Airlines or BA Cityflyer.

Before the rise of the LCC, regional air traffic in Europe had grown well, with the number of weekly departures of 40-60 seater aircraft almost doubling from about 12k in 1993 to about 24k in 2000 (Source: OAG). One reason behind this trend was the emergence of new regional jet aircraft in the 90s (see e.g. Dresner et al, 2002), allowing for faster and quieter regional air transport at competitive unit costs. Existing regional subsidiaries were strengthened or new investments in regional affiliations were undertaken to establish cheap(er) operating platforms (Graham, 1997). From the early 2000s, then, the structure of regional air transport in Europe changed again, as the number of weekly flights operated by 40-60 seaters declined massively from about 26k in 2002 to only 15k in 2009 (Source: OAG). This trend is also illustrated in more detail in Figure 1 which shows the development of yearly intra-European departures by aircraft class from 2000 to 2016. The biggest losers in terms of market shares and absolute traffic volumes were the 1-20 and 21-50 seaters.

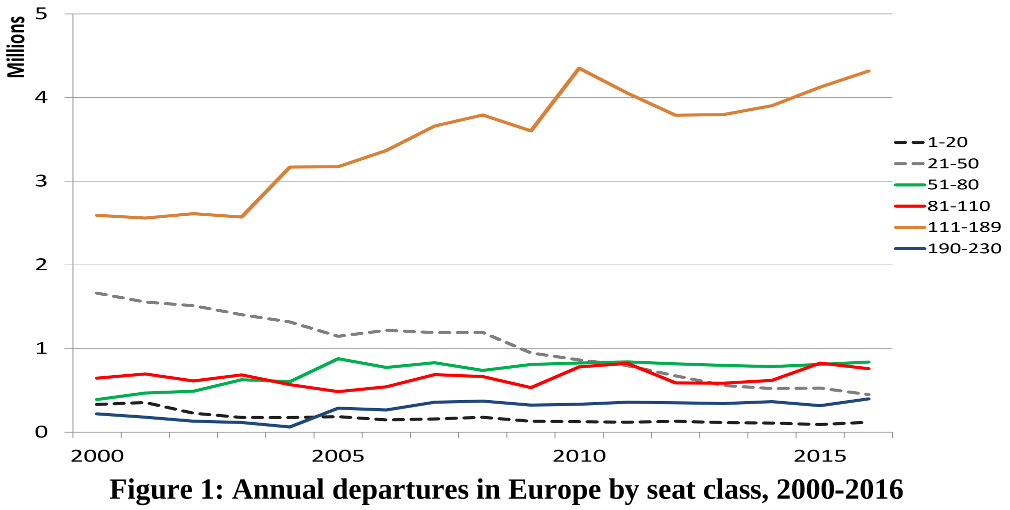


Figure 1: Annual departures in Europe by seat class, 2000-2016
Source: Own figure based on Sabre Market Intelligence data

Business model-wise, one can now differ between…

- contracted (affiliated) operations on behalf of legacy carriers on hub feeder or decentralized routes by either subsidiaries (e.g. Lufthansa Cityline, KLM Cityhopper, Eurowings, Hop!...) or financially independent franchise operators (e.g. BA Cityflyer, Air Nostrum…), and

- own operations of fully independent, mostly small to medium-scale regional airlines (e.g. Flybe, Air Baltic, Cityjet…).

Most of the European regional airline seat capacity is currently represented by affiliated operations (415 aircraft or 62% of the European fleet if only those European regional airlines that are among the global Top100 as reported by Airline Business (2013) are counted), be it on a franchise basis or by subsidiaries, while independent regional networks only account for 256 aircraft and hence about 38% of the European fleet out of the global top 100.

The described trends towards large regional air traffic also mirrors in the manufacturers' fleet forecasts for regional aircraft which are summarized in Table 1. While the forecast values are difficult to compare as different aircraft size classes are applied it is quite obvious that smaller aircraft do not play a major role. Only ATR considers the 40-60 seats segment at all (which comes with no surprise as the ATR42 model is one of the main remaining aircraft being still in production here), and both ATR, Bombardier and Embraer see much more potential for larger regional aircraft. Boeing does not at all differentiate within the group of regional aircraft and only considers jets. Aircraft below 40 seats are not considered in any of the forecasts.

Table 1: Future deliveries of regional aircraft as currently estimated by manufacturers (Own compilation)

Manufacturer	Timeframe	Small a/c	Medium a/c	Large a/c
ATR[i]	2016-2035	40-60 seats: 600	61-80 Seats: 2,200	n/a
Boeing[ii]	2015-2034	Regional Jets: 2,490		
Bombardier[iii]	2015-2034	n/a	60-100 Seats: 5,700	100-150 Seats: 7,000
Embraer[iv]	2016-2035	n/a	70-90 seat jets: 2,300 70+ seats turboprop: 2,040 Total: 2,340	91-130 seat jets: 4,100

The following table shows how the groups of regional hub feeder flights and regional "non-hub" flights have developed between 2000 and 2012. All flights within Europe (EU, NO, CH) with aircraft of less than 120 seats have been considered. Out of these, flights from, to or between the following airports have been classified as hub feeder flights: AMS, BRU, CDG, CPH, FCO, FRA, LHR, LIS, MAD, MUC, VIE, ZRH. The results underline the overall decline of regional air transport and here in particular of the smallest aircraft segments. In relative terms, decentralized routes have declined slightly more than hub feeder routes.

Table 2: Number of annual frequencies by aircraft size and route type (intra-Europe), 2000/2006/2012

0-120 seats			
Year	**Feeder**	**decentralized**	**Total Flights**
2000	110231	169405	279636
2006	100510	140185	240695
2012	81580	114976	196556
Change 2012/2000	-26%	-32%	-30%
0-50 seats			
Year	**Feeder**	**decentralized**	**Total Flights**
2000	43944	105655	149599
2006	33630	76942	110572
2012	17237	53780	71017
Change 2012/2000	-61%	-49%	-53%
51-80 seats			
Year	**Feeder**	**decentralized**	**Total Flights**
2000	14213	23051	37264
2006	25745	32384	58129
2012	23722	37021	60743
Change 2012/2000	67%	61%	63%

Source: OAG

While – at the aggregated, Europe-wide level – we can assume this reduction in regional air services to have been overcompensated by e.g. new low cost services, actual connectivity impacts at the airport and regional levels turn out to be more diverse. In the last 10-15 years, many regions have lost regional air connectivity to other regions – which may probably contradict the above-mentioned EC Flightpath 2050 connectivity goal.

From the early 00's, many regional airports suffering from overcapacities have started to focus on low cost carriers and reduced airport charges, which has in many cases boosted overall capacities and passenger numbers at the airport level, often at the expense of former regional operations. At the route-level, however, LCC-frequencies are usually lower than those of regional airlines (see Table 3), meaning that many daily or double-daily services suited for business travelers have vanished. What is more, at many smaller airports, LCC supply has not really proofed to be sustainable as many former LCC bases have now been abandoned in exchange for larger airports, resulting in a stagnation of capacities at the original, smaller LCC airports (Malighetti et al, 2016).

Table 3: Average number of weekly frequencies by route of selected low cost and regional airlines in 2015

Airline	Type	avg weekly frequency per route, 2015	Airline	Type	avg weekly frequency per route, 2015
Ryanair	*LCC*	*4.1*	Flybe	Regional	7.9
easyJet	*LCC*	*5.9*	LH Cityline	Regional	8.5
Twinjet	Regional	5.9	BA Cityflyer	Regional	9.5
BMI	Regional	6.0	KLM Cityhopper	Regional	16.5
AIS Airline	Regional	6.1	People Vienna Airline	Regional	17.1
Sun Air of Scandinavia	Regional	6.8			

Source: Sabre-ADI

The resulting decline of reliable, regional "business" connections can however have adverse impacts on a region's connectivity and, potentially, its economic development. Also, airport subsidies could become more difficult to justify if declining connectivity levels result in lower catalytic effects for the region. The following figure exemplarily depicts the decline of former high-frequency (daily/double-daily) routes at selected German regional airports. For example, at Nuernberg (NUE), the number of destinations served at least daily / twice daily has plummeted from 20/18 in 2000 to 11/10 in 2014. Similar – or even worse developments can be observed for Bremen (14/12-10/8, BRE), Dresden (12/9-10/5, DRS), Leipzig (13/9-10/9, LEJ), Muenster/Osnabrueck (12/8-5/4, FMO), Dortmund (15/11-9/4, DTM), Paderborn (7/6-2/2, PAD) and Saarbruecken (6/5-4/3, SCN). Berlin Tempelhof was closed down in 2008.

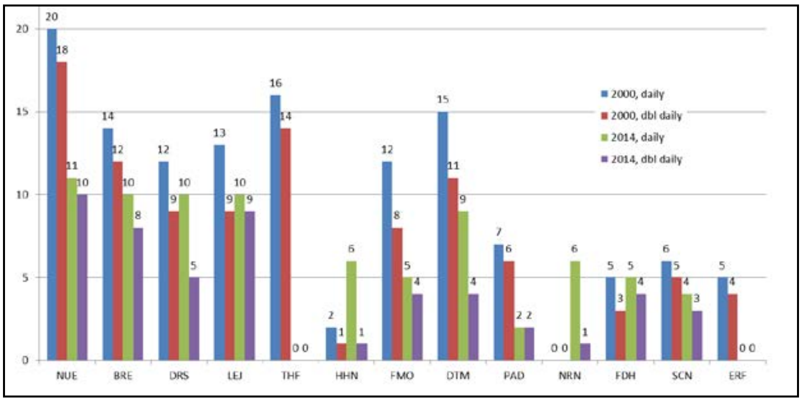


Figure 2: Number of high-frequency destinations by airport, 2000 vs. 2014
Source: Sabre-ADI

3. Reasons behind downfall of regional air traffic and starting points for revitalization

We first identify a number of supply-side, i.e. cost-related drivers behind the increasing use of larger aircraft, which has resulted in the withdrawal of many smaller regional routes. In general, aircraft operating costs grow disproportionately with aircraft size, resulting in decreasing unit costs (see e.g. Swan and Adler, 2006). This does e.g. apply to capital and maintenance cost as major components (cockpit, wings, engines, tail, flaps, gears, etc.) are identical within a given aircraft family, independent from the number of seats. The same applies to fuel cost (aircraft weight usually develops disproportionately with size, e.g. 422kg MTOM per seat for the ATR42 compared to 331kg for the larger ATR72), and to flight deck crew expenses. Finally, at some airports, unit landing fees decline with increasing aircraft size: E.g., at Dusseldorf airport a flat fee of 178 EUR per movement applies to all aircraft between 10 and 40 tons MTOM (Dusseldorf Airport, 2015), which equals to 4.05 EUR per seat for a 44-seat ATR-42 and 1.98 EUR per seat for a 90-seat CRJ 900.

Apart from this, the increased use of larger aircraft even on regional routes might be explained by demand-related and other outside factors. First, given the rise of the low cost carriers, we can assume an increased price awareness of the passengers, making it more difficult for regional carriers to stick to their "small aircraft – high fares" formula. Second, 6-15% of global air traffic is operated in capacity-constrained conditions (Gelhausen et al., 2013), especially in Europe and the US. The obvious way to push passenger numbers at congested airports is to increase average aircraft size, although e.g. Givoni/Rietveld (2009) have shown that aircraft size is more influenced by route characteristics, such as distance, demand and competition, rather than by airport characteristics like the number of runways and the capacity situation. Nevertheless, small regional aircraft (and especially slow(er) turboprops) have almost completely disappeared from the most capacity-constraint airports in Europe.

What is more, regional operations seem to suffer from other adverse operating conditions which do not only occur at the congested hubs but at many, if not most airports: Given the relatively high price level compared to ground transport modes, it is reasonable to assume that regional air services will only be successful if they come up with a competitive advantage, e.g. a significant reduction of total travel time, which also depends on airport access time and airport passenger processing. However, most airports have yet failed to provide time-conscious passengers with real opportunities for quick check-in, security control, boarding and de-boarding processes. Even at small airports, regional flights are often time-consumingly boarded by bus, and check-in deadlines hardly undercut 30 minutes. All this may easily translate a 40min regional flight into a 2-3 hours door-to-door trip, encouraging potential passengers to use alternative transport means instead. In contrast, airports (or better airfields) where short handling times could easily be achieved tend to suffer from insufficient airfield infrastructure, ruling out most commercial air services in the current regulatory regimes.

Bases on these findings, we can derive the following pillars that should be tackled by specific stakeholders – including policy-makers – to re-vitalize the (small) regional air transport market:

- Technological view (vehicle-perspective)

Given the high level of competition and the increased price awareness, bringing down the unit costs of regional air transport can be regarded as a prerequisite for re-vitalizing this segment. New concepts like the Cleansky Green Regional Aircraft are currently under development, aiming at reducing the weight and emissions (and thus major cost drivers) of small regional aircraft (Cleansky, 2015). In the shorter run, existing cost disadvantages of the sector could probably be reduced to some extent by employing the newest generation of fuel-efficient regional aircraft such as the ATR-600 series, which apparently allows for unit costs savings of about 30% compared jet aircraft (ATR, 2014). From a policy-perspective, other, more fundamental innovations regarding the reduction of unit costs in regional air transport are of particular interest. Policies that would e.g. allow for single-crew cockpits, as for instance envisaged by Thales and Embraer (Flightglobal, 2010), or single-engine regional aircraft (which could probably emerge from Pilatus' PC-12) could drive down unit costs considerably.

- Operational view (system-perspective)

While it is not straightforward to re-design existing airports in a way that they would better meet the needs of regional air services (e.g. short access and handling times), policy measures and financial means could e.g. be applied to allow for the creation of terminal and ramp areas dedicated to regional aircraft where e.g. boarding by walk would be allowed. Other measures could allow for an increased use of airfields for commercial scheduled flights. Potential areas of innovation here may e.g. tackle e.g. the terminal airspace level, where e.g. GLS (GBAS) could be implemented instead of more expensive ILS. Other, simpler measures could be joined use and hence financing of airport fire brigades together with nearby communities, or relaxed operational rules for smaller aircraft.

4. Demand potential for new regional services from Germany

We conclude our analysis in assessing the potential demand for new, decentralized regional flights using a simple approach based on origin-destination (OD) demand and segment supply data available from Sabre Market Intelligence for 2015. For each of a total of 7,698 unique ODs within Germany and from Germany to Europe, we assess the passenger number that could be captured by new regional air services as follows, based on a number of assumptions and simplifications (Figure 3).

First, we derive the distance, and the total, nonstop and indirect passenger numbers, respectively, for each OD from Sabre MI's "OD" module. We then retrieve the average weekly number of direct flights (if applicable) for each OD from Sabre MI's "leg" module. On routes with many direct flights, almost all travellers tend to fly nonstop. On other relations, however, all or most OD-demand is only carried indirectly, be it due to the lack of (a sufficient number of) nonstop flights or for other reasons such as inconvenient departure times of the nonstop option(s).

We regard a minimum of 7.7 average weekly direct flights in each direction as pre-requisite for a successful regional air transport operation. This figure is based on an assumed 40 relevant weeks per year (not counting low-demand summer and x-mas periods when regional flights are often cancelled) multiplied by 10 flights per week (double week-daily) divided by 52 weeks. In other words: We assume that all ODs currently served nonstop by existing carriers at an average weekly frequency of 7.7 or more would not be chosen as new regional routes as existing flight supply is already satisfactorily for most travellers. We hence regard the current indirect demand volume on each OD with less than 7.7 average weekly direct flights as potential demand for a new regional air service, provided that the distance remains below 1,500km (862 of all 878 intra-European routes served by regional aircraft from Germany in 2015 remain below this frontier). A (not yet empirically backed) 25%-multiplier is finally applied to our estimate to account for any supply-induced demand.

We finally assume that a minimum of 8 passengers per flight would be required to successfully operate a small regional aircraft, e.g. the 16-seats Jetstream 31(or, in future, a new model of similar size) with a 50% load factor. Consequently, we also do not count all ODs with an estimated demand per flight below 8. As a result, we identify a market potential of 313 new routes from Germany, which could generate an additional 2,264,182 passengers per year. This equals an average 7,233 annual passengers per route or 18 passengers per flight.

2	Route	Dis-tance	Pax nonstop	Paxe Connect	Share nonstop	Freq/ Week	Cap/f light	Relevant annual demand	incl. 25% supply-induced demand	relevant annual demand per flight	relevant annual demand per flight adj (min = 8)
1074	TXLVNO	1108	5378.77	10282	34%	1	76	10282.12	12852.65	32.131625	32.131625
1075	MUCNTE	1012	5526.43	4047	58%	1	125	4047.36	5059.2	12.648	12.648
1076	MUCPOZ	580	5493.44	1086	83%	14	88	0	0	0	0
1077	MUCOPO	2256	2689.76	12993	17%	1	165	0	0	0	0
1078	TXLSVO	1599	5455.38	717	88%	1	256	0	0	0	0
1079	DUSDBV	1310	5420.81	2478	69%	1	145	2478.04	3097.55	7.743875	0
1080	PADBHX	718	5394	94	98%	0	0	93.59	116.9875	0.29246875	0
1081	TXLBLL	446	5364.92	2350	70%	5	50	2350.35	2937.9375	7.34484375	0
1082	TXLGVA	896	2.93	17229	0%	0	0	17228.5	21535.625	53.8390625	53.8390625
1083	HAMLUX	613	2.07	7436	0%	0	0	7436.24	9295.3	23.23825	23.23825
1084	SXFFNC	3284	0	5430	0%	0	0	0	0	0	0
1085	BRETLS	1189	5332.71	6043	47%	4	49	6043.49	7554.3625	18.88590625	18.88590625
1086	FRAKLU	853	0	5353	0%	0	0	5352.77	6690.9625	16.72740625	16.72740625
1087	SXFACE	3444	5211.71	262	95%	0	180	0	0	0	0
1088	HAMINN	719	5202.37	6704	44%	1	144	6703.69	8379.6125	20.94903125	20.94903125
1089	DUSPOZ	706	5199.11	3117	63%	4	88	3117.07	3896.3375	9.74084375	9.74084375
1090	MUCCWL	1139	5192.13	621	89%	1	118	620.54	775.675	1.9391875	0

Figure 3: Market potential calculation (screenshot)

The above assessment shall serve as a very first approach as several aspects have not (yet) been considered, such as the consumers' willingness to pay and resulting achievable fares for (potential) direct regional flights; assumptions for those passenger volumes that would still fly one-stop despite of the introduction of a new, direct regional service; and the actual degree of supply-induced demand at the route level. In this context, our methodology is also not capable of delivering demand estimates for airport-pairs which are currently not served indirectly. We also have not considered both demand and (potential) supply from other airports serving the same origins and destinations.

What is more, we have not (yet) tackled the cost side and hence could not assess if actual aircraft operating costs would be low enough to successfully offer flights on the identified routes. In this context, we have also not considered future/envisaged aircraft technologies and suggested operational enhancements that might – one day – help bring down unit costs to significantly lower levels which could help exploit new markets.

5. Summary and outlook

This paper reflected and discussed the development and potential outlook of intra-European regional air services. We found that…

- Regional air traffic in Europe is a declining sector, especially on decentralized routes.
- Average aircraft size of regional operators has been increased considerably.
- More and more regional air transport links have disappeared, leaving many small(er) airports without any, or with fewer high-frequency (business) routes, contradicting e.g. the EC Flightpath 2050 connectivity goal and reducing catalytic effects for local businesses.

We then identified technological and operational pillars that could help reducing unit costs of small air transport services and hence make them more viable. Examples include policies that would lower regulatory restrictions for smaller airports and small regional air transport movements, or new technologies such as GLS (GBAS) at the airport level.

We finally performed a simple demand estimation to get a first impression of the potential market size for new regional air services in Europe, which builds on existing demand volumes on indirect routings between Germany and Europe derived from Sabre's MI database. Based on a number of assumptions that should be relaxed in future research, we see a potential of 313 new routes from Germany, which could generate an additional 2,264,182 passengers per year, equaling an average 7,233 annual passengers per route or 18 passengers per flight.

References

Airline Business (2013) Regional Airline Rankings. October 2013, pp. 32-33.

ATR (2014) 600 Series. http://www.atraircraft.com/products_app/media/pdf/Brochure-ATR-600-SeriesBD.pdf [retrieved 05 June, 2015].

Bieger, T., Wittmer, A. (2006) Air transport and tourism – Perspectives and challenges for destinations, airlines and governments. Journal of Air Transport Management, 12, pp. 40-46.

Brueckner, J., Pai, V. (2009) Technological innovation in the Airline Industry: the impact of regional jets. International Journal of Industrial Organization, 27, pp. 110-120.

Cleansky (2015) GRA - Green Regional Aircraft. http://www.cleansky.eu/content/page/gra-green-regional-aircraft [retrieved 05 June, 2015].

Dusseldorf Airport (2015) Tariff Regulations 2015. https://www.dus.com/~/media/fdg/dus_com/businesspartner/aviation/entgelte/tariff_regulations_2015_02-02-2015.pdf [retrieved 05 June, 2015].

Dresner, M., Windle, R., Zhou, M. (2002) Regional jet services: supply and demand. Journal of Air Transport Management, 8, pp. 267-273.

Ehmer, H., Berster, P., Bischoff, G., Grimme, W., Grunewald, E., Maertens, S. (2008) Analyses of the European air transport market - Airline Business Models. Study prepared on behalf of the European Commission, DG Energy and Transport, EC contract number: TREN/05/MD/S07.74176, Cologne, http://ec.europa.eu/transport/modes/air/doc/abm_report_2008.pdf [retrieved 14 August, 2016].

European Commission (2011) Flightpath 2050, Europe's Vision for Aviation. http://ec.europa.eu/research/transport/pdf/flightpath2050_final.pdf [retrieved 05 June, 2015].

Fageda, X., Flores-Fillol, R. (2012) Air services on thin routes: regional versus low cost carriers. Regional Science and Urban Economics, 42, pp. 702-714.

Flightglobal (2010) Thales outlines thinking on single-crew cockpits. 7 July 2010, http://www.flightglobal.com/news/articles/thales-outlines-thinking-on-single-crew-cockpits-344156/ [retrieved 05 June, 2015].

Gelhausen, M., Berster, P., Wilken, D. (2013) Do airport capacity constraints have a serious impact on the future development of air traffic? Journal of Air Transport Management, 28, pp. 3-13.

Gillen, D., Hazledine, T. (2015) The Economics and Geography of Regional Airline Services in Six Countries. Journal of Transport Geography, 46, pp. 129-136.

Givoni, M., Rietveld, P. (2009) Airline's choice of aircraft size – Explanations and implications. Transportation Research Part A: Policy and Practice, 43, pp. 500-510.

Graham, B. (1997) Regional airline services in the liberalized European Union single aviation market. Journal of Air Transport Management, 3, pp. 227-238.

Grubesic, T., Wei, F. (2013) Essential air service: a local, geographic market perspective. Journal of Transport Geography, 30, pp. 17-25.

Hanlon, J.P. (1992) Regional air services and airline competition. Tourism Management, 13, 181-195.

Malighetti, P., Paleari, S., Redondi, R. (2016) Base abandonments by low-cost carriers. Journal of Air Transport Management, 55, pp. 234-244.

Merkert, R., O'Fee, B. (2016), Managerial perceptions of incentives for and barriers to competing for regional PSO air service contracts. Transport Policy, 47, pp. 22-33.

Swan, W.M., Adler, N. (2006) Aircraft trip cost parameters: A function of stage length and seat capacity. Transportation research Part E, 42, pp. 105-115.

---

[i] See: http://www.ainonline.com/aviation-news/aerospace/2016-07-11/atr-confident-continued-market-dominance (retrieved 11 August, 2016).

[ii] See: http://www.boeing.com/resources/boeingdotcom/commercial/about-our-market/assets/downloads/Boeing_ Current_ Market_Outlook_2015.pdf (retrieved 11 August, 2016).

[iii] See: http://www.bombardier.com/content/dam/Websites/bombardiercom/supporting-documents/BA/Bombardier-Aerospace-20150614-Commercial-Aircraft-Market-Forecast_2015-34_V13.pdf (retrieved 11 August, 2016)

[iv] See http://www.embraermarketoutlook2016.com/ (retrieved 11 August, 2016).

Choosing Suitable Aircraft for Business Charters in the Cross-Strait Market

Jin-Ru Yen and Chen-Fang Zhong

Department of Shipping and Transportation Management, National Taiwan Ocean University, Keelung, Taiwan. Email: jinruyen@gmail.com

Corresponding author

Abstract

While business aviation in the world has been flourishing, the industry in Taiwan is still in its infancy. Taiwan has a good geographical location and economic background, making her a great potential to develop business aviation industry. However, the uncertainty of the environment generates difficulties in making decisions for operators. How to choose a suitable fleet of business jets is one of the critical issues that face business charters. This study aims to find out the type of aircraft that is suitable for cross-strait market and provide a model to assist the business jet company in aircraft-choosing evaluation. Factors that will be considered include benefits of the business charters and the preference of business travelers. The Multi Criteria Decision Making (MCDM) approach with be employed in the study, with information obtained from interviewing panel experts in the related areas. It is expected that this study will reveal the essential factors that have a bearing on the business charter's decision for aircraft types.

Keywords: Business aviation, Aircraft type, Cross-strait, MCDM

1. Introduction

While business aviation in the world has been booming, the industry in Taiwan is still in its infancy. After the publication of laws and regulations related to business aviation in 2007, the first business jet company was established and the first business aircraft started operating in 2010. The Government is also actively revising the relevant regulations regarding to business aviation. It is expected that the support from government will promote the industries relevant to domestic business aviation and set a higher standard of service in the future.

Bombardier (2013) defined that business jet in a forecast region relative to the growth rate of the millionaire. According to Asia-pacific business jet charter report 2016, historical data for the total number of high-net-worth individuals (HNW) and ultra-high-net-worth (UHNW) is presented thus providing a guideline of the growth and potential market size of charter demand in each country (Asian Sky Group, 2016). There are 356 thousands millionaires in Taiwan and we project a gradual rise of the number in future. As indicated previously, the millionaires are potential clients of business aviation. It means that the business aviation has unlimited potential in Taiwan.

According to Credit Suisse's Global Wealth report in 2016, GDP per capita of Taiwan is USD 22,288, and therefore the average business jets per capita (million) should be 7 (correspond to the curve in Figure 1). The population in Taiwan is 23 million, thus, according to Bombardier's study, the number of business jet in Taiwan should be 161. However, there are only 9 business jets in Taiwan. It means that the development of business aviation in Taiwan is still slow and there is a large room of growth for the industry.

Since the restriction on family visit to China was deregulated in 1987, the direct air link between Taiwan and China in 2008, economic activity and tourism increase ever since. Based on the statistical data of Civil Aeronautics Administration Ministry of Transportation and Communications at the end of 2016, the load factor of Cross-Strait Direct Flight was 78.7%, and there were 10,339,284 people taking airplanes that year, accounting 21.7%. The figures showed the great demand between cross-strait. However, scheduled flight still cannot meet the special needs of business travellers. On the other hand, business aviation with the time flexibility, reliability, privacy and security, will become the future development of Taiwan's aviation industry.

Taiwan has a good geographical location and economic background, making the development of business aviation extremely potential. Due to the immature regulations, political factors, and public unfamiliarity, the development of business aviation is still very slow. This study aims to find out the type of aircraft that is suitable for cross-strait market.

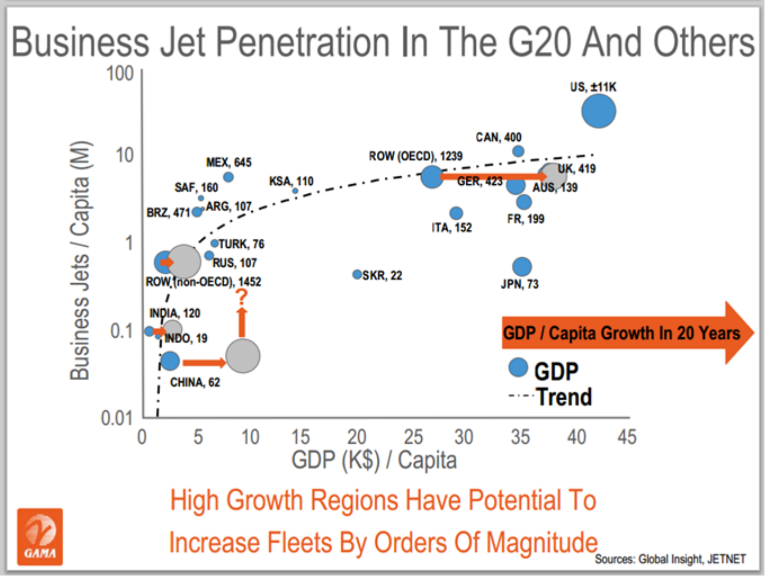


Figure 1: Business Jet Penetration
Source: GAMA (2009)

2. Literature Review

2.1 Business Aviation

- *1st Definition of Business Aviation*

Business aviation is a part of general aviation that can be used for business purposes (National Business Aviation Association, NBAA, 2014). International Business Aviation Council (IBAC) definite the business is sector of aviation which concerns the operation or use of aircraft by companies for the carriage of passengers or goods as an aid to the conduct of their business, flown for purposes generally considered not for public hire and piloted by individuals having, at the minimum, a valid commercial pilot license with an instrument rating.

- *2nd Operation Model of Business aviation*

According to IBAC (2015), business aviation is divided into five segments: (1) owner operated (2) corporate (3) fractional ownership (4) jet-card program (5) commercial.

Owner operated is about the individual has full ownership of the airplane. Corporate is means for an individual or a company entity owns the plane. Fractional ownership is an individual or a company owns 1/16 to 1/2 of an aircraft through a third party (fractional share provider) and receives management and pilot services associated with a fractional share provider. Jet card programs are about individual or companies purchase a block of flight hours (usually under 50 hours per year), in order to get a specific price on the contracts. The last segment is commercial, it’s divided into two kinds of operations: air taxi and branded charter. Air taxi is per-seat charter while branded charter is chartering the whole airplane. The operation models are shown in Figure 2.

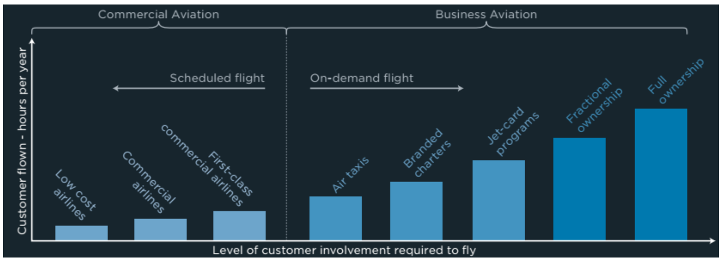


Figure 2: Operational Model of Business Aviation
Source: Bombardier (2013)

2.2 Aircraft Type Selection

Purchase a new aircraft is a huge investment, it's essential to consider many factors, such as demand, performance, finance, economics, market condition, fleet commonality, airline strategy, etc.

Paul Clark (2007) establishes a series of categories of the fleet selection process. It's divided into five categories: (1) market and route: size, growth, mix, comfort, schedule, airport compatibility, economics, turn times. (2) operations: crewing, aircraft mix, ETOPS, minimum equipment list, performance. (3) finance and contractual: purchase vs. lease, residual value, buy back, insurance, price escalation, guarantees, spares pricing, cost of updates. (4) engineering: spares inventory, pooling, commonality, facilities, third party needs. (5) regulatory and environmental: certification rules, environment standards special conditions.

Moshe Givoni and Piet Rietveld (2009) point out that the choice of aircraft size factors related to market conditions include competitive conditions related to regulation of markets, airport policies, and cost parameters. Research shows that the choice of aircraft size is mainly influenced by route characteristics (e.g. distance, level of demand and level of competition) and almost not at all by airport characteristics (e.g. number of runways and whether the airport is a hub or slot coordinated). Slavica Dožić and Milica Kalić (2015) develop a three-stage model for fleet planning that cope with both fleet composition and fleet size problems for airline operating in short haul and medium haul route by taking into consideration aircraft seat capacity, price of new aircraft, luggage per passenger, maximum take-off weight (MTOW), and unit trip costs that include fuel costs, maintenance costs, flight crew costs, insurance, and some other costs. Vivek Pai (2010) explores the relationship between aircraft size and frequency of flights by considering market demographics, airport characteristics, airline characteristics, and route characteristics. The results show that the flight frequency and aircraft size increase with the population, income, and runway length.

Dipasis Bhadra (2005) uses a multinomial qualitative choice model to establish empirical linkages among aircraft choice, passenger flows, distance, types of airport hubs, network, and time of the year. The research shows that both passengers and distance play important roles in selecting types of aircraft.

This paper aims to solve aircraft type selection problem for business charter in the cross-strait market. The aircraft type that meets the market condition, business jet company and business travelers' benefit should be chosen from the defined set of aircraft. According to the previous literature review, listing the factors as follows.

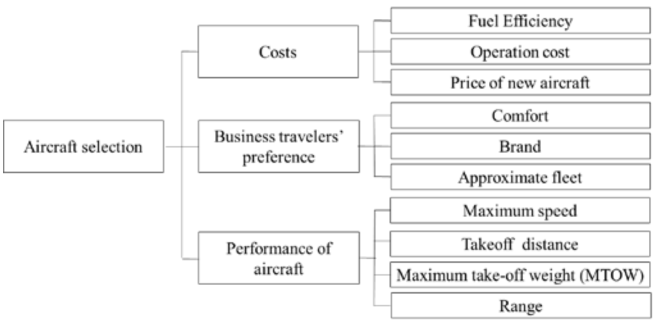


Figure 3: Hierarchy of decision level

Table 1: Description of each criteria

Criteria		Description
Cost	Fuel efficiency	A rate considered optimal with regard to the amount of fuel consumed, influenced by taxing, takeoff cruising…. Using the fuel consumption rate provided by manufacturers as consideration.
	Operation cost	Including crew, maintenance, insurance cost, etc.
	Price of new aircraft	Due to the wide selection of aircraft interiors and the difference in price, use the unit price of aircraft provided by manufacturers as consideration.
Business travelers' preference	Comfort level	Related to the volume of cabin and number of seats.
	Brand	For the confidence of aircraft type, according to place of origin, brand and accident rate.
	Approximate fleet	By comparing with nearby area speculating the aircraft type meets travelers' requirements.
Performance of aircraft	Maximum speed	Aircraft speed affects productivity.
	Takeoff distance	Business aviation decreases total travel time by using the smaller airports closer to final destination. The shorter takeoff distance, the more airports for choice.
	Maximum take-off weight (MTOW)	MTOW related to operating empty weight (OEW), total payload (passenger and baggage) and total fuel loaded (taxi-out fuel, trip fuel, and reserve fuel). Using the data provided by manufacturers as consideration.
	Range	The longer flying distance means the larger operation scope.

2.3 Methodology - Evaluation of mixed data method

i. 1st Conceptual Framework

The conceptual framework to explore aircraft type for business charter is showed in figure 4. First, the assigning criteria are listed in the previous section. Second, we get the weight of each criterion from questionnaire and obtain weighting with AHP methods. Third, we collect the data of qualitative criteria and quantitative criteria separately. Last, we get the appraisal score through the EVAMIX, which solves the problem of aircraft choice evaluation

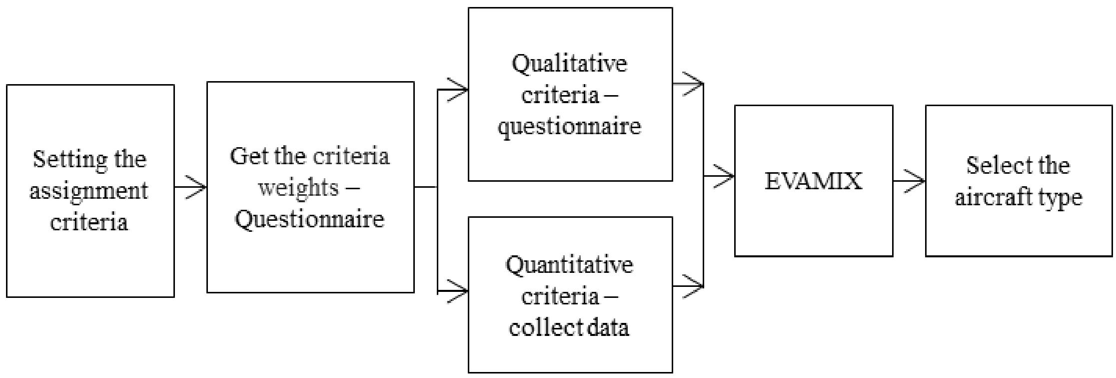


Figure 4: Conceptual framework

ii. 2nd EVAMIX Model

Application of Multi Criteria Decision Making (MCDM) could support decision makers in choosing the best solution. MCDM establishes preferences by considering a set of conflicting criteria to assess the extent to which the goal is achieved. MCDM technique establishing criteria and estimating the relative importance weights of each criterion.

Evaluation of mixed data (EVAMIX) method was established by Voogd in 1983 and later advocated by Martel and Matarazzo (2005). The EVAMIX method is a generalization of concordance analysis in the case of mixed information on the evaluation of alternatives on the judgment criteria. Thus a pairwise comparison is made for all pairs of alternatives to determine the so called concordance and discordance indices. The difference with standard concordance analysis is that separate indices are constructed for the qualitative and quantitative criteria. The comprehensive ranking of alternatives is the result of a combination of the concordance and discordance indices for the qualitative and quantitative criteria (Martel and Matarazzo, 2005).

It is based on the determination of the dominance score of an alternative on criterion-by-criterion basis. The main difference between EVAMIX and other MCDM methods is that it can treat the ordinal or qualitative criteria and cardinal or quantitative criteria separately. Both the ordinal and cardinal data are separately normalized in the range of 0–1 using linear normalization procedure. The degree of pair-wise dominance for each pair of alternatives is calculated, as the difference in score received by the higher performing alternative compared to the poorer performing alternative. The weighted sum of the dominance scores is then assigned to each alternative. The criteria weights can be obtained applying any of the weighting techniques, e.g. AHP and entropy method. The outcome of this aggregation procedure is similar to the outcome of the weighted sum method; the relative performance of the alternatives is the same but there is difference in the scale of the measure of performance (Prasenjit Chatterjeea et al., 2011).

According to literature view, EVAMIX method consists of the seven steps (Voogd, 1983; J.M. Martel, B. Matarazzo, 2005; V.P. Darji, R.V. Rao, 2014; Prasenjit Chatterjeea et al., 2011; Veera P. Darji et ai., 2013):

Step 1: In the decision matrix, differentiate between the ordinal and cardinal criteria.

Step 2: Normalizing the data set is done in the range of 0 - 1 using linear normalization procedure. The beneficial and non-beneficial attributes are weighted by different equations. For beneficial attributes, normalize the decision matrix using the following equation:

- For beneficial attributes, normalize the decision matrix using the following equation:

  $$r_{ij} = \left[x_{ij} - \min\left(x_{ij}\right)\right] / \left[\max\left(x_{ij}\right) - \min\left(x_{ij}\right)\right] \quad (1)$$

  $$(\mathrm{i} = 1, 2, \dots, \mathrm{m};\ \mathrm{j} = 1, 2, \dots, \mathrm{n})$$

- For non-beneficial attributes the above equation can be rewritten as:

  $$r_{ij} = \left[\max\left(x_{ij}\right) - x_{ij}\right] / \left[\max\left(x_{ij}\right) - \min\left(x_{ij}\right)\right] \quad (2)$$

  $$(\mathrm{i} = 1, 2, \dots, \mathrm{m};\ \mathrm{j} = 1, 2, \dots, \mathrm{n})$$

Step 3: Calculate the evaluative differences of i^{th} alternative on each ordinal and cardinal criteria with respect to other alternatives. This step involves the calculation of differences in criteria values between different alternatives pair-wise.

Step 4: Compute the dominance scores of each alternative pair, (i,i') for all the ordinal and cardinal criteria using the following equations:

$$\alpha_{ii'} = \left[\sum_{j \in O} \left\{W_J sgn\left(r_{ij} - r_{i'j}\right)\right\}^c\right]^{1/C} \quad (3)$$

Where

$$\mathrm{sgn}\left(r_{ij} - r_{i'j}\right) = \begin{cases} +1, & if\ r_{ij} > r_{i'j} \\ 0, & if\ r_{ij} = r_{i'j} \\ -1, & if\ r_{ij} < r_{i'j} \end{cases}$$

$$\gamma_{ii'} = \left[\sum_{j\in C}\{W_J sgn(r_{ij} - r_{i'j})\}^c\right]^{\frac{1}{c}} \quad (4)$$

where the symbol c denotes a scaling parameter, for which any arbitrary positive odd number, like 1, 3, 5, … may be chosen, O and C are the sets of ordinal and cardinal criteria respectively, and $\alpha_{ii'}$ and $\gamma_{ii'}$ are the dominance scores for alternative pair, (i,i') with respect to ordinal and cardinal criteria respectively.

Step 5: Calculate the standardized dominance scores which can be obtained using three different approaches, i.e. (a) subtractive summation technique, (b) subtracted shifted interval technique, and (c) additive interval technique. Martel and Matarazzo proposed a systematic additive interval approach to derive the standardized ordinal score ($\delta_{ii'}$) and cardinal dominance score ($d_{ii'}$) for the alternative pair, (i,i') as follows:

Standardized ordinal dominance score $(\delta_{ii'}) = \frac{(\alpha_{ii'} - \alpha^-)}{(\alpha^+ - \alpha^-)}$ (5)

where α^+, (α^-) is the highest (lowest) ordinal dominance score for the alternative pair, (i,i').

Standardized cardinal dominance score $(d_{ii'}) = \frac{(\gamma_{ii'} - \gamma^-)}{(\gamma^+ - \gamma^-)}$ (6)

where γ^+, (γ^-) is the highest (lowest) cardinal dominance score for the alternative pair, (i,i'). If the subtractive summation technique is used for calculating the standardized dominance scores, then Eqs. (5) and (6) become as follows:

$$\boldsymbol{\delta}_{ii'} = \alpha_{ii'}\left(\sum_{i=1}^{m}\sum_{i'=1}^{m}|\alpha_{ii'}|\right)^{-1} \quad (7)$$

$$\boldsymbol{d}_{ii'} = \gamma_{ii'}\left(\sum_{i=1}^{m}\sum_{i'=1}^{m}|\gamma_{ii'}|\right)^{-1} \quad (8)$$

Step 6: Determine the overall dominance score. The overall dominance score, (Dii') for each pair of alternatives, (i,i') is calculated which gives the degree by which alternative i dominates alternative i'.

$$D_{ii'} = w_O\delta_{ii'} + w_C d_{ii'} \quad (9)$$

where w_O is the sum of the weights for the ordinal criteria ($w_O=\sum_{j\in O} w_j$) and w_C is the sum of the weights for the cardinal criteria ($w_C=\sum_{j\in C} w_j$).

Step 7: Calculate the appraisal score. The appraisal score for i^{th} alternative (S_i) is computed which gives the final preference of the candidate alternatives. Higher the appraisal score, better is the performance of the alternative. The best alternative is the one which has the highest value of the appraisal score.

$$\text{Appraisal score } (S_i) = \sum_{i'}\left(\frac{D_{i'i}}{D_{ii'}}\right)^{-1} \quad (10)$$

3. Empirical study

It's estimating Data will be collected through expert interview and general survey from a sample containing 10 to 15 experts.

3.1 Criteria Weights

In this part, calculating the weight of each criterion with AHP methods.

3.2 Evamix

i.) 1st Criteria Weights of Qualitative and Quantitative Data

Compute the qualitative and quantitative data to get the appraisal score.

ii.) 2nd Aircraft Type Selection

Use the score calculated in the previous section and find out the suitable aircraft type.

4. Conclusion

This study aims to find out the type of aircraft that is suitable for cross-strait market and provides a model to assist the business jet company in aircraft-choosing evaluation. Expecting results of this study as follow:

- Establish a business aircraft choice model. The factors listed in this study as a reference to business jet company although in different environment.

- Since the purchase of aircraft is a huge investment, there are conflicting factors taken into consideration when evaluating the process. EVAMIX generalizes the case and mixes with qualitative and quantitative data, which assist decision-making more extended.

References

Bombardier (2014), Bombardier Business Aircraft Market Forecast 2014-2033, Bombardier Aerospace.

Clark Paul (2007), Buying the big jets: fleet planning for airlines, England: Ashgate.

Dipasis Bhadra (2005), “Choice of aircraft fleets in the U.S. domestic scheduled air transportation system: findings from a multinomial logit analysis”, Journal of the Transportation Research Forum, Vol. 44, pp. 143–162.

J. M. Martel and B. Matarazzo, “Other Outranking Approaches,” In: F. J. Salvatore and G. M. Ehrgott, Eds., Multiple Criteria Decision Analysis: State of the Art Surveys, Springer, New York, 2005, pp. 197-262.

Moshe Givoni, Piet Rietveld (2009), “Airline’s choice of aircraft size – Explanations and implications”, Transportation Research Part A: Policy and Practice, Volume 43, Issue 5, Pages 500–510.

Prasenjit Chatterjeea, Vijay Manikrao Athawaleb, Shankar Chakraborty (2011), “Materials selection using complex proportional assessment and evaluation of mixed data methods”, Materials & Design, Vol. 32, Issue 2, pp. 851–860.

Prasenjit Chatterjeea and Shankar Chakraborty (2014), “Flexible manufacturing system selection using preference ranking methods : A comparative study”, International Journal of Industrial Engineering Computations, Vol. 5, Issue 2, pp. 315-338.

Slavica Dožić , Milica Kalić (2015), “Three-stage airline fleet planning model”, Journal of Air Transport Management, Volume 46, Pages 30–39.

Voogd, H. (1982) “Multi-criterion evaluation with mixed qualitative and quantitative data”, Environment and Planning Bulletin, Vol. 9, pp. 221-236

V.P. Darji, R.V. Rao (2014), “Intelligent multi criteria decision making methods for material selection in sugar industry”, Procedia Materials Science, Vol. 5, pp. 2585-2594.

Veera P. Darji, Ravipudi V. Rao (2013), “Application of AHP/EVAMIX Method for Decision Making in the Industrial Environment”, American Journal of Operations Research, Vol. 3, pp.542-569.

Vivek Pai (2010), “On the factors that affect airline flight frequency and aircraft size”, Journal of Air Transport Management, Vol. 16, Issue 4, Pages 169–177.

Exploring Characteristics of Reefer Logistics in a Multi-actor Setting: A Systems Analysis

Yun Fan, Behzad Behdani and Jacqueline M. Bloemhof-Ruwaard

Operations Research and Logistics Group, Wageningen University & Research, The Netherlands
Email: yun.fan@wur.nl

Abstract

Reefer logistics is an important part of the temperature-controlled chain in which reefer containers are involved as the packaging for perishable goods. In recent years, the demand for reefers has increased, which consequently puts pressure on industries and governments to design effective reefer logistics systems. Reefer logistics is challenging, as it deals with not only costs and time constraints but also with product quality and sustainability requirements. Furthermore, many actors, e.g., shipper, transport carriers, etc., are involved in reefer logistics with different (and sometimes conflicting) goals. When introducing new concepts to reefer logistics, it is necessary to consider these distinctive features. Most of existing research on reefer logistics has not thoroughly considered these characteristics; and usually solutions have been proposed from one actor's perspective. Thus, the main purpose of this paper is to provide an overview of the characteristics of reefer logistic, using system analysis. The objective of this paper is twofold: firstly, to gain an understanding of the system of each actor in reefer logistics with a single-actor system analysis, including objectives, means, internal factors and external factors; secondly, to identify the interactions among different actors with a system analysis in a multi-actor setting.

The results show that actors have a number of means to meet their own objectives; however, there are trade-offs between benefits and risks if an actor takes certain actions. Furthermore, the means of one actor may have negative impacts on the objectives of other actors. A delay of one process requires other operators to speed up the processes to compensate for the loss of product shelf life; however, increasing speed consumes more energy that reduces the operators' profit and emits more pollution. The results also indicate that several means benefit more than one actor in the system, such as applying planning tools to terminal operation and exchanging information. Additionally, the findings suggest that port authority and governments, as public parties, need to actively guide the market players by issuing regulations and providing subsidies. These are essential to stimulate information sharing and to vitalize intermodality for reefer logistics. Overall, this work contributes to a better understanding of the characteristics of reefer logistics. The identified causal relations will support to develop propositions in the field of reefer logistics. Further studies need to be carried out in order to validate the findings.

Keywords: Reefer logistics, System analysis, Multi-actor setting, Trade-offs

1. Introduction

Reefer logistics is an important part of the temperature-controlled chain. In global reefer trade, the reefer logistics process starts from a cool warehouse of an exporter where perishable goods are loaded into reefer containers. Then the full reefer containers are transported through the hinterland to an export port to be loaded onto vessels. The vessels ship the full reefer containers to an import port where the full reefers are unloaded from the vessels and loaded onto next modalities, e.g., barges, trains or trucks. At a cool warehouse of an importer, the full reefer containers are unloaded. After that, the empty reefer containers are maintained and repositioned (mostly back to the empty reefer depot in the seaport). In short, reefer logistics is the part of temperature-controlled chain where reefer containers are involved as the packaging for perishable goods (Jung & Kim, 2015).

Reefer containers are used to carry goods that require controlled temperature. There are two main types of reefer containers: (1) portholes, which are supplied with cold air; and (2) integrated reefers, which have refrigeration units built into their structure (Accorsi et al., 2014). These refrigeration units operate electrically, either from an external power supply during transportation and at a container yard (Rodrigue & Notteboom, 2015). In general, reefer containers are intermodal containers with standard measures that can be operated on multiple transport modes, such as vessels, trains and trucks (Bömer & Tadeu, 2013). A modular structure realizes handling flexibility and efficiency, which leads to a shift from refrigerated vessels to reefer containers in global transportation of perishable goods.

In recent years, reefer logistics has an increasing demand with the growth of global trade. The estimated average annual growth rate is 2.5% from 2007 to 2017 (Drewry, 2014). By 2020, the demand of seaborne reefer logistics is forecasted to reach 120 million tonnes (Drewry, 2015). The increase in reefer demand is closely related to the growth of perishable goods consumption in mature markets, such as West Europe and North America, and also depends on the development of emerging markets, for example, China, East Europe and India (Arduino et al., 2015). These are the main importers of reefer commodities in recent years. The perishable goods are mainly from Latin-America and Africa (Bömer & Tadeu, 2013). The growing demand consequently puts pressure on industries and governments to design (more) effective reefer logistics systems in order to fulfil the demand.

However, effective planning for reefer logistics is challenging, since reefer logistics has some distinctive features compared with dry containers. Firstly, reefer logistics requires high investment in refrigeration equipment. The price of a reefer is five times higher than that of a dry container of the same size (Rodrigue & Notteboom, 2014). Achieving high asset utilization through effective planning of reefer transportation and repositioning is necessary. Secondly, reefer logistics not only deals with cost constraints but also intrinsic factors of food that might degrade during the distribution (Luning & Marcelis, 2009). Thus, an additional requirement is to preserve product quality along the supply chain. Thirdly, to maintain product quality, reefer containers use energy to supply refrigeration units during storage and transportation. Therefore, minimizing the energy consumption can be a challenging issue in reefer logistics (Steenken et al., 2004). Extra energy consumption creates more pollution to the environment, for instance, reefers are responsible for about 30-35% of the energy consumption at sea terminals (Geerlings & Duin, 2011). Hence, consideration of sustainability is more important for reefer logistics. Last but not least, the maintenance of reefers not only impacts the availability of reefers but also influences the energy consumption in the transport and storage process (Hartmann, 2013). All these technological features make reefer logistics more complicated than dry container logistics.

In addition to the technological features, there are many actors involved in different segments of reefer logistics, e.g., shippers, transport operators and port authority. On one hand, an individual actor has limited knowledge and less interest to improve performances of the whole system. On the other hand, actions to achieve one's own goals might have negative impacts on other actors. For instance, a slow steaming strategy of maritime carriers can reduce fuel consumption in the transportation. However, it increases the shipping time which makes hinterland operators choose road transport in order to fulfil total transit time requirement. Road transport is more costly and has more pollution to the environment, which is not preferred by hinterland operators and government parties. The trade-offs between benefits and risks among multiple actors make reefer logistic more complicated.

Due to the special characteristics of reefers and reefer logistics, typical problems of port-hinterland container logistics can be more problematic for reefers. Delay in terminal operation, partly due to lack of space and delays in custom control, results in lack of insight in times that containers are available for further processing, which might also influence the product quality. Information sharing in port-hinterland container logistics is another typical problem. Transport operators might be reluctant to install monitoring devices to collect product information during transportation (Huh et al., 2016). Without accurate cargo information, shippers have fewer chances to detect problems of their products. Furthermore, currently single-mode road transport is the dominant mode in port-hinterland transportation (Menesatti et al., 2014). This causes road congestion in the port area and increases in total transit time, which might further affect the product quality and sustainability. Intermodal transport can reduce operational costs compared with single-mode road transport

(Menesatti et al., 2014). However, the reality is that inland waterway and rail transport are even losing market share (Port of Rotterdam, 2014). In addition, maintenance hours of reefers by experts are too high (Ballieux et al., 2014). Inefficient maintenance processes result in low reefer utilization and excessive use of energy during transportation and storage. In other words, to efficiently tackle these problems in the field of reefer logistics, it is important to consider the technological and managerial characteristics of reefer logistics in the decision-making process and in designing tailored solutions.

Thus, the main purpose of this paper is to provide an overview of the characteristics of reefer logistic, using system analysis. The objective of this paper is twofold:

- Firstly, to gain an understanding of the system of each actor in reefer logistics with a single-actor system analysis, including objectives, means, internal factors and external factors;
- Secondly, to identify the interactions among different actors with a system analysis in a multi-actor setting.

The results of this work are (1) a system diagram for each of the main actors in reefer logistic to obtain insights into the relations between the means, objectives, internal factors and external factors; and (2) a system diagram for each means that shows the impacts of this means on multiple actors. The results can be further quantified and validated by mathematical programming models. The results can be used to provide managerial indications for the governments and industries. This makes the study highly relevant, not only in terms of academic interest, but also from a practical point of view.

Following this brief introduction, Section 2 is a brief literature survey on existing studies of reefer logistics. Section 3 describes the methodology used in this study: an iterative system analysis approach. Section 4 discussed the system analysis results on the characteristics of reefer logistics and the interactions among actors. Section 5 addresses some discussions and conclusions, stressing the most important characteristics and their indication to the governments and industries.

2. Literature Overview

A number of researches have been carried out on the topic of reefer logistics. Some researchers discuss trends and challenges of reefer logistics in general. Arduino et al. (2015) find the rapid growth of reefer container capacity in the recent decades. They show the great potential of reefer container by comparing of costs of reefer container and bulk reefer ship for banana transportation. Besides, Bömer and Tadeu (2013) emphasize that reefer logistics is a profitable market niche in the future development. Although reefer containers have a promising growth, a number of challenging issues might hinder the development, e.g., demand mismatches, cold chain integrity, transportation and transhipment issues (Rodrigue & Notteboom, 2015). In addition to the general discussion, other studies have proposed solutions for a part of reefer logistics usually from the perspective of one actor.

The studies in the field of reefer logistics are classified into four categories. The number of papers in each category is depicted in Figure 1. The categories are modified according to cold chain technique discussed by Rodrigue et al. (2013):

- Transport, which includes maritime transport and hinterland transport;
- Transhipment, which includes strategic and operational terminal decisions;
- Monitoring, which includes intelligent transport system and product quality measurement; and
- Packaging, which includes atmosphere control in reefer, container redesign and refrigeration unit design.

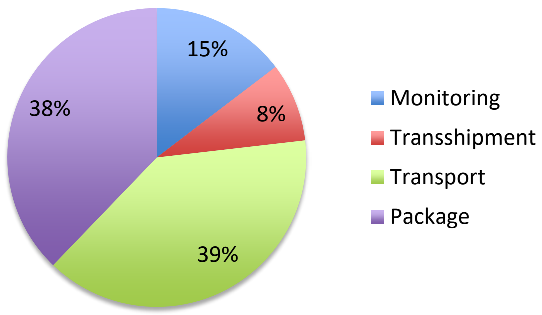


Figure 1: Categorization of articles on reefer logistics

A considerable number of papers discuss solutions for reefer transportation to lower energy consumptions, to reduce greenhouse gas (GHG) emissions or to decrease operational costs. Some researchers focus on reefer maritime transport, for example, Ambrosino et al. (2015) discuss multi-port stowage planning problem considering reefer containers in order to reduce re-handles costs. Lu et al. (2010) develop an integer programming model for ship's slot allocation that takes into account reefer containers to maximize profits for a liner shipping company. Cheaitou and Cariou (2012) analyse the slow steaming strategy of liner shipping operators. They find that this strategy reduces energy consumption of ships' main engine, while it increases energy usage for the refrigeration units due to longer transit time. In their work, consequences of longer transit time on other actors, e.g. reduction of product shelf life and less remaining time for hinterland transportation, are not discussed. Another research direction of reefer transportation is hinterland transport. However, there has been limited focus in current research. Menesatti et al (2014) conduct a case study of reefer transportation to compare costs and transit time of single-mode road transport and intermodal transport. They show that intermodalilty has advantages for reefers with respect to operational costs and CO_2 production. They also suggest that further research is needed to design integrated networks and schedules for multiple modes and to analyse the impacts on product quality and sustainability. Besides, Lütjen, et al. (2013) and Haass et al. (2015) describe a concept to use intelligent containers with quality-driven distribution, which provides an opportunity to reduce food waste by flexible distribution decision. They evaluate the concept from the perspective of a shipper. They do not discuss the willingness of a maritime carrier (i.e., reefer owner) to invest in intelligent reefers and to share reefers in hinterland.

With regard to reefer transhipment, limited studies have been carried out. At a terminal, reefers are connected with power supply by operators during storage. Hartmann (2013) use a hybrid optimization and simulation approach to analyse the scheduling of reefer mechanics at a container terminal. The objective of Hartmann is to minimize weighted sum of total tardiness and total travel time (2013). A simulation study has been conducted to analyse the reefer processes in general. Filina and Filin (2008) identify different reasons why power connections are cut off at a terminal. Filina et al. (2015) further measure risk of load loss in a terminal under different situations. In addition, some other studies are not specific for reefers but included reefer containers in the terminal decision models, e.g., Wiese, et al. (2011) discuss the decisions on reefer container yard design. Bazzazi et al. (2009) propose a generic algorithm to solve the storage space allocation problem in a container terminal including reefers. Martin et al. (1988) describe a heuristic method for vessel stowage plan and they recognize the constraint of reefer container connection on a vessel.

Monitoring refers to devices and systems able to track and record conditions in reefer containers, such as temperature and humidity throughout the whole reefer logistics process (Rodrigue et al., 2013). A number of publications have been in the field of intelligent transport systems due to worldwide concerns about food safety. Sensor network techniques are described by Ruiz-Garcia et al. (2007) and Jiménez-Ariza et al. (2015). Heidmann et al. (2012) and Wessels et al. (2011) discuss software and hardware design for intelligent freight transport systems. These techniques increase information transparency of reefer chain and the concept of intelligent transport systems is becoming more popular (Ruiz-Garcia et al., 2007). However, most of the studies mainly focus on the technical part of the system design. Investment in monitoring devices is left out in their discussion. In reality, extra investment is needed to implement certain systems (i.e., intelligent containers and wireless sensor networks). Risk and profit sharing are issues that need further analysis (Haass et al., 2015). There is also research on data measurement and analysis, see for instance the models developed by Jiménez-

Ariza et al. (2015). They analyse the shelf life of the lemon with the data collected with multi-distributed wireless sensor. Furthermore, Jedermann et al. (2014) show the possibility to use a structured system model for banana chain that reduce the information on the measured temperature curves to a set of only two index values. Bollen et al. (2013) describe a wireless temperature monitoring system and they compare different quality prediction model based on the data collected by the monitoring system. In addition, Jedermann et al. (2014), Palafox-Albarrán et al. (2011), James et al. (2006), and Tanner and Amos (2002) conduct research on temperature prediction models that can improve accuracy of product quality prediction.

Table 1: Overview of publications reviewed – by category

Category	Topics		Actors
Transportation	Maritime	Rodrigue and Notteboom (2015): facts of containerazation and cold chain	shipper, maritime carrier, terminal operator, hinterland transport operator
		Fitzgerald et al. (2011): energy usage estimation during transportation	
		Blanke (2005): life cycle assessment to calculate energy usage	
		Arduino et al. (2015): reefer container vs. bulk reefer vessel	
	Hinterland	Lütjen et al. (2013) Haass et al. (2015): quality driven distribution using intelligent containers	
		Menesatti et al. (2014): Intermodal vs. Conventional logistics	
Transhipment	Strategic decisions	Wiese et al. (2011): terminal layouts planning	terminal operator
	Operational decisions	Fitzgerald et al. (2011): energy usage estimation at a sea port	
		Bazzazi et al. (2009): terminal storage space allocation	
		Hartmaan (2013): scheduling of equipment and manpower	
		Filina and Filin (2008): influence of lack of electricity supply	
Monitoring	Monitoring system design	Huh et al. (2016): power line communication based technology	shipper, maritime carrier
		Ruiz-Garcia et al. (2007): sensor network review	
		Lukasse et al. (2003): automatic monitoring procedure	
	Intelligent object	Wessel et al. (2010): hardware and software design	
		Heidmann et al. (2012): intelligent container	
	Quality measurement method	Jedermann et al. (2013) Palafox-Albarran et al. (2011) James et al. (2006) Tanner and Amos (2013): temperature prediction	
		Jiménez-Ariza et al. (2014): real time monitoring and shelf life	
		Jedermann et al. (2014): remote quality monitoring for banana chain	
		Bollen et al. (2015): evaluation on quality predicting model	
		Sman and Verdijck (2003): model prediction control of condition in reefer	
		Verdijck and Straten (2002): product quality control method design	
Packaging	Container design	Sepe et al. (2015): PCM in container	shipper, maritime carrier
		Harrison and Herlihy, (1995) Moureh et al. (2009): re-design of reeer container	
	Atmosphere container	Dodd (2013) (Moureh et al. (2009) Alpteken et al. (2014) Smale et al. (2006): airflow characteristics	
		Trinidad et al. (1997) Lawton and Rhodes (2014): controlled atmosphere	
	Refrigeration unit	Tso et al. (2001) Tso et al. (2006) Jolly et al. (2000) Yan-Qiao and Shi-Liang (1996)	
	Comparison of containers	Accorsi et al. (2014)	

Another large part of existing research has focused on the reefer itself. An experiment has been conducted by Accorsi et al. (2014) to compare thermal protection ability of dry containers and reefer containers. They also provide a general comparison of costs and emission of CO_2 equivalent between dry containers and reefer containers. To maintain product quality, some researchers have carried out studies on managing air flow in reefer containers, e.g., Dodd (2012), Moureh et al. (2009), Smale et al (2006) and Alptekin et al. (2014) discuss the airflow characteristics within a reefer container. Trinidad et al. (1996) and Lawton and Rhodes (2014) analyse controlled atmosphere in containers. Some researchers have focused on redesign of the bin or the envelope of a container, e.g., Copertaro (2016) analyse the potential to use phase change materials (PCMs) in the envelope of a container to maintain temperature homogeneity inside the reefer and to reduce energy usage. Sepe et al. (2015) propose to use PCMs in containers to achieve lower manufacturing costs and energy consumption. Harrison and Herlihy (1995) propose to utilize glycol-chilled wall for reefer containers in order to maintain product quality. However, costs of additional materials have been rarely discussed. Another research direction is on the efficiency of refrigeration units, see for instance (Tso et al., 2001), (Tso et al., 2006), (Jolly et al., 2000), and (Jiang & Wang, 1996).

The detailed topics that are discussed in the existing papers are summarized in Table 1. In general, limited studies have been conducted for reefer logistics, although there is an increasing focus on reefer market in the industry. Existing studies have developed a number of solutions that can improve cost-efficiency, product quality or sustainability. However, most of the studies do not thoroughly consider the characteristics of reefer logistics. The solutions are proposed from one actor's perspective, e.g. shippers, maritime carriers, terminal operators and hinterland operators. Other actors are not focused in current researches, e.g., public parties. An integrative perspective is lacking on an overall understanding of the specific characteristics of reefer logistic in a multi-actor setting. To conclude from the literature study, since technological aspects in the multi-actor setting create a complex socio-technical system, there is a need for a comprehensive understanding of the characteristics of reefer logistics, in order to achieve effective operation.

3. Methodology

In this research, an iterative system analysis approach was used, which is described in this section. The approach includes three steps: (1) systematic literature review; (2) system analysis; and (3) expert interviews, as depicted in Figure 2. In section 2, a number of researches have been described. The actors discussed in each paper were identified. Information related to the system of each actor was extracted and collected with the systematic review. With system analysis, the objectives, means, internal factors and external factors were identified for each actor involved in reefer logistics based on the systematic literature review results. Interactions between different actors were also analysed. After that, a preliminary system analysis result was generated and discussed with experts in the field of reefer logistics. Feedback was used to update the system analysis until a comprehensive understanding of reefer logistics was achieved. In the following content, details of each step are described.

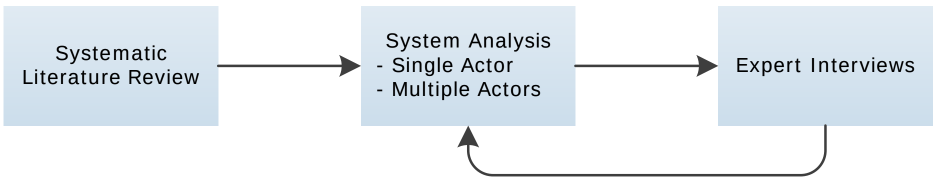


Figure 2: Iterative system analysis approach

3.1 Systematic Literature Review

A systematic literature review is a comprehensive approach used to extract and summarize desired information from the existing research, which can avoid bias on literature searching (Dickson et al., 2013). In this research, a considerable number of scientific publications in the field of reefer logistics have been reviewed. The learning objective is to collect information and data of reefer logistics from the literature to support a system analysis. The information and data include the objectives, means, internal factors and external factors of each actor, and also the relations between the factors. Scopus was selected as the electronic literature search engine since most of operations research and logistics publications were published in Scopus. For the literature search, keywords were formulated and classified into two groups:

- Reefer: reefer, refrigerated container, temperature-controlled container, climate-controlled container, environment-controlled container and insulated container
- Logistics: logistics, cold chain, supply chain, transport, intermodal, hinterland transport, shipping, inland waterway, road and rail.

The searching strategy was to combine the keywords in these two groups using the Boolean operator "OR" and "AND", and wildcards, e.g., an asterisk (*). In total, 82 articles have been selected for full paper review. The detailed literature searching strategy and data extraction table are discussed in Appendix A.

3.2 System Analysis

A system analysis was conducted after the systematic literature review. The information extracted from the literature was the input to the system analysis. A systems analysis method is a structured, empirically based, verifiable and reproducible method to analyse a large and complex system (Walker, 2000). The output of a system analysis for a single actor is an actor-specified system diagram, as shown in Figure 3. A system diagram consists of four major components: objectives, means, internal factors, and external factors (Enserink et al., 2010). Objectives are the expected situation of the system from the perspective of the actor; the achievement of the objectives is measured by a number of criteria. Means are elements represent what the actor can do to influence the system and increase the chance to achieve the objectives. The main part of a system diagram is a causal-relationship map that links the means, internal factors and criteria. It shows how the means influence the objectives. In addition, external factors are considered in the system diagram to represent factors that are outside the control of the actor and can influence the system.

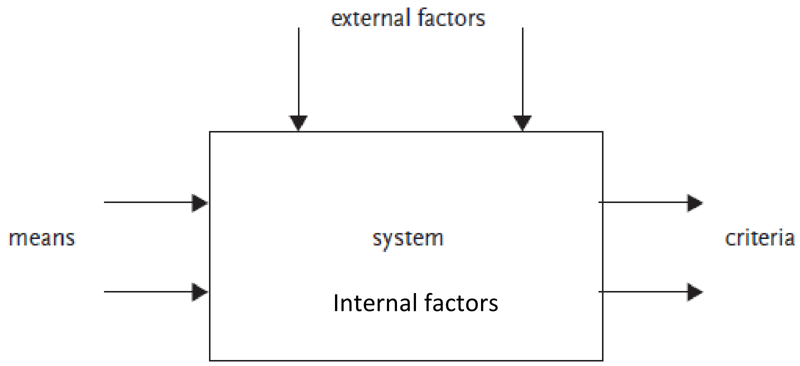


Figure 3: System diagram: conceptual framework for system analysis
Source: Enserink et al. (2010)

In this study, system diagrams have been developed based on a modification of the steps introduced by Enserink et al. (2010). Firstly, a system analysis was conducted for each single actor that started from defining an initial objective for each individual actor. Then, fundamental objectives were identified by asking "why" questions to the initial objective (Enserink et al., 2010). After identifying the fundamental objectives of each actor, a means-ends analysis was carried out, which started from the fundamental objectives by asking "how" questions in order to find lower level means that can be taken to achieve the objectives (Enserink et al., 2010). The "how" questions were frequently asked until a means-ends analysis links all specific actions (identified from the literature) with the fundamental objectives. The means-ends analysis provided alternative solutions that an actor might do to achieve the specific objectives. In practical, there are more factors that can influence the system. Thus the means-ends analysis was extended by adding the relations of identified internal factors and external factors. In the end, a system diagram was developed for each actor that showed a system description. The system diagram provides a qualitative form of a "what if" analysis that helps the understanding of a relationship between the element in the system (Enserink et al., 2010). Secondly, a multi-actor system analysis was conducted by analysing whether a means has impacts on more than one actor. A "what if" analysis was carried out for each identified means. The multi-actor system analysis results help to understand what the impacts on the other actors' systems are, if a specific means is used by an actor.

3.3 Expert Interview

In this research, a preliminary system analysis was carried out based on the information and data collected from the systematic literature review. After that, the results were validated and improved by interviewing experts in the field. The developed system diagrams were validated by at least one of the experts. Interviews were used as a method of both information validation and information gathering. As an information gathering method, the interviews were needed to complete some information that was not provided in the existing scientific publications.

4. Results

This section discussed the results of the research. The focus is on the main actors involved in reefer logistics, which are identified in section 4.1. Single actor system diagrams are depicted and described in section 4.2, which include the relations between the means, internal factors, external factors and objectives; the main focus is on a shipper due to the limitation of space. The system diagrams of the other actors are in Appendix B. Section 4.3 discusses the interactions among actors. An example of multi-actor system diagrams is shown. The other multi-actor system diagrams are in Appendix C.

4.1 Segments and Actor Identification

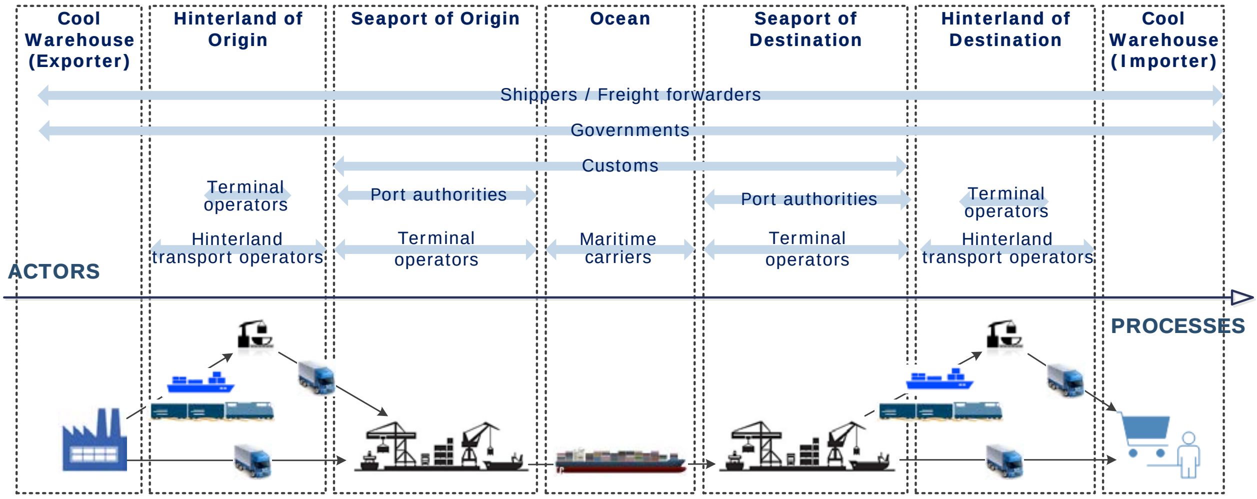


Figure 4: Reefer logistics process and segments with involved actors

As shown in Figure 4, reefer logistics are divided into several segments according to the locations and activities. The segments in export part and import part are symmetrical, which is similar to dry container logistics. A number of actors are involved in different segments of reefer logistics. There are a number of market players, i.e., shippers, freight forwarders, maritime carriers, terminal operators and hinterland operators. In general, shippers own the perishable cargo that needs to be delivered from an origin to a destination (Chopra & Meindl, 2010). Freight forwarders, who are also called third-party logistics service providers, organize transport services for shippers (van den Berg, 2015). The freight forwarders make agreements with transport operators and terminal operators in order to fulfil requirements of shippers. In this way, shippers and freight forwarders expect to have control on the whole process of reefer logistics; therefore, they are involved in all the segments. Maritime carriers are involved in the ocean part. They own or rent deep sea vessels and reefer containers to transport perishable cargo over sea. Their reefer containers are sometimes also used for hinterland transportation. Terminal operators handle reefer containers at a sea terminal or an inland terminal. In general, the operation includes loading, unloading, stacking, storage, etc. They realize the transhipment of reefer containers from one mode to another mode (Vis & Koster, 2003). Hinterland transport operators use trucks, trains and barges to transport reefer containers from a sea terminal to cool warehouses and vice versa (Horst & Langen, 2008).

In addition to the market players, public parties are also involved in reefer logistics; they are port authority, customs and government parties. Port authorities are responsible for the port area's development and management (van der Lugt et al., 2014). They have landlord function that consists of elements such as the development of the port estate (Verhoeven, 2010). In addition, port authorities have the regulator function and the operator function that covers the provision of port services (Verhoeven, 2010). Customs protect people and facilitate trade, which are closely related to reefer logistics (European Commission, 2014). In addition, governmental parties involved in reefer logistics are such as ministry of transport, public works and water management, environmental office, and food and consumer product safety authority (Meijer, 2007).

4.2 Single-actor System Analysis

Before means-ends analysis, fundamental objectives of each actor are identified that are shown in Table 2. One of the fundamental objectives of market players is to maximize profit. Besides, there is growing interest in sustainable transport in the recent years (Litman & Burwell, 2006). Sustainable transportation concerns environment, social and economic factors in decision-making that affects transportation activities (OECD, 1996). Since reefer logistics consumes extra energy for refrigeration units, environmental impact is an important issue considered by the market actors involved in the reefer logistics system. Thus, another fundamental objective of commercial actors is to minimize environmental impact. In this research, the government party is discussed in general, which is not specific to a certain department. The fundamental objective of government is sustainable development. The main goal of port authority is to increase competitive position of the port and customs aims to protect import and export products. In the following content, the system analysis results for each actor are discussed.

Table 2: Fundamental objectives of each actor

Actor	*Fundamental objectives*
Shipper	Maximize profit Minimize environmental impacts
Freight forwarder	
Maritime carrier	
Terminal operator	
Hinterland transport operator	
Government	Keep sustainable development
Port authority	Increase competitive position of the port
Custom	Protect import and export products

i. Shippers

The system diagram of a shipper is shown in Figure 5. In this research, spoilage rate and operational costs are defined as criteria to evaluate the profit objective. The high product quality is represented by low spoilage rate in this research. With high product quality, shippers increase their sells that further gain more profit. Operational costs include facility investment cost, transportation cost, energy usage cost, labour cost and product preparation cost (i.e., chemical, fungicides and package R&D expense, and etc.). In addition, CO_2 emission is used in this research as a criterion to measure the environmental performance.

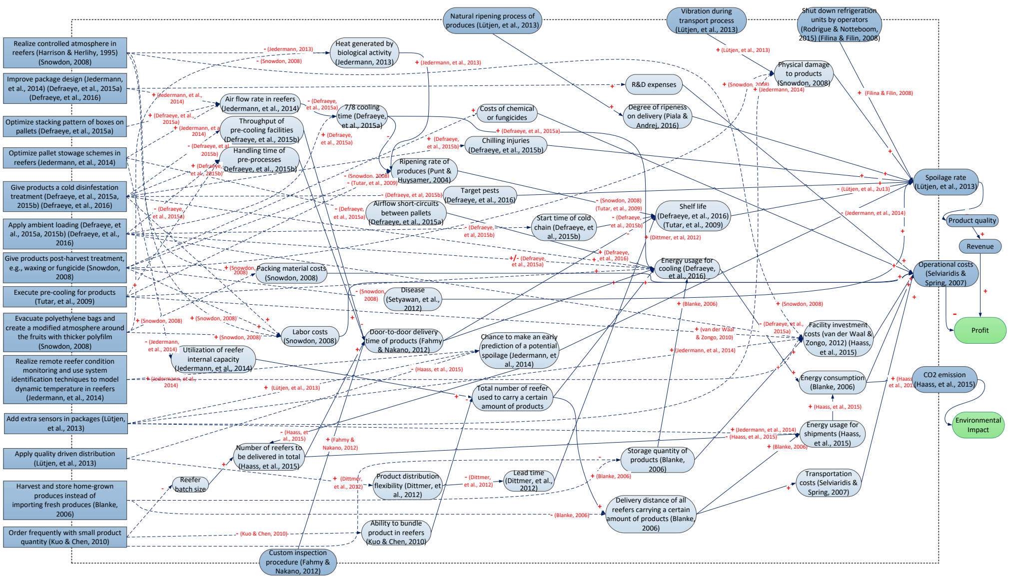


Figure 5: System diagram of a shipper

One means to reduce spoilage rate is to apply *controlled atmosphere* in reefers discussed by Harrison et al. (1995) and Snowdon (2008). The heat generated by biological activity is reduced by maintaining appropriate concentrations of CO_2 and O_2 within the reefers (Jedermann et al., 2014). The low O_2 and high CO_2 concentration reduces the living products' sensitivity to ethylene, thereby reducing the microbiological activity and respiration rate and extending the shelf life (Snowdon, 2008), which finally reduces spoilage rate. By realizing controlled atmosphere, special devices are required to provide the optimal atmosphere. Additional handling is needed to pack the products in special packing materials (e.g., 'Polypack') (Snowdon, 2008). Therefore, there is a trade-off between the operational costs and product quality. Another similar way is *modified atmosphere*. Polyethylene bags of the products are firstly evacuated. Then a modified atmosphere is created around the products by using thicker polyfilm (Snowdon, 2008). With thicker polyfilm, other gases outside the cardboard take longer to permeate through boxes, which results in and maintains a low O_2 and high CO_2 atmosphere that slower the respiration process (Snowdon, 2008). Compared with fully controlled atmosphere, modified atmosphere do not need specific apparatus to supply optimal atmosphere that reduces investment cost and chemical costs. However, thicker polyfilm costs additionally that also increases operational costs. Furthermore, the atmosphere around the products is not optimal that might cause a loss on shelf life. Additional handling is still needed to pack products in specific materials, to evacuate the package and to tightly seal the package (Snowdon, 2008).

Improving package design is another way to maintain the product quality (Jedermann et al., 2014). Additional vent holes on the boxes form horizontal and vertical ventilation pathways after palletisation, which can improve air flow rate (Defraeye et al., 2016). The cooling can be improved by approximately 15% according to a rough estimation of Jedermann et al., (2014). Air flow rate is a significant factor for shippers in reefer logistics sector, since it influences the seven-eighths cooling time (SECT). SECT is the time used to reduce seven-eighths of the temperature difference between the fruit and cooling air (Defraeye et al., 2015a), which is highly related to energy usage for cooling and product quality. *Optimizing stacking pattern* in box and *optimizing pallet stowage scheme* in reefers can also increase the air flow rate (Defraeye et al., 2015a) (Jedermann et al., 2014). According to Jedermann et al., (2014), new channels can be created by separating the products to several patterns in a box in order to increase air flow inside a box. By optimizing the pallet stowage scheme in reefers, air short-circuits between pallets can be closed, which will further improve the cooling and reduce energy usage (Defraeye et al., 2015a) (Defraeye et al., 2016). However, a drawback of using more space for air flow pathways is that the utilization of the cardboards and reefers are reduced. According to Jedermann et al., (2014), the reduction of capacity utilization is 4%, while the cooling can be improved by approximately 50%.

Perishable products, especially fruits, can be given a number of treatments before the transportation, for instance *cold disinfestation* (Defraeye et al., 2015b). A cold disinfestation treatment cools the fruits in order to destroy target pest, which is a required process by some import countries (Defraeye et al., 2016). By destroying target pest, the spoilage rate of the fruits can be reduced, which increases the profit of a shipper. However, more energy is used for cooling. Furthermore, a chill injury might occur due to the low temperature during the treatment (Defraeye et al., 2015b). In addition, a cold disinfestation treatment needs additional handling, which increases handling time and labour costs (Defraeye et al., 2015b). It also reduces the throughput of pre-cooling facility (Defraeye et al., 2015b). Higher pre-treatment time and lower throughput of cooling facility increase product door-to-door delivery time, which further reduces product shelf life and increases the probability of spoilage. Energy usage for cooling is also increased, which influence the operational costs and environmental performance. Other types of *post-harvest treatment* can be waxing or fungicide that control diseases and the ripeness rate of products (Snowdon, 2008). Extra handling is required that is similar to cold dissertation, which increases labour costs. Furthermore, each product needs to be put into special chemical which increase the potential of physical damage to products; and the shippers need to pay for chemical or fungicide.

In general, *pre-cooling* is a common means for shippers to keep product quality which is to cool the products before loading them into a reefer (Tutar et al., 2009). The microbiological activity and respiration rate can be reduced (Tutar et al., 2009). One shortage of pre-cooling is that it requires specific facilities for the cooling and additional energy is consumed (van der Waal & Zongo, 2010). Another drawback is that more handling time is required for pre-cooling that increases the product door-to-door delivery time. On the contrary, Defraeye et al., (2015a) (2015b) (2016) conducted studies that discussed the potential of ambient loading, which is to load products into reefer without pre-cooling process. The products are cooled directly by reefers (Defraeye et al., 2015a). Obviously, no facilities and energy are needed for pre-cooling. Furthermore, handling time of pre-process is also reduced (Defraeye et al., 2015a) that lowers the door-to-door delivery time and increases product shelf life. However, SECT is increases by applying ambient loading which increase the energy consumption for cooling during transportation and increases spoilage rate (Defraeye et al., 2015a). Thus, there are trade-offs between product quality and energy usage.

A potential spoilage can be predicted early by *remote reefer condition monitoring* (Jedermann et al., 2014). System identification techniques are used to model dynamic temperature in reefers; the reefers can send a warning if unexpected temperature situation are detected. Additional investment costs are required to realize remote condition monitoring. Furthermore, *extra sensors* can be added to the reefers or packages in order to retrieve more accurate information of product quality; however, choices of types of sensors are limited to temperature and humidity sensors (Jedermann et al., 2014). Size, energy supply and cost are needed to be considered when additional sensors are used (Jedermann et al., 2014). Another issue related to extra sensors is that handling is required to locate sensors in packages or reefers, which might cause physical damage to the products (Jedermann et al., 2014). Therefore, it is important to consider the trade-offs between investment costs, product quality and energy supply when making a decision on realizing wireless sensor network or adding extra sensors for remote condition monitoring.

Quality driven distribution is allocating goods to customer orders based on product quality. In cases of changes in the product quality, a new allocation is made to distribute goods with lower shelf-life to nearby customers (Lütjen et al., 2013). Distribution is more flexible with exchangeable allocation of goods to customer orders (Dittmer et al., 2012). Lead time of certain customer orders can be reduced that is better for the product quality. Furthermore, it increases the chance to make an early prediction of the spoilage (Haass et al., 2015). When a reefer is detected with spoiled product, it is not necessary to complete the distribution, therefore, total number of reefers to be delivered is reduced (Haass et al., 2015), which decreases the energy usage for the transportation and further reduces operational costs and CO_2 emission. Thus, quality driven distribution is a proper means for both profit and environmental performance from a shipper's perspective.

Most of the means are related to product quality, while there are also costs-related means. Products can be *harvested and stored locally* instead of importing from other countries (Blanke, 2006). Transportation cost is reduced since shipping distance is less. However, inventory holding costs are increased as more produces are stored for a longer period. Furthermore, cool warehouses are needed to store the products that increases fixed facility costs. Although energy consumption of the shipments is reduced, energy consumption for storage is increased. Thus, regarding both profit and environmental impact, there is a trade-off between the transportation costs and storage cost. A shipper can also choose to *order more frequently with small order quantity*, which is more commonly used by shippers nowadays (Kuo & Chen, 2010). With smaller order quantity, the reefer batch size is reduced, which reduces storage quantity, door-to-door delivery time and energy usage for the shipment. However, the ability to bundle product in reefer is reduce (Kuo & Chen, 2010) that might increase the total number of reefer to carry a certain amount of products. Then the shipping costs and energy consumption will be higher. Therefore, it is important to determine the optimal order quantity, in order to balance transportation cost, storage cost and energy cost.

In addition, some external factors also influence the objectives of a shipper, such as natural ripening process of produces, vibration during the transportation and refrigeration unit disconnection during the transportation (Lütjen et al., 2013) (Rodrigue & Notteboom, 2015). These external factors are closely related to the product quality. Furthermore, customs inspection has an impact on door-to-door delivery time that further influences the energy consumption and product quality.

ii. Freight Forwarders

For freight forwarders, criteria are logistics service quality, operational costs and CO_2 emission. Since freight forwarders organize transportation service for shipper; their focus is not only product quality, but also logistics performance, such as service reliability and flexibility. A profitable and obvious operational means is to *integrate demand of multiple shippers* (Büyüközkan et al., 2008), which is applicable for both dry and reefer container logistics. Economies of scale and scope could be achieved by bundling demand of different customers (Hesse & Rodrigue, 2004). The probability to choose rail and inland waterway as hinterland transport modes can be increased. The chance to reserve capacity from large vessels can also be increased due to large demand volume. Energy consumption for the shipments is reduced by using rail, inland waterway and large vessels. However, door-to-door delivery time is longer because of two reasons: (1) extra handling in needed at inland terminal and (2) larger reefer batch size requires longer reefer terminal dwell time. With increased door-to-door delivery time, more energy is required for product cooling inside the reefers. Thus, there is a trade-off between energy usage for cooling and for shipments by bundling demand flows. Another way to achieve economies of scale and scope is to *form horizontal logistics alliances* (Büyüközkan et al., 2008). In addition, freight forwarders provide *customized services* to improve the service diversification and service quality in the recent years (Kuo & Chen, 2010) (Murphy & Daley, 2001). For reefer logistics, service diversification can be achieved by, for instance, offering reefers with different sizes and temperature ranges. However, customized service reduces the probability to combine demand and decreases the economies of scale and scope.

Managing real-time logistics information is important for freight forwarders to make accurate planning (Kuo & Chen, 2010). In reefer logistics, the information is not only about cargo transportation tracking, but also food quality tracing. With more accurate reefer container information, freight forwarders are possible to reduce door-to-door delivery time of products. By reducing the delivery time, shelf life can be extended; energy usage for shipment and cooling are also reduced by less delivery time. Service quality is improved by less spoilage and more reliable service. Operational costs and pollution are both reduced due to less energy consumption. Therefore, it is essential for freight forwarders to get access to and to manage the information on transportation, reefer containers and products.

iii. Maritime Carriers

Similar to freight forwarders, the criteria of maritime carriers are also divided into three categories, but in more detail, since more means, internal factors and external factors are identified for maritime carriers. In this research, the detailed criteria are listed as below.

- logistics service relevant, i.e., food waste, schedule reliability and service flexibility;
- cost relevant, i.e., maritime costs, handling costs, and resource investment costs; and
- environment relevant, i.e., CO_2 emission.

Maritime carriers have a strong market power in reefer logistics. A number of means can be done to meet the fundamental objectives of high profit and low emission. Two means are related to protecting product quality, which are conducting container *pre-cleaning* and executing *pre/post-trip inspections* (Rodrigue & Notteboom, 2015) (Jung & Kim, 2015). Contamination of products can be reduced by pre-clean the reefers before sending them to shippers. In addition, pre/post-trip inspections are able to identify a potential defect of reefers and allow preventive maintenance of reefers (Sørensen et al., 2013). With preventive maintenance, the cooling system failure during the shipments can be reduced that keeps a high product quality (Sørensen et al., 2013). However, both pre-cooling and pre/post-trip inspections need extra handling that increases the energy consumption of terminal handling. Thus, additional operational costs are required in order to fulfil high product quality.

Energy consumption is another essential factor considered by a maritime carrier that is highly related to operational costs (Cheaitou & Cariou, 2012). A number of means are used by maritime carriers to reduce fuel usage for cooling. Changing reefer design or refrigeration unit is one way. For instance, *adding phase change materials (PCMs)* to the envelope of reefer containers can increase the thermal inertia, which reduces peak energy consumption (Copertaro et al., 2016). Using *energy efficient refrigeration units* can increase cooling efficiency and reduce fuel usage (Haass et al., 2015). However, adding PCMs and using new cooling units require additional device costs. Another way to reduce energy consumption for cooling is to use *substitution of integrated reefers*. PCMs can also be used inside the reefers to keep thermal inertia (Gwanpua et al., 2015). A third way to reduce energy usage for cooling is to cut power supply, for example, maritime carriers can use controllers to *adjust set points of reefers remotely* (Verdijck & Straten, 2002). With remote control, over circulation and over-ventilation can be avoided that reduces energy consumption (Verdijck & Straten, 2002). Furthermore, product quality loss is also reduced by avoiding chill injuries (Verdijck & Straten, 2002). However, temperature variability in reefers will increase by changing the set points frequently, which is undesired for product quality (Verdijck & Straten, 2002). Moreover, investment needs to be made on the remote control devices. Finally, *using waste heat powered system* is also a popular approach to reduce energy usage for cooling (Cao et al., 2016).

Energy consumption reduction can also be achieved by reducing energy usage for shipments. *Vessel size leverage* is a method that invests on replacing small vessels with bigger vessels (Bömer & Tadeu, 2013). By increasing the vessel capacity, economies of scale are achieved; and fuel usage per unit is reduced. However, vessel size leverage have promoted a higher discharge time because of the increase in the volume of reefers being transported. Another popular method to reduce energy consumption for shipments is to apply *slow steaming strategy* (Cheaitou & Cariou, 2012). With slow steaming, Cheaitou and Cariou (2012) analysed that fuel usage for main energy is reduced, while more energy is consumed for cooling since maritime time is increased. Therefore, both energy usages for shipments and cooling need to be taken into account in order to find a balance. Longer shipping time does not only increase fuel usage for cooling, but also reduces product shelf life which might have an influence on the product quality.

Less number of transhipment is one way to reduce the number of terminal handling and maritime time (Rodrigue & Notteboom, 2015). Furthermore, the time that reefers are unconnected with power supply is reduced because of fewer terminal handlings (Rodrigue & Notteboom, 2015). From this point of view, reducing transhipment can reduce energy consumption and improve product quality. However, economies of scale and scope are difficult to realize without transhipment. As a consequence, vessel utilization is reduced; and fuel usage per loading unit is increased, which further increases operational costs. On the other hand, fewer reefers on the same vessel can reduce the risks of potential spoilage and food loss (Bömer & Tadeu, 2013).

Maritime carriers also try to improve the utilization of their resources to reduce operational costs. One way is to realize *vessel pooling* that increases economies of scale and scope (Coyle et al., 2001). Service flexibility is also increased by pooling the resources together of different maritime carriers. Diesel generator on the vessels can be used to increase the connection of reefer capacity that also increases service flexibility, while energy consumption might also be increased (Piala & Andrej, 2016). In addition, reefer container utilization is also a consideration that can be improved by *making leasing decisions*. It reduces empty movements of reefer and increases reefer availability (Chao & Chen, 2015). However, the unit rent might be higher (Lu et al., 2010). Using triangulation scheme is another way to reduce empty movements. The reduction in the container repositioning cost is a noteworthy involvement of shipping lines in inland operations (van den Berg & de Langen, 2015). *Triangulation scheme* deals strategy, empty container movement can be decreased that offers a possibility of a reduction in the fuel consumption. Furthermore, triangulation increases the reefer availability that increases the service quality by providing more flexible service.

In order to gain control of the properties, maritime carriers are willing to *keep reefer containers in their own network* (Rodrigue & Notteboom, 2015). However, this requires trans-loading at a terminal to unload the products from a maritime reefers to a hinterland reefer. Reefer logistics processes are interrupted with increased handling costs and reduced product quality. One way to increase the controllability of reefer in hinterland is to *make a carrier haulage arrangement* with the shippers (Veenstra, 2005). Maritime carriers can choose hinterland transport operators and build relationships with them. Furthermore, economies of scale can be achieved by the possibility to bundle reefers of different shippers (Veenstra, 2005).

Information exchange is another important issue considered by a maritime carrier. Realizing container monitoring system is able to provide more accurate cargo information and reduce number of manual inspection (Huh et al., 2016). With more accurate information, the reliability of temperature control in reefers can be improved (Verdijck & Straten, 2002). Then the product quality loss is reduced which reduces food waste (Lütjen et al., 2013). Furthermore, decision making process is more efficient with accurate cargo information (Haass et al., 2015), which has a positive impact on schedule reliability. Another method to increase information exchange is by *using intelligent containers* (Dittmer et al., 2012). With the concept of intelligent container, wireless sensor nodes are arranged in packages which continuously measure environmental parameters relevant to product quality. The sensor nodes send the information to a central computer that calculates the shelf life of the goods and shares the information with the operator (Dittmer et al., 2012). One advantage of intelligent container is high transparency of food supply chain by collecting more accurate cargo information, which increases customer trust (Haass et al., 2015). Since intelligent containers are able to monitor the parameters on real time, over circulation and over-ventilation can be avoided which is good for the product quality and energy usage. Furthermore, intelligent containers use sensors to collect the information that reduces the human intervention (Lütjen et al., 2013). It reduces human inspection which further reduces on-board accidents (Huh et al., 2016). However, the cost of intelligent containers need to be considered. So far the costs-efficiency of intelligent container has not been studies in the existing literature. It is necessary to evaluate the costs and potential savings when making a decision to use intelligent containers.

In order to reduce pollution, *green technology* is used by maritime carriers (Eyring et al., 2010). Green technology not only concerns about a reduction in the fuel consumption but also less emission from the same amount of fuel consumption. Taxes on fuel and environmental emission are established to drive the actors in reefer logistics to improve the environmental performance (Lindstad et al., 2011). Cost to cover emission tax can also be reduced by applying green technology. It has a positive impact on the reduction of costs and environmental impact on long term, while investment costs are needed that reduces short-term profit.

iv. Terminal Operators

Criteria of terminal operators are product quality, CO_2 emission, operational reliability, and operational costs. Several means are suitable for terminal operators to meet their objectives. A new concept discussed by van Duin et al., (2016) is to *apply intermitted distribution of power among the reefer racks*. The peak demand of power is reduced by coordinating the reefer power connection (van Duin et al., 2016). However, the temperature variability in reefer is increased, which need to be carefully monitored during the terminal storage in order to maintain the product quality (van Duin et al., 2016).

In addition, *optimization reefer handling and stacking planning* is mean has been discussed in existing literature and the quantitative models have been developed (Geerlings & Duin, 2011). Optimizing the terminal operation minimizes number of re-handles, differences of workload between resources and crane total movements (Ambrosino et al., 2015) (Gifford et al., 1988). Number of re-handles is an important indicator of terminal handling, which is relevant to energy usage, container dwell time and labour cost (since reefers need to be connected and disconnected by reefer mechanisms) that in the end influences the profit and environmental impacts.

A service provided by ECT terminal in the port of Rotterdam is *an extended gateway service* (van der Lugt et al., 2014). Reefer dwell time at a maritime terminal is reduced since there are direct rail and inland waterway shuttle services carrying the reefers to an inland terminal. Product quality is improved by shortening the delivery time. With the extended gateway services, terminal throughput is increased that reduces congestions in the terminal area. Service reliability is increased with less delay during terminal operation. The probability to bundle reefer flows are increased that realizes cold chain integration; while it is highly related to the willingness of information sharing by freight forwarder, maritime carriers and hinterland transport operators. The drawback of extended gateway service is the facility investment and logistics costs since inland terminals need to be rented and operated (van der Lugt et al., 2014).

Terminal handling service quality can be improved by *increasing handling and storage capacity*, which also increases terminal throughput. With increased throughput, delivery time of the product can be reduced which is good for the product quality. But extra investment costs need to be considered by the terminal operator. Furthermore, the resource idle time might increase. Another way to increase terminal throughput is to reduce free storage time for containers (Rodrigue & Notteboom, 2009); however the service quality will be reduced and might have a negative influence on the reputation of a terminal operator. In addition, a terminal operator can provide value-added service to attract more customers, such as cold storage, quality inspection and packaging for perishable products (Port of Rotterdam). Service quality is improved with more integrative cold chain service.

In general, maritime terminal is the point where most of the actors are involved that makes a number of external factors influence the system of the terminal operator. The uncertainty of terminal operation process is increased with the increasing of the number of arriving reefers and vessel arrival frequency (Hartmann, 2004). Custom inspection procedure also increases the operation difficulty (Veenstra, 2014). Reefer dwell time at the terminal is longer that might influence the product quality. With increased uncertainty of demand, operational reliability is reduced. Furthermore, vessel stowage plan at previous terminals on the route also increases the operational difficulty (Gifford et al., 1988), since some of the re-handles are unable to be avoided unless coordination is realized among the terminals on the route. In addition, port authorities make performance related condition with terminal operators in concession contracts that require the terminal operators to pay more attention on modal split and emissions (van der Lugt et al., 2014).

v. Hinterland Transport Operators

Similar to terminal operator, criteria of hinterland transport operators are defined as service quality, operational costs and CO_2 emission. In the current operation, truck drivers are willing to *switch on and off the cooling compressor* to regulate temperature in reefer containers (Rodrigue & Notteboom, 2015). Energy usage can be saved while product quality might suffer.

Hinterland transport operators can generate economies of scale in terms of size and frequency by realizing *transport capacity pool* and *a joint cargo pool* (van der Horst & de Langen, 2008). Number of idle resources can be reduced. However, the difficulty of coordination needs to be tackled (van der Horst & de Langen, 2008). In addition, operating *intermodal transportation service* can achieve economies of scale and provide more flexible service to customers and stimulate the use of inland waterway and rail that reduces transportation costs and CO_2 emission. However, intermodal transport uses longer time if there is no coordination between different modes and service (Menesatti et al., 2014). Longer transportation time leads to more energy usage for cooling and might reduce product quality.

Another concept discussed by Crainic et al., (2009) is *intelligent freight transport*. The core of intelligent transport system (ITS) consists in obtaining, processing and distributing information for better use of the transportation system, infrastructure and services (Crainic et al., 2009). Freight ITS can be dedicated to a specific company; and it aims at simplifying and automating freight and fleet management operations and allow safety information exchanges (Crainic et al., 2009). With improved information provided by freight ITS system, it is possible to reduce the uncertainty of loads; and planning will be more accurate based on real-time information. The decision making process will be more streamlines, rapid and demand-responsive, which further improve the service level and enhance customer satisfaction (Crainic et al., 2009). Enhancement of information and decision systems will result in a modal shift to more eco-friendly modes, e.g., rail and inland waterway (Crainic et al., 2009). Furthermore, reduction of human intervention improves the service quality (Crainic et al., 2009). However, the cost of freight ITS should also be considered.

vi. Port Authorities

Port authorities are public parties that aim to improve the competitiveness of the port, the regional economic growth and sustainability (van der Lugt et al., 2014) (Port of Rotterdam, 2011). Port authorities have the landlord function that *plan the space for container growth* (Verhoeven, 2010), which will promote the development of reefer logistics. More maritime facilities, e.g., waiting berth for inland vessels and feeders will increase the land use productivity of the port that leads to a high competitiveness of the port (Port of Rotterdam, 2011). However, more facilities will put more financial pressure on the port.

Port authorities also have the regulator functions (Verhoeven, 2010), for example, the port of Rotterdam *introduced modal split clauses in concession contracts* with terminal operators to enforce a more sustainable use of port's hinterland transportation network (van der Lugt et al., 2014). The externalities can be reduced by introducing the new concession contracts, which contributes to the goal of sustainability.

Port authorities have operator functions to provide value-added services (Verhoeven, 2010). They can invest in *information exchange platform* that increases logistics services by providing more transparent cold chain.

This helps port authorities to attract more clients. Furthermore, port authorities, as neutral parties, can accommodate between conflicting interests of market players (Verhoeven, 2010). In addition, hinterland connection will be improved because of the improved information (Port of Rotterdam, 2011). Although investments need to be made, providing information exchange platform can increase the competitiveness of the port. Reefer logistics can be more integrative due to information sharing and better utilize relevant information.

In addition, port authorities sometimes work together with the market parties to *develop new hub* for reefer containers or to *invest on inland infrastructure* (Port of Rotterdam, 2011) (van der Lugt, et al., 2014). Although there is increased financial pressure on port authority, hinterland connection can be improved; and reefer distribution can be more efficient.

vii. Customs and Governments

The goal of customs is to protect import and export products. Some actions can be done which are generic for container transportation. The means of customs are *charging tariff*, *requesting reefer to be scanned or physically inspected*, *requesting ship manifest*, and *using new technology for inspection* (European Commission, 2014). Furthermore, *customs union* can be formed to improve the efficiency of control procedure (European Commission, 2014). To avoid customer inspection becoming a bottleneck, customs can *communicate with operators about the release status of the reefers* (Veenstra, 2014). In practical, freight forwarders might be not willing to share the cargo information because they want to protect the confidential customer information, which makes it more difficult for customs to control the cargo (European Commission, 2014).

For the governments, the goal is defined as to achieve sustainable development. Government parties can also *supervise the information exchange* that will increase the operational efficiency of reefer logistics. *Subsidy, tax incentive and soft loans* can be provided for renewable energy and eco-friendly modes (Wüstenhagen & Bilharz, 2006). *Infrastructure network* can also be developed by the government parties to facilitate reefer logistics.

4.3 Multi-actor System Analysis

After means of all the actors are identified, each means is analysed to find out its impact on other actors. In the following content, one means of a shipper that have impacts on other actors are depicted with multi-actor system diagrams and discussed in detail, which is to apply quality driven. Other multi-actor analysis diagrams are shown in Appendix C.

The impact on other actors is shown in Figure 6, if a shipper applies quality driven distribution. In the above analysis, it was found that applying quality driven distribution is a method to allocate the reefers with relatively low quality to nearby customer orders that improve the profit and reduces environmental impacts from a shipper's perspective. In order to make re-allocation decision of reefers, shippers need to know the real-time and accurate product information, which requires maritime carriers to invest in information collection and sharing equipment, e.g., intelligent containers, which further increases facility costs of maritime carriers (Huh, et al., 2016). In addition, number of reefers to be delivered in total is reduced because of the opportunity to make an early prediction of the spoilage. Therefore, profit of maritime carriers, terminal operators and hinterland transport operators are reduced due to less demand. On the other hand, fuel usage for cooling, shipments and handlings are also reduced, which further reduces the operational costs and emissions. Furthermore, there are other impacts on hinterland transport operators. The ability to bundle the volume of reefers are reduced. With small reefers volumes, hinterland transport operators might prefer to use single-mode road transport rather than rail and inland waterway transport (Crainic, et al., 2009). Road transportation in general consumes more energy that further increases operational costs and pollution. Compared with road transportation, rail and inland waterway have lower energy consumptions for the shipment. However in the situation of reefer logistics, rail and inland waterway transport takes longer time, which requires more energy for cooling. Therefore, there is a trade-off between the fuel usage for shipments and for cooling. Hinterland transport operators need to consider this issue when choosing transport modes. In addition, quality driven distribution has impact on freight forwarder, since the demand is more uncertain, which makes freight forwarders difficult to keep high service level. The profit of the freight forwarders might be reduced.

If a shipper orders frequent with small order quantity, there are also impacts on other actors. With reduced order quantity, the ability to bundle products into reefers might reduce, that increases total number of reefers to be delivered. With increased demand, the profit of hinterland transport operator, terminal operator and maritime carriers can be increases, while energy usage for cooling, shipping and handling will increase. Furthermore, the reefer batch size is smaller that reduces the chance to bundle reefer flow by hinterland transport operators. Therefore, hinterland operators might prefer to use single-road transport, which is better for the energy saving on cooling and is worse for the energy saving on shipment compared with rail and inland waterway. Reduced batch size also decreases economies of scale that reduces the probability for a freight forwarder to reserve large vessel and to arrange rail and inland waterway service. Maritime carriers might use smaller vessels since the demand volume is reduced for each time; and vessels needs to ship more frequently, which consumes more energy for shipments.

Freight forwarders, as an organizer of transportation service, set requirements on reefer logistics operators. Utilizing real-time information on transportation service and product quality by freight forwarders requires reefer logistics operators, i.e., maritime carriers, terminal operators and hinterland transport operators to collect and exchange an increasing amount of information with external partners. New investments are needed on equipment and information system in order to satisfy the requirements of freight forwarders. In short-term, these investments will reduce the profit of logistics operators, while planning accuracy can be improved with increased information quality. The product quality can be better maintained and operational costs can be reduced. Therefore, profit will be increased in long-term development. In addition, three means of freight forwarders, i.e., form horizontal logistics alliance, synchronize demand of multiple shippers, and provide customized service have impact on economies of scale, which will further influence the operation of logistics operators. With increased economies of scale, the maritime carriers are able to increase vessel utilization that further reduces fuel usage for shipments; hinterland transport operators have more chance to bundle reefer flows that promotes rail and inland waterway. On the other hand, large reefer batch sizes will increase terminal handling time and create congestion in the terminal area, which increases operational costs and reduces service level of terminal operators.

Decisions made by maritime carriers influence the shippers, terminal operators and hinterland transport operators in general. By reducing the number of transhipment, number of reefer trans-loading is reduced that reduces the demand of terminal operator. Energy usage for terminal handling is also reduced; however, profit is also less. Shippers gain more profit with higher product quality, since door-to-door delivery time is reduced by fewer terminal handlings. Furthermore, using vessel size leverage makes terminals become more congested, because an increasing number of reefers need to be handled at once. Door-to-door delivery time is increased that reduces product shelf life. On the other hand, with large volume of reefers, hinterland transport operators can synchronize the demand flows to promote the usage of rail and inland waterway. Therefore, using larger vessels reduce the operational cost of maritime carrier and hinterland transport operator; however, there might be congestions at the terminal. Longer handling time puts more risk on product quality. Door-to-door delivery time, which is an important factor of shippers, is closely related to product quality. Door-to-door delivery time includes maritime time, hinterland transport time and handling time. If maritime carriers use slow steaming strategy or keep maritime reefers in their own network, the maritime time will increase. Thus, terminal operators and hinterland transport operators have to speed up to meet customers' requirements on product shelf life. Hinterland operators might prefer to use truck in order to achieve high speed, which not only increases the operational costs, but also produces more pollution to the environment.

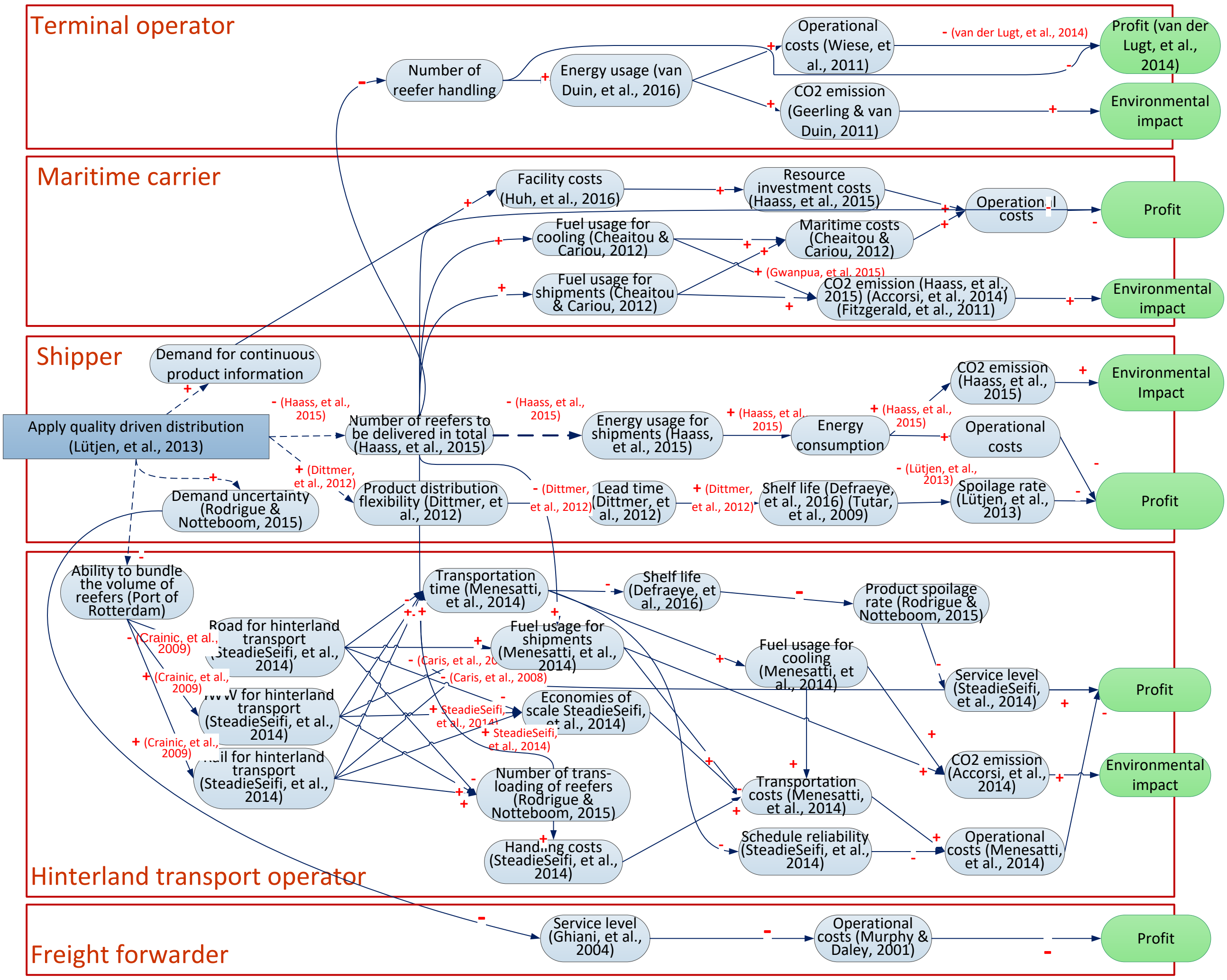


Figure 6: Impact of applying quality driven distribution by a shipper

Terminal operators supply electricity for reefers during terminal storage. A number of means of terminal operators influence shipper, hinterland operators and maritime carriers. In order to reduce the peak demand of power, terminal operators can use intermitted distribution of power among the reefer racks (van Duin, et al., 2016). However, the temperature variability is increased in reefer that might reduce the profit of shippers. By optimizing reefer handling and stacking planning, reefer terminal handling time is reduced (Rodrigue & Notteboom, 2009). The remaining due time for hinterland transport can be increased which make hinterland operators choose rail and inland waterway to reduce costs and CO_2 emission. With reduced terminal handling time, the transit time of maritime carriers can also be reduced, which is good for the product quality and saves energy for the shipments. Therefore, optimizing terminal operation also benefits maritime carriers and hinterland operations. In addition, the ECT terminal in the port of Rotterdam is applying the extended gate services that allow direct shipments of containers from the maritime terminal to an inland terminal (van der Lugt, et al., 2014). Thus, the usage of maritime reefer in the hinterland is increased, which increases the turnaround time of reefers. Maritime carriers need to carry a larger amount of reefers that cost high rent. But the trans-loading of products from maritime reefers to hinterland reefers can be avoided, which reduces handling costs and reduces physical damage to the products. From this perspective, it improves product quality and increases profit for maritime carriers. Since terminal operators arrange shuttle service of rail and inland waterway to deliver containers to inland terminals in batches, the chance to bundle containers increases, which makes a modal shift to rail and inland waterway. For hinterland operator, transportation costs can be reduced; however, shippers might not prefer the usage of rail and inland waterway due to longer transport time and more terminal handling. Therefore, it is important to arrange synchronized service with smooth connection of different transport modes to avoid long waiting. For port authority, the congestion in port area can be reduced that increases competitiveness of the port. Therefore, the port authorities also try to be involved in the development of inland terminal and to make investment together with market players (Rodrigue & Notteboom, 2009).

Hinterland transport operators operate intermodal transport service to deliver reefers from maritime terminal to cool warehouses and vice versa. Truck drivers sometimes turn off the compressor to reduce fuel consumption or to follow the regulation of municipalities (Rodrigue & Notteboom, 2015). This reduces product quality, which makes shippers lose profit. Hinterland transport can realize intelligent freight transport system, which needs companies to invest on new IT systems; however, it creases planning accuracy that reduces the loads uncertainty for maritime carriers and terminal operators. Thus, maritime carriers and terminal operations can increase their service reliability. Furthermore, freight forwarder can provide more accurate transport information to the shippers that build customer trust. Therefore, realizing intelligent freight transport systems not only benefit hinterland transport operators, but also maritime carriers, terminal operators and freight forwarders.

In general, information exchange is beneficial to and required of all logistics operators along reefer logistics processes. If they can exchange the freight and transport information along the chain, the cold chain can be more transparent and the operation can be more efficient. The port authority and government parties, as neutral parties, can support and supervise the realization of information exchange. The port of Rotterdam has invested in an information exchange platform that shares vessel, terminal handling and hinterland transport information.

Besides, the usage of rail and inland waterway can be promoted by port authorities to make concession contracts with terminal operators or by government parties to release regulations and provide subsidies. However, investment on railway and inland waterway facilities need to be made by terminal operators, e.g. railway tracks and additional berths for barge, which reduces their profit. Port authorities also work together with market players to make investment on new hubs and hinterland network for reefers, which reduce the financial pressure of market players. Then the market players are more willing to improve their facilities. With improves network, the door-to-door delivery time of reefers is reduced, which benefit for the shippers.

To conclude, there are higher and lower impacts on other actors if one actor uses a specific means. Decisions should be made by considering the integrated cold chain instead of optimize one’s own goals. The trade-offs among the actors should be considered during the decision making in order to find a global optimal solution.

5. Discussion and Conclusions

In this research, a system analysis is conducted for reefer logistics that uses information from a systematic literature review and expert interviews. The system analysis method is suitable to analyse a complex socio-technical system, such as a reefer logistics network. The approach is applicable for reefer logistic sector to understand the relations between the technological and institutional factors. It is not only suitable for single actor analysis, but also provides the relations among multiple actors. A comprehensive understanding of the reefer logistics system and the relations between different factors is achieved by using a system analysis approach.

To conclude, market players use means to meet their own objectives, while there are trade-offs on benefits and risks on their own objectives. In a multi-actor setting, actions taken by one player could probably have both higher and lower impacts on other actors’ objectives. As clients of reefer logistics operators, shippers and freight forwarders use several means to set additional requirements to maritime carriers and hinterland transport operators, such as using quality driven distribution and ordering frequently with small size. When they use these means to achieve their own goals on product quality, they require the whole cold chain to be more integrative and efficient to support their needs, which usually increases operational costs of reefer logistics operators. Among the operators, maritime carriers are strong market players. In the literature, they have the most focus. Thus the most means are found for them. When they take certain actions, there usually are interactions with hinterland transport operators and terminal operators. For instance, slow steaming strategy and vessel size leverage will increase maritime time. Consequently terminal operators and hinterland operators need to speed up their processes to compensate for the loss of shelf life. Another example is that if liner shipping companies are not willing to share maritime reefers in hinterland, hinterland transport operators must trans-load products at terminals. They also need to buy or rent hinterland reefers. Sea ports are the nodes that involved most of the actors. An efficient planning tool for terminal operation is important to increase the operational efficiency; and when the terminal handling time is reduced, it provides more flexibility to the maritime carriers and hinterland operators. About hinterland transport operator, they operate intermodal freight transport to increase service flexibility and reduce costs. This provides an opportunity for reefer logistics. However, the transit time of intermodal transport might be longer, which requires more energy for cooling.

Some means are both applicable for dry and reefer container logistics. Because of the specific characteristics of reefer logistics, i.e., perishability of the products and more energy consumption by refrigeration units, the same means have different impact on reefer logistics compared with dry container logistics. An example is intermodal transport, which reduces costs and emission for dry container logistics. However, when product perishability is taken into account, transit time becomes a more important factor, which makes intermodal transport less attractive to shippers. Trade-offs between the product quality, environmental impacts and operational costs need to be analysed in detail, to see how to design an integrated intermodal transport service network to make it more attractive to shippers who own the reefer cargo.

Information exchange is a means that benefit all actors in the reefer logistics network. It is difficult to realize, since it requires terminal operators, maritime carriers and hinterland operators to make investment on information systems and equipment. However, they all have their own goals on maximizing profit. Although it reduces profit in short-term, it will support efficient reefer logistics for long-term development. Governments and port authorities have strong position in the transition of reefer logistics, since they can use regulations, law, soft loans and subsidies to spur market players to share information. They are neutral parties that can balance the conflicted interests of market players. Therefore, they can supervise the information exchange to stimulate the collaboration among actors.

In the future, more focus can be made on reefer transhipment and hinterland transport, since the existing literature focuses more on maritime transport and reefer packaging. Further quantitative models are needed to understand the details of the characteristics of reefer logistics. The relations of the factors depicted in the system diagrams can be further analysed and verified by the quantitative models.

6. Acknowledgements

Authors are grateful to the project: Effective Use of Reefer Containers for conditioned products through the Port of Rotterdam; a transition oriented approach (EURECA) and the external partners involved in this project for kindly providing us with required information and to Netherlands Organisation for Scientific Research (NWO) for its financial support.

References

Accorsi, R., Manzini, R., & Ferrari, E. (2014). A comparison of shipping containers from technical, economic and environmental perspectives. Transportation Research Part D: Transport and Environment, 26, 52-59.

Alptekin, E., Ezan, M. A., & Kayansayan, N. (2014). Flow and heat transfer characteristics of an empty refrigerated container. In Progress in Exergy, Energy, and the Environment (pp. 641-652). Springer International Publishing.

Ambrosino, D., Paolucci, M., & Sciomachen, A. (2015). Computational evaluation of a MIP model for multi-port stowage planning problems. Soft Computing, 1-11.

Arduino, G., Carrillo Murillo, D., & Parola, F. (2015). Refrigerated container versus bulk: evidence from the banana cold chain. Maritime Policy & Management, 42(3), 228-245.

Ballieux, M. et al., (2014). Freezer Container Shipping. [Online] Available at: http://www.maritimesymposium-rotterdam.nl/uploads/Route/freezer%20container%20shipping.pdf.

Bazzazi, M., Safaei, N., & Javadian, N. (2009). A genetic algorithm to solve the storage space allocation problem in a container terminal. Computers & Industrial Engineering, 56(1), 44-52.

Blanke, M. M. (2006, August). Life cycle assessment (LCA) and food miles-an energy balance for fruit imports versus home-grown apples. In XXVII International Horticultural Congress-IHC2006: International Symposium on Sustainability through Integrated and Organic 767 (pp. 59-64).

Bollen, A. F., Tanner, D. J., Soon, C. B., East, A. R., Dagar, A., Sharshevsky, H., & Pelech, Y. (2013, September). Wireless temperature monitoring system in a global kiwifruit supply chain. In VI International Conference on Managing Quality in Chains 1091 (pp. 205-212).

Bömer, G. C., & Tadeu, R. L. (2014). The South America East Coast Reefer Cargo: A Diagnosis of a Competitive Market. IBIMA Business Review, 2014, 1-14.

Büyüközkan, G., Feyzioğlu, O., & Nebol, E. (2008). Selection of the strategic alliance partner in logistics value chain. International Journal of Production Economics, 113(1), 148-158.

Cao, T., Lee, H., Hwang, Y., Radermacher, R., & Chun, H. H. (2016). Modeling of waste heat powered energy system for container ships. Energy, 106, 408-421.

Caris, A., Macharis, C., & Janssens, G. K. (2008). Planning problems in intermodal freight transport: accomplishments and prospects. Transportation Planning and Technology, 31(3), 277-302.

Chao, S. L., & Chen, C. C. (2015). Applying a time–space network to reposition reefer containers among major Asian ports. Research in Transportation Business & Management, 17, 65-72.

Cheaitou, A., & Cariou, P. (2012). Liner shipping service optimisation with reefer containers capacity: an application to northern Europe–South America trade. Maritime Policy & Management, 39(6), 589-602.

Chopra, S., & Meindl, P. (2007). Supply chain management. Strategy, planning & operation. Das summa summarum des management, 265-275.

Copertaro, B., Principi, P., & Fioretti, R. (2016). Thermal performance analysis of PCM in refrigerated container envelopes in the Italian context–Numerical modeling and validation. Applied Thermal Engineering, 102, 873-881.

Coyle, W., Hall, W., & Ballenger, N. (2001). Transportation technology and the rising share of US perishable food trade. Changing Structure of Global Food Consumption and Trade, 31-40.

Crainic, T. G., Gendreau, M., & Potvin, J. Y. (2009). Intelligent freight-transportation systems: Assessment and the contribution of operations research. Transportation Research Part C: Emerging Technologies, 17(6), 541-557.

Defraeye, T., Cronjé, P., Verboven, P., Opara, U. L., & Nicolai, B. (2015b). Exploring ambient loading of citrus fruit into reefer containers for cooling during marine transport using computational fluid dynamics. Postharvest Biology and Technology, 108, 91-101.

Defraeye, T., Nicolai, B., Kirkman, W., Moore, S., van Niekerk, S., Verboven, P., & Cronjé, P. (2016). Integral performance evaluation of the fresh-produce cold chain: A case study for ambient loading of citrus in refrigerated containers. Postharvest Biology and Technology, 112, 1-13.

Defraeye, T., Verboven, P., Opara, U. L., Nicolai, B., & Cronjé, P. (2015a). Feasibility of ambient loading of citrus fruit into refrigerated containers for cooling during marine transport. Biosystems Engineering, 134, 20-30.

Dickson, R., Cherry, M. & Boland, A., (2013). Carrying Out a Systematic Review as a Master's Thesis. In: A. Boland, M. Cherry & R. Dickson, eds. Doing a Systematic Review: A Student's Guide. s.l.:SAGE Publications, pp. 1-16.

Dittmer, P., Veigt, M., Scholz-Reiter, B., Heidmann, N., & Paul, S. (2012, May). The intelligent container as a part of the Internet of Things. In Cyber Technology in Automation, Control, and Intelligent Systems (CYBER), 2012 IEEE International Conference on (pp. 209-214). IEEE.

Dodd, M. C. (2012, June). Managing airflow inside reefer containers benefits produce quality. In VII International Postharvest Symposium 1012 (pp. 1159-1166).

Drewry, (2014). Global reefer trades –2014. [Online] Available at: http://www.joc.com/sites/default/files/u221106/SpeakerPresentations/March3/Dekker_Neil_Cool_Cargoes_Presentation.pdf.

Drewry, (2015). Reefer Containership Capacity to Increase 20% by 2018. [Online] Available at: http://www.drewry.co.uk/news.php?id=388.

Enserink, B., Kwakkel, J., Bots, P., Hermans, L., Thissen, W., & Koppenjan, J. (2010). Policy analysis of multi-actor systems. Eleven International Publ.

European Commission, (2014). The European Union explained: Customs, Brussels: European Commission. [Online] Available at: http://www.eesc.europa.eu/resources/docs/customs_en-1.pdf.

Eyring, V., Isaksen, I. S., Berntsen, T., Collins, W. J., Corbett, J. J., Endresen, O., ... & Stevenson, D. S. (2010). Transport impacts on atmosphere and climate: Shipping. Atmospheric Environment, 44(37), 4735-4771.

Fahmy, K., & Nakano, K. (2012, September). Favorable transportation conditions preventing quality loss of'Jiro'persimmon for exports. In II Asia Pacific Symposium on Postharvest Research Education and Extension: APS2012 1011 (pp. 73-80).

Filina-Dawidowicz, L., Iwańkowicz, R., & Rosochacki, W. (2015). Risk measures of load loss during service of refrigerated containers in seaports. Archives of Transport, 34.

Filina, L., & Filin, S. (2008). An analysis of influence of lack of the electricity supply to reefer containers serviced at sea ports on storing conditions of cargoes contained in them. Polish Maritime Research, 15(4), 96-102.

Fitzgerald, W. B., Howitt, O. J., Smith, I. J., & Hume, A. (2011). Energy use of integral refrigerated containers in maritime transportation. Energy Policy, 39(4), 1885-1896.

Ghiani, G., Laporte, G., & Musmanno, R. (2004). Introduction to logistics systems planning and control. John Wiley & Sons.

Geerlings, H., & Van Duin, R. (2011). A new method for assessing CO 2-emissions from container terminals: a promising approach applied in Rotterdam. Journal of Cleaner Production, 19(6), 657-666.

Gwanpua, S. G., Verboven, P., Leducq, D., Brown, T., Verlinden, B. E., Bekele, E., ... & Hoang, H. M. (2015). The FRISBEE tool, a software for optimising the trade-off between food quality, energy use, and global warming impact of cold chains. Journal of Food Engineering, 148, 2-12.

Haass, R., Dittmer, P., Veigt, M., & Lütjen, M. (2015). Reducing food losses and carbon emission by using autonomous control–A simulation study of the intelligent container. International Journal of Production Economics, 164, 400-408.

Harrison, M., & Herlihy, P. (1995). Controlled atmosphere systems for marine vessels. Marine technology, 32(2), 147-150.

Hartmann, S. (2004). Generating scenarios for simulation and optimization of container terminal logistics. OR Spectrum, 26(2), 171-192.

Hartmann, S. (2013). Scheduling reefer mechanics at container terminals. Transportation Research Part E: Logistics and Transportation Review, 51, 17-27.

Heidmann, N., Janßen, S., Lang, W., & Paul, S. (2012). Implementation and verification of a low-power UHF/LF wireless sensor network as part of the intelligent container. Procedia Engineering, 47, 68-71.

Hesse, M., & Rodrigue, J. P. (2004). The transport geography of logistics and freight distribution. Journal of transport geography, 12(3), 171-184.

Huh, J. H., Koh, T., & Seo, K. (2016). A Design of Reefer Container Monitoring System Using PLC-Based Technology. In Proceedings of the 2015 International Conference on Electrical and Information Technologies for Rail Transportation (pp. 795-802). Springer Berlin Heidelberg.

James, S. J., James, C., & Evans, J. A. (2006). Modelling of food transportation systems–a review. International Journal of Refrigeration, 29(6), 947-957.

Jedermann, R., Geyer, M., Praeger, U., & Lang, W. (2013). Sea transport of bananas in containers–Parameter identification for a temperature model. Journal of Food Engineering, 115(3), 330-338.

Jedermann, R., Praeger, U., Geyer, M., & Lang, W. (2014). Remote quality monitoring in the banana chain. Philosophical Transactions of the Royal Society of London A: Mathematical, Physical and Engineering Sciences, 372(2017), 20130303.

Jiang, Yan-Qiao, & Shi-Liang, W. (1996). Statistical analysis of reliability of container refrigeration units. International journal of refrigeration, 19(6), 407-413.

Jiménez-Ariza, H. T., Correa, E. C., Diezma, B., Moya-González, A., Arranz, F. J., & Barreiro, P. (2015). Multi-distributed wireless sensors for monitoring a long distance transport in a reefer container. International Journal of Postharvest Technology and Innovation, 5(2), 149-166.

Jolly, P. G., Tso, C. P., Wong, Y. W., & Ng, S. M. (2000). Simulation and measurement on the full-load performance of a refrigeration system in a shipping container. International Journal of Refrigeration, 23(2), 112-126.

Jung, J. U., & Kim, H. S. (2015, August). Big Data Governance for Smart Logistics: A Value-Added Perspective. In Conference on Smart Spaces (pp. 95-103). Springer International Publishing.

Kuo, J. C., & Chen, M. C. (2010). Developing an advanced multi-temperature joint distribution system for the food cold chain. Food control, 21(4), 559-566.

Lawton, A. & Rhodes, C., (2014). Proceedings from 3rd IIR International Conference on Sustainability and the Cold Chain: Development of a fruit simulator to test controlled atmosphere systems in transport systems. St Mary's University, TwickenhamLondon; United Kingdom.
Lindstad, H., Asbjørnslett, B. E., & Strømman, A. H. (2011). Reductions in greenhouse gas emissions and cost by shipping at lower speeds. Energy Policy, 39(6), 3456-3464.
Litman, T., & Burwell, D. (2006). Issues in sustainable transportation. International Journal of Global Environmental Issues, 6(4), 331-347.
Lu, H. A., Chu, C. W., & Che, P. Y. (2010). Seasonal slot allocation planning for a container liner shipping service. Journal of Marine Science and Technology, 18(1), 84-92.
Luning, P. A., & Marcelis, W. J. (2009). A food quality management research methodology integrating technological and managerial theories. Trends in food science & technology, 20(1), 35-44.
Lütjen, M., Dittmer, P., & Veigt, M. (2013). Quality driven distribution of intelligent containers in cold chain logistics networks. Production Engineering, 7(2-3), 291-297.
Maersk Line, (2010). Reefer Containers The present and the future. Cape Town, s.n. paper presented at the annual meeting of Cool Chain Association workshop 2010, Cape Town, South Africa. Abstract retrieved from http://coolchain.org/Websites/cca/Images/CCA%20Workshop%20SA%202010%20Presentations/MAERSK_HenrikLindhardt_Reefers_the%20present%20and%20future.pdf.
Macharis, C., & Pekin, E. (2009). Assessing policy measures for the stimulation of intermodal transport: a GIS-based policy analysis. Journal of Transport Geography, 17(6), 500-508.
Martin, G. L., Randhawa, S. U., & McDowell, E. D. (1988). Computerized container-ship load planning: A methodology and evaluation. Computers & Industrial Engineering, 14(4), 429-440.
Meijer, M. (2007). Supply Chain Security in Container Transport-Recommendations Towards an Improved Information System Architecture. Master's degree, Erasmus University Rotterdam.
Menesatti, P., Pallottino, F., De Prisco, N., & Laderchi, D. R. (2014). Intermodal vs. conventional logistic of refrigerated products: a case study from Southern to Northern Europe. Agricultural Engineering International: CIGR Journal, 80-87.
Moureh, J., Tapsoba, S., Derens, E., & Flick, D. (2009). Air velocity characteristics within vented pallets loaded in a refrigerated vehicle with and without air ducts. International journal of refrigeration, 32(2), 220-234.
Murphy, P. R., & Daley, J. M. (2001). Profiling international freight forwarders: an update. International Journal of Physical Distribution & Logistics Management, 31(3), 152-168.
Murty, K. G., Liu, J., Wan, Y. W., & Linn, R. (2005). A decision support system for operations in a container terminal. Decision Support Systems, 39(3), 309-332.
Notteboom, T. E., & Winkelmans, W. (2001). Structural changes in logistics: how will port authorities face the challenge?. Maritime Policy & Management, 28(1), 71-89.
OECD, 1996. Towards Sustainable Trnasportation. Paris, OECD.
Palafox-Albarrán, J., Jedermann, R., & Lang, W. (2011). Energy-efficient parameter adaptation and prediction algorithms for the estimation of temperature development inside a food container. In Informatics in Control, Automation and Robotics (pp. 77-90). Springer Berlin Heidelberg.
Piala, P., & Dávid, A. (2016). Transport of Tropical Fruits to Central Europe. NAŠE MORE, Znanstveno-stručni časopis za more i pomorstvo, 63(2), 62-65.
Port of Rotterdam, n.d. Port Community System. [Online] Available at: https://www.portofrotterdam.com/en/connections-logistics/logistics-maritime-services/port-community-system.
Port of Rotterdam, 2011. Port Vission 2030 Port Compass. [Online] Available at: https://www.portofrotterdam.com/sites/default/files/upload/Port-Vision/Port-Vision-2030.pdf.
Port of Rotterdam, 2014. Modal split maritime containers. [Online] Available at: https://www.portofrotterdam.com/sites/default/files/Modal%20split%20maritieme%20containers%202014-%202011.pdf.
Port of Rotterdam, n.d. Rotterdam as Your Cool Port. [Online] Available at: https://www.portofrotterdam.com/sites/default/files/downloads/rotterdam_cool_port.pdf.
Punt, H., & Huysamer, M. (2004, November). Temperature variances in a 12 m integral reefer container carrying plums under a dual temperature shipping regime. In International Conference Postharvest Unlimited Downunder 2004 687 (pp. 289-296).
Rodrigue, J. P., Comtois, C., & Slack, B. (2013). The geography of transport systems. Routledge.

Rodrigue, J. P., & Notteboom, T. (2009). The terminalization of supply chains: reassessing the role of terminals in port/hinterland logistical relationships. Maritime Policy & Management, 36(2), 165-183.

Rodrigue, J. P., & Notteboom, T. (2013). The cold chain and its logistics. Rodrigue JP, The Geography of Transport Systems. New York: Routledge. Available online (https://people. hofstra. edu/geotrans/eng/ch5en/appl5en/ch5a5en. html), accessed on May, 29, 2016.

Rodrigue, J. P., & Notteboom, T. (2015). Looking inside the box: Evidence from the containerization of commodities and the cold chain. Maritime Policy & Management, 42(3), 207-227.

Ruiz-Garcia, L., Barreiro, P., Rodríguez-Bermejo, J., & Robla, J. I. (2007). Review. Monitoring the intermodal, refrigerated transport of fruit using sensor networks. Spanish Journal of Agricultural Research, 5(2), 142-156.

Selviaridis, K., & Spring, M. (2007). Third party logistics: a literature review and research agenda. The International Journal of Logistics Management, 18(1), 125-150.

Sepe, R., Armentani, E., & Pozzi, A. (2015). Development and stress behaviour of an innovative refrigerated container with pcm for fresh and frozen goods. Multidiscipline Modeling in Materials and Structures, 11(2), 202-215.

Setyawan, N., Mulyawanti, I., Setyabudi, D. A., & Rachmat, R. (2012, September). Trials for application of handling technology in mango export. In II Asia Pacific Symposium on Postharvest Research Education and Extension: APS2012 1011 (pp. 405-411).

Smale, N. J., Moureh, J., & Cortella, G. (2006). A review of numerical models of airflow in refrigerated food applications. International Journal of Refrigeration, 29(6), 911-930.

Snowdon, A. L. (2008, October). Carriage of bananas (Musa spp.) in refrigerated ships and containers: preshipment and shipboard factors influencing cargo out-turn condition. In IV International Symposium on Banana: International Conference on Banana and Plantain in Africa: Harnessing International 879 (pp. 375-383).

Sørensen, K. K., Nielsen, J. D., & Stoustrup, J. (2014). Modular simulation of reefer container dynamics. Simulation, 90(3), 249-264.

SteadieSeifi, M., Dellaert, N. P., Nuijten, W., Van Woensel, T., & Raoufi, R. (2014). Multimodal freight transportation planning: A literature review. European journal of operational research, 233(1), 1-15.

Steenken, D., Voß, S., & Stahlbock, R. (2004). Container terminal operation and operations research-a classification and literature review. OR spectrum, 26(1), 3-49.

Tanner, D. J., & Amos, N. D. (2002, June). Temperature variability during shipment of fresh produce. In International Conference: Postharvest Unlimited 599 (pp. 193-203).

Top Sector Logistics, (2011. June). Partituur naar de top – Adviesrapport Topteam Logistiek. [Online] Available at: http://www.topsectorlogistiek.nl/wp-content/uploads/2014/10/Partituur-naar-de-Top-Adviesrapport-Topteam-Logistiek-2011_2013-10-01_52.pdf.

Topsector Logistiek, (2012). Top Sector Logistics. [Online] Available at: http://www.nwo.nl/binaries/content/documents/nwo-en/common/documentation/application/nwo/top-grants-social-sciences---logistics.

Trinidad, M., Bósquez, E., Escalona, H., Diaz de Leon, F., Pérez Flores, L., Kerbel, C., ... & Pérez, L. (1996, September). Controlled Atmospheres (5% CO2-5% O2 AND 10% CO2-5% O2) Do Not Significantly Increase The Storage Life Of Refrigerated Kent Mangoes. In V International Mango Symposium 455 (pp. 643-653).

Tso, C. P., Cheng, Y. C., & Lai, A. C. K. (2006). Dynamic behavior of a direct expansion evaporator under frosting condition. Part II. Field investigation on a shipping container. International journal of refrigeration, 29(4), 624-631.

Tso, C. P., Wong, Y. W., Jolly, P. G., & Ng, S. M. (2001). A comparison of hot-gas by-pass and suction modulation method for partial load control in refrigerated shipping containers. International Journal of Refrigeration, 24(6), 544-553.

Tutar, M., Erdogdu, F., & Toka, B. (2009). Computational modeling of airflow patterns and heat transfer prediction through stacked layers' products in a vented box during cooling. International Journal of refrigeration, 32(2), 295-306.

van den Berg, R. (2015). Strategies and new business models in intermodal hinterland transport.

Van den Berg, R., & De Langen, P. W. (2015). Towards an ‘inland terminal centred’value proposition. Maritime Policy & Management, 42(5), 499-515.

Van Der Horst, M. R., & De Langen, P. W. (2008). Coordination in hinterland transport chains: a major challenge for the seaport community. Maritime Economics & Logistics, 10(1-2), 108-129.

van der Lugt, L. M., Rodrigues, S. B., & Van den Berg, R. (2014). Co-evolution of the strategic reorientation of port actors: insights from the Port of Rotterdam and the Port of Barcelona. Journal of Transport Geography, 41, 197-209.

Van der Waal, J. W. H., & Zongo, A. (2010, July). Developing a Fresh Mango Export Value Chain with West-African Smallholder Mango Farmers. In III International Symposium on Improving the Performance of Supply Chains in the Transitional Economies 895 (pp. 283-291).

van Duin, J. H. R., Geerlings, H., Oey, M. A., & Verbraeck, A. (2017). Keep It Cool: Reducing Energy Peaks of Reefers at Terminals (No. 17-00483).

Veenstra, A. (2005). Empty container reposition: the port of Rotterdam case. Managing closed-loop supply chains, 65-76.

Veenstra, A. (2015). Ocean transport and the facilitation of trade. In Handbook of Ocean Container Transport Logistics (pp. 429-450). Springer International Publishing.

Verdijck, G. J. C., & Van Straten, G. (2002). A modelling and control structure for product quality control in climate-controlled processing of agro-material. Control Engineering Practice, 10(5), 533-548.

Verhoeven, P. (2010). A review of port authority functions: towards a renaissance?. Maritime Policy & Management, 37(3), 247-270.

Vis, I. F., & De Koster, R. (2003). Transshipment of containers at a container terminal: An overview. European journal of operational research, 147(1), 1-16.

Walker, W. E. (2000). Policy analysis: a systematic approach to supporting policymaking in the public sector. Journal of Multicriteria Decision Analysis, 9(1-3), 11.

Wiese, J., Suhl, L., & Kliewer, N. (2011). Planning container terminal layouts considering equipment types and storage block design. Handbook of terminal planning, 219-245.

Wüstenhagen, R., & Bilharz, M. (2006). Green energy market development in Germany: effective public policy and emerging customer demand. Energy policy, 34(13), 1681-1696.

Yin, J., Zhang, X., Lu, Q., Xin, C., Liu, C., & Chen, Z. (2012). IOT based provenance platform for vegetables supplied to Hong Kong. In Recent Advances in Computer Science and Information Engineering (pp. 591-596). Springer Berlin Heidelberg.

Appendix A: Systematic Literature Review Strategy

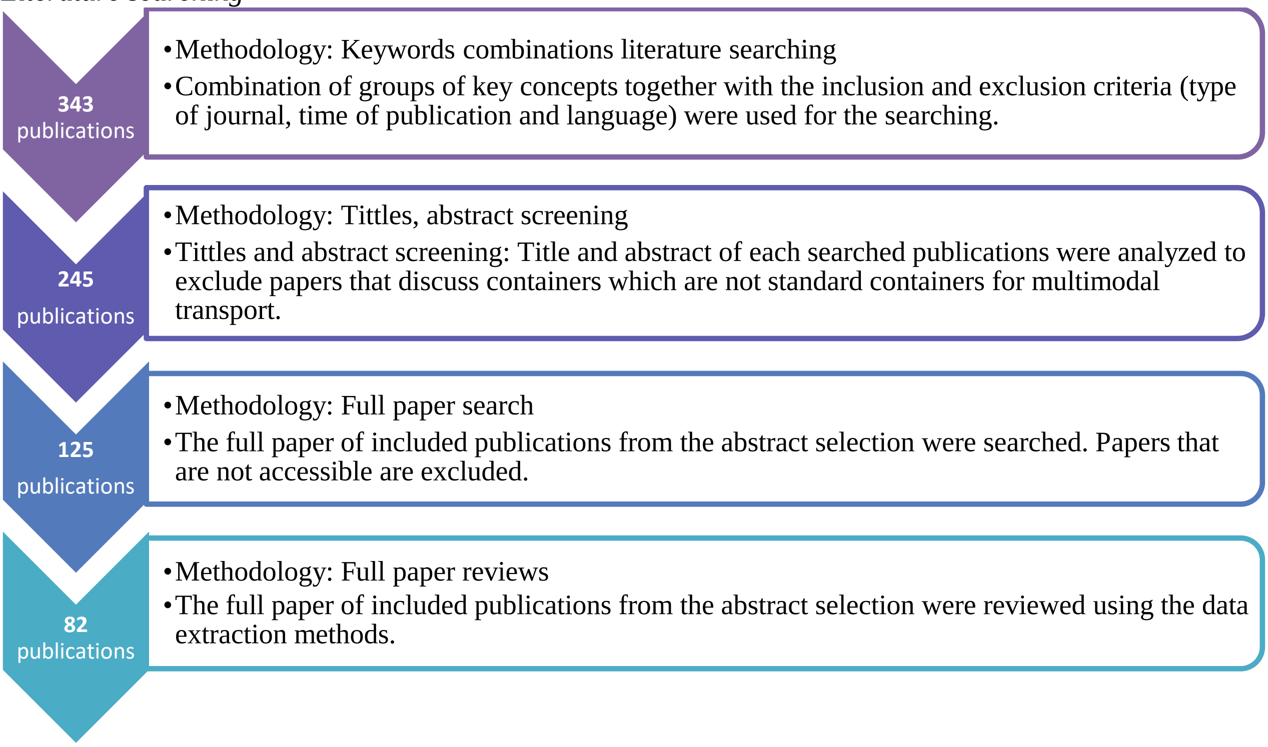
Inclusion criteria

1. Scope: all segments and the involved actors in reefer logistics
2. The source of publication: articles from Scopus
3. Time frame: publications since 1960, as the first refrigerated marine containers, based upon converted truck units, came into use in the 60's (Maersk Line, 2010)
4. Publication language: English

Exclusion criteria

1. Publications that discussed containers which are not standard containers for multimodal transport
2. Articles published in trade journal

Literature searching



Data extraction

The information and data in the 82 publications are put in the table below.

Table 3: Data extraction

#	Title	Author	Topic	Actors	Objectives	Means	Internal factors	External factors	Other data

Appendix B: Single Actor System Analysis

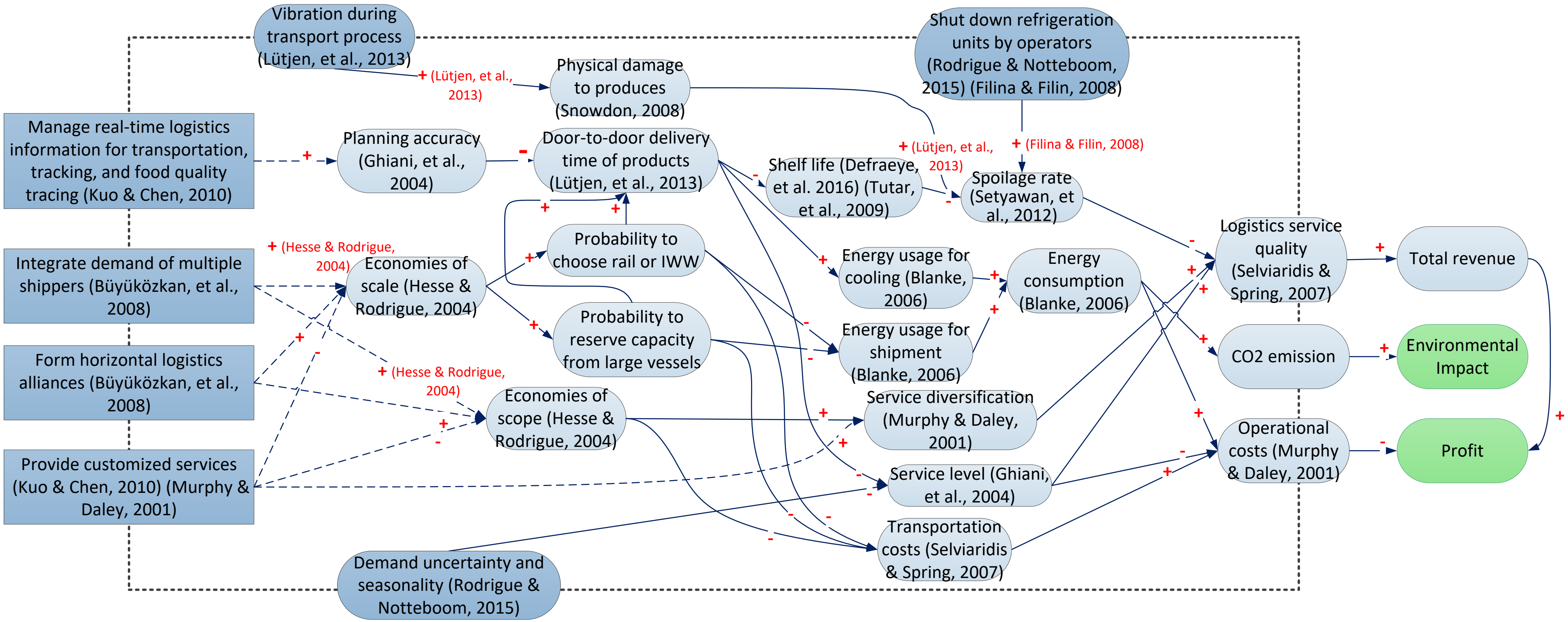


Figure 7: System diagram of a freight forwarder

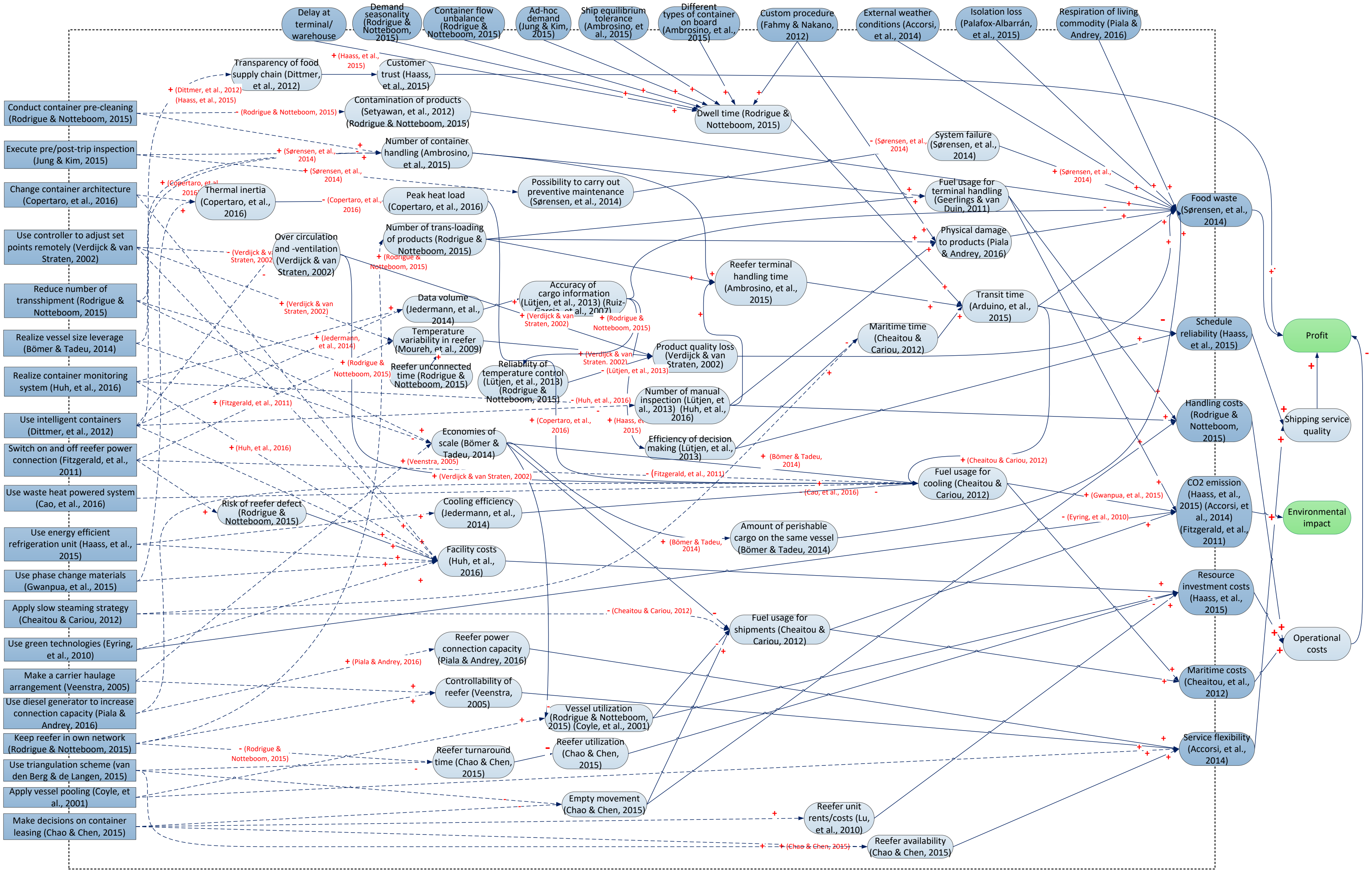


Figure 8: System diagram of a maritime carrier

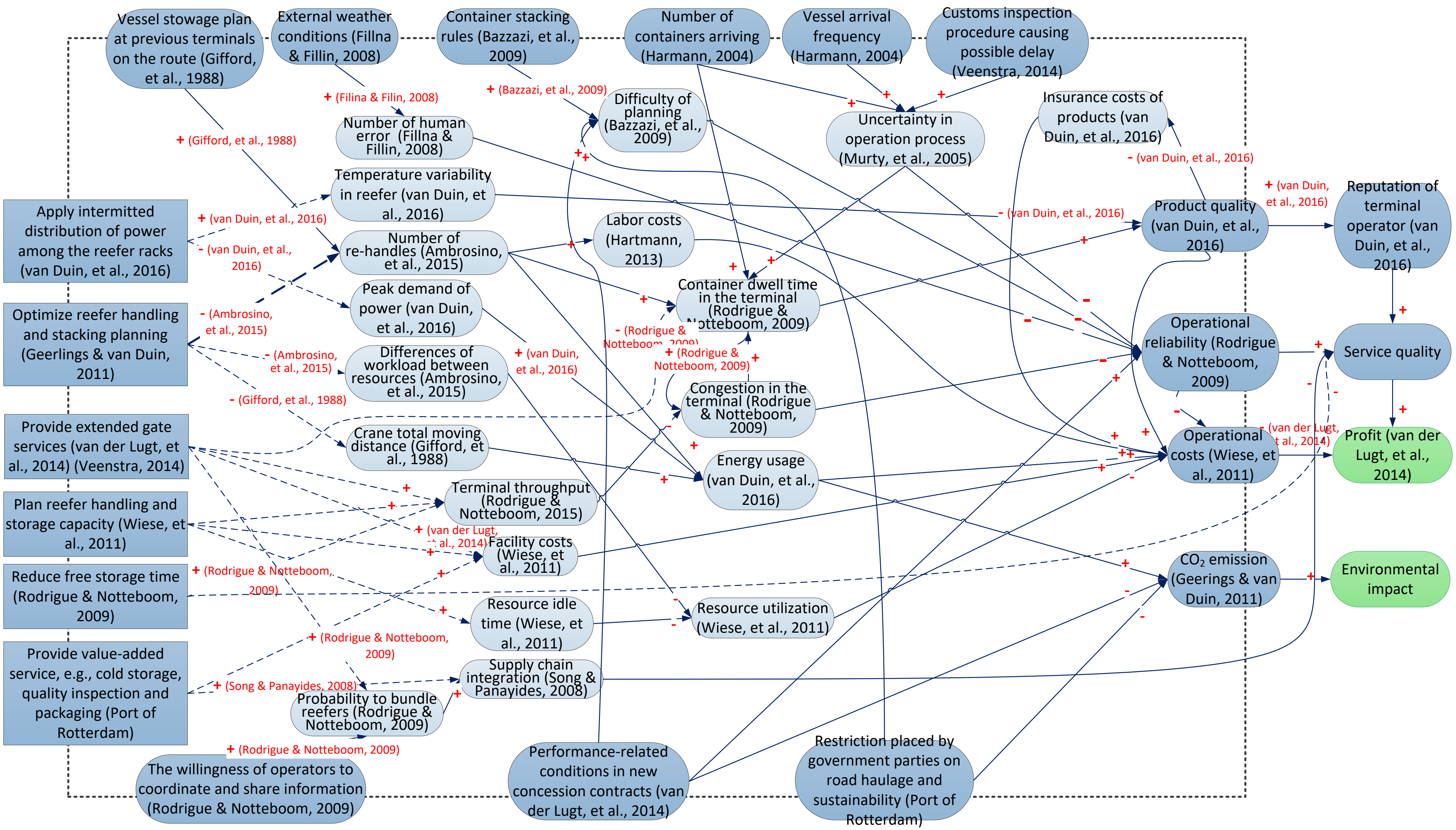


Figure 9: System diagram of a terminal operator

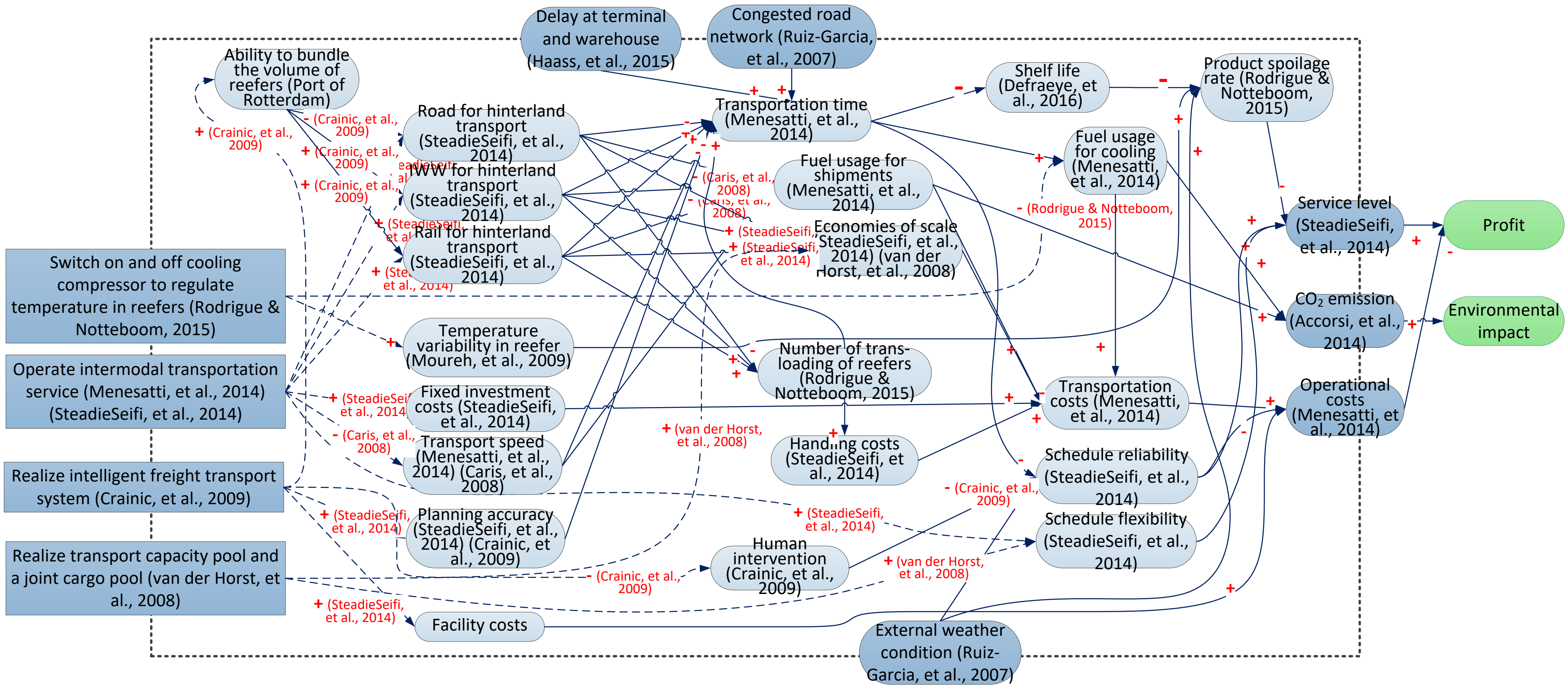


Figure 10: System diagram of a hinterland transport operator

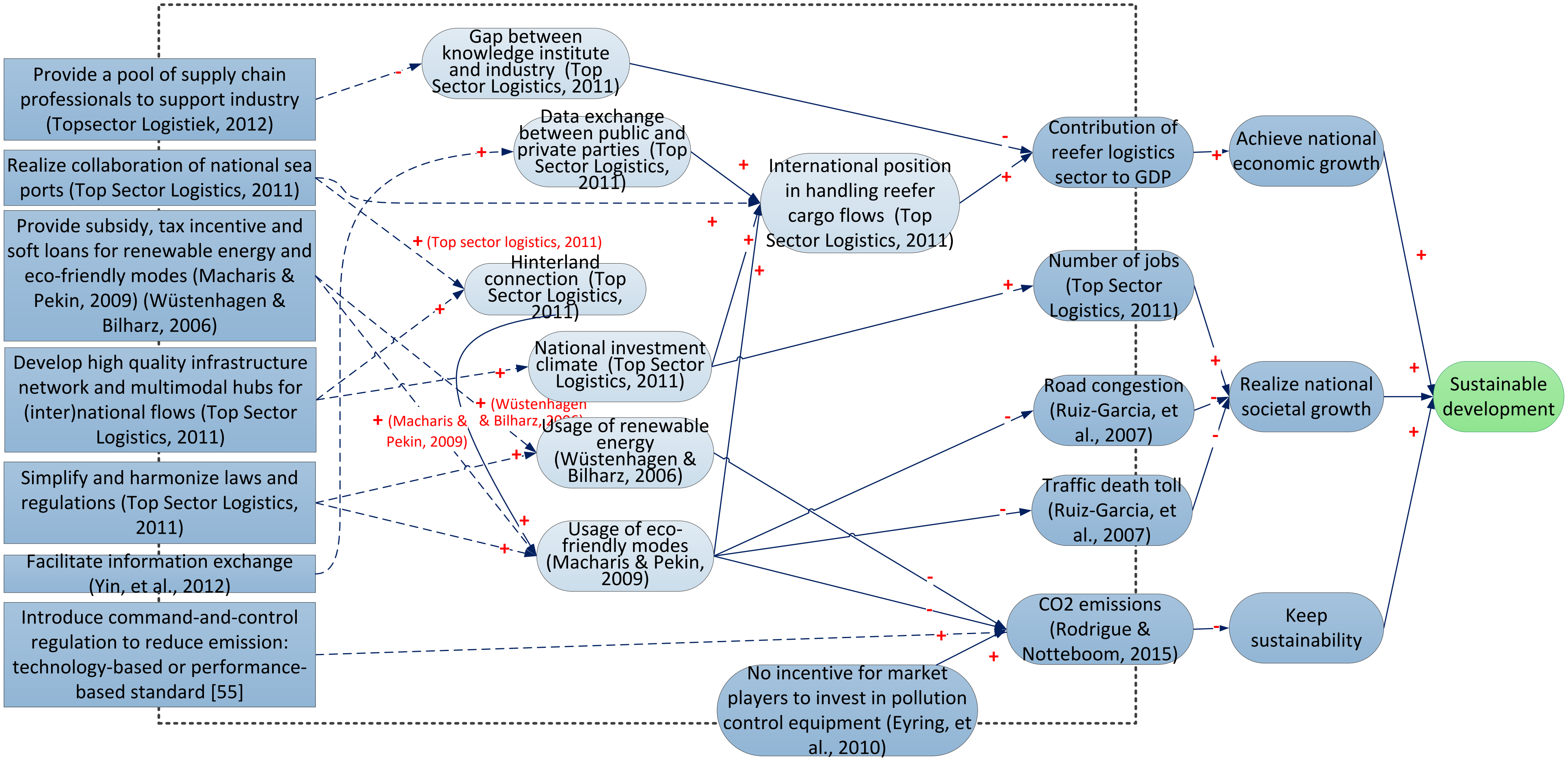


Figure 11: System diagram of a government

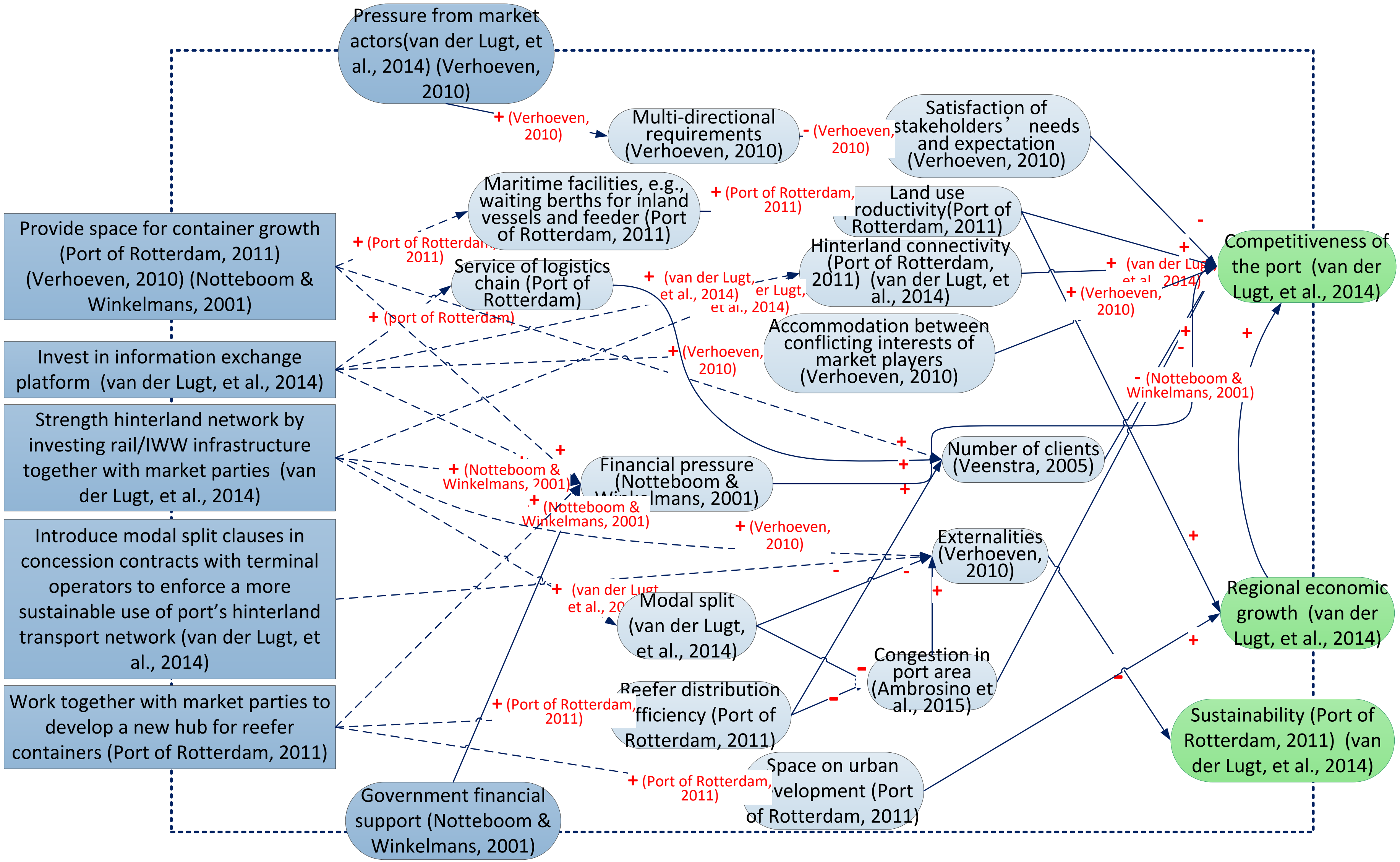


Figure 12: System diagram of a port authority

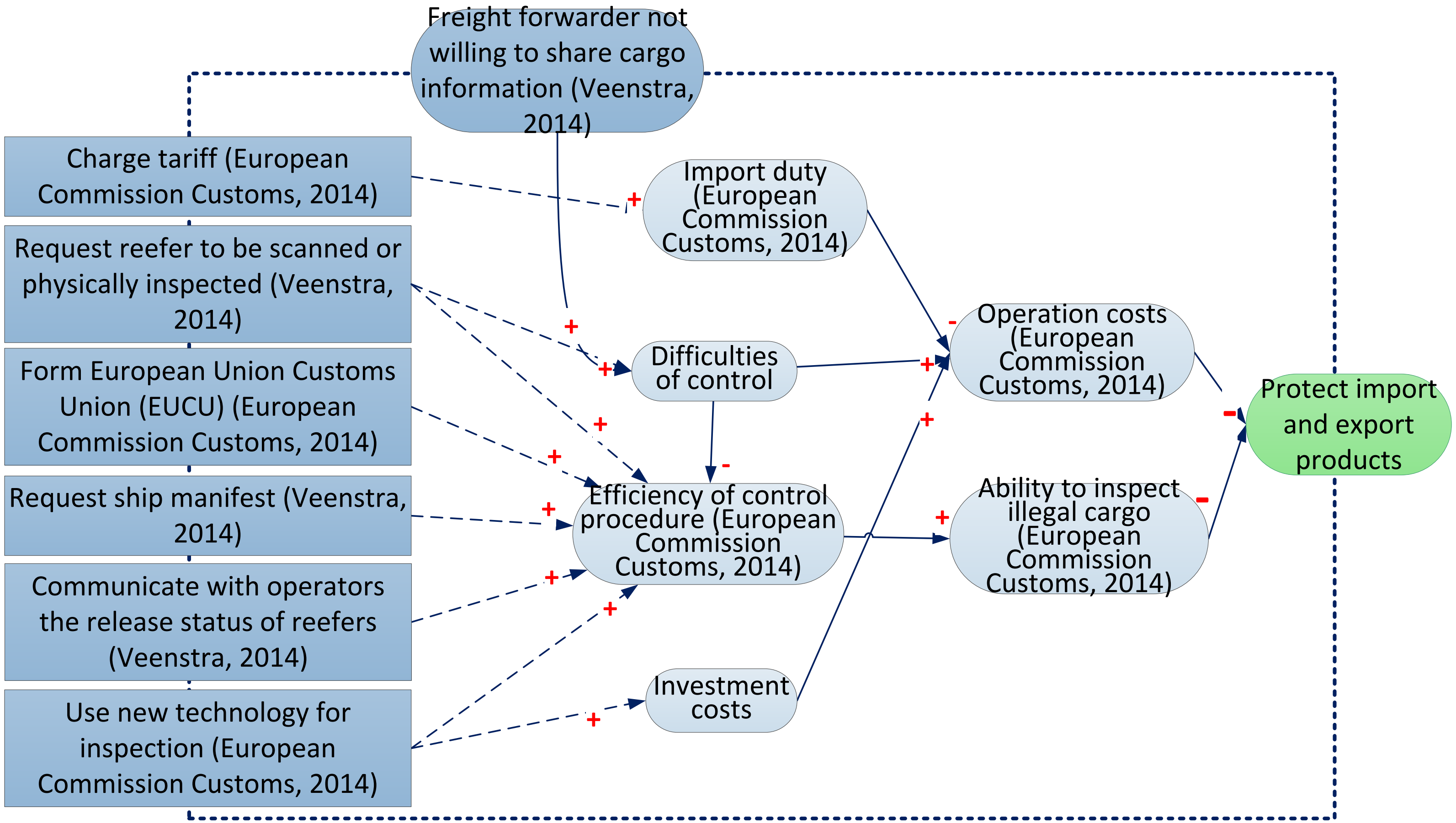


Figure 13: System diagram of a custom

Appendix C: Multiple Actors System Analysis

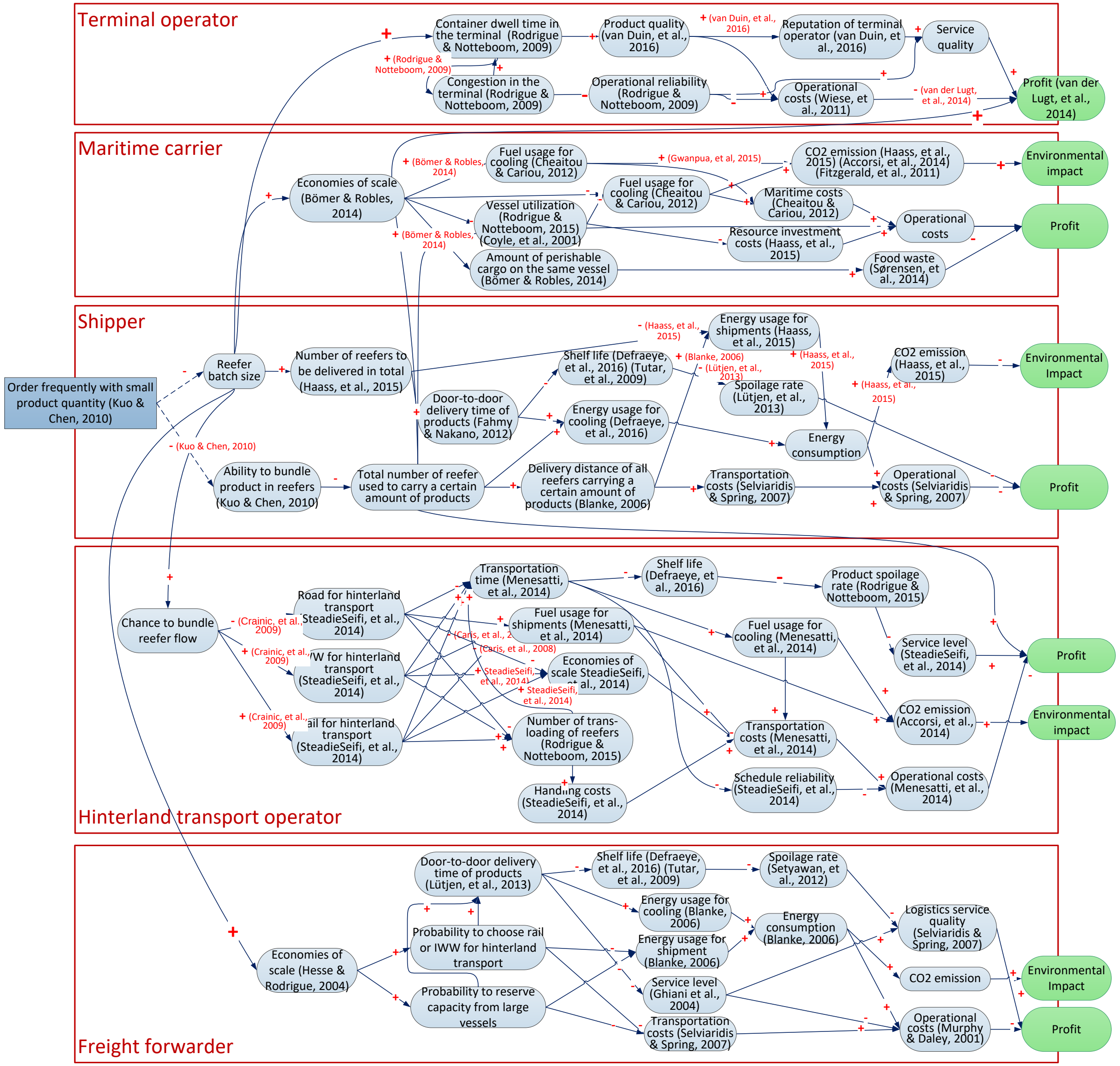


Figure 14: Impacts on other actors if a shipper orders frequently with small product quantity

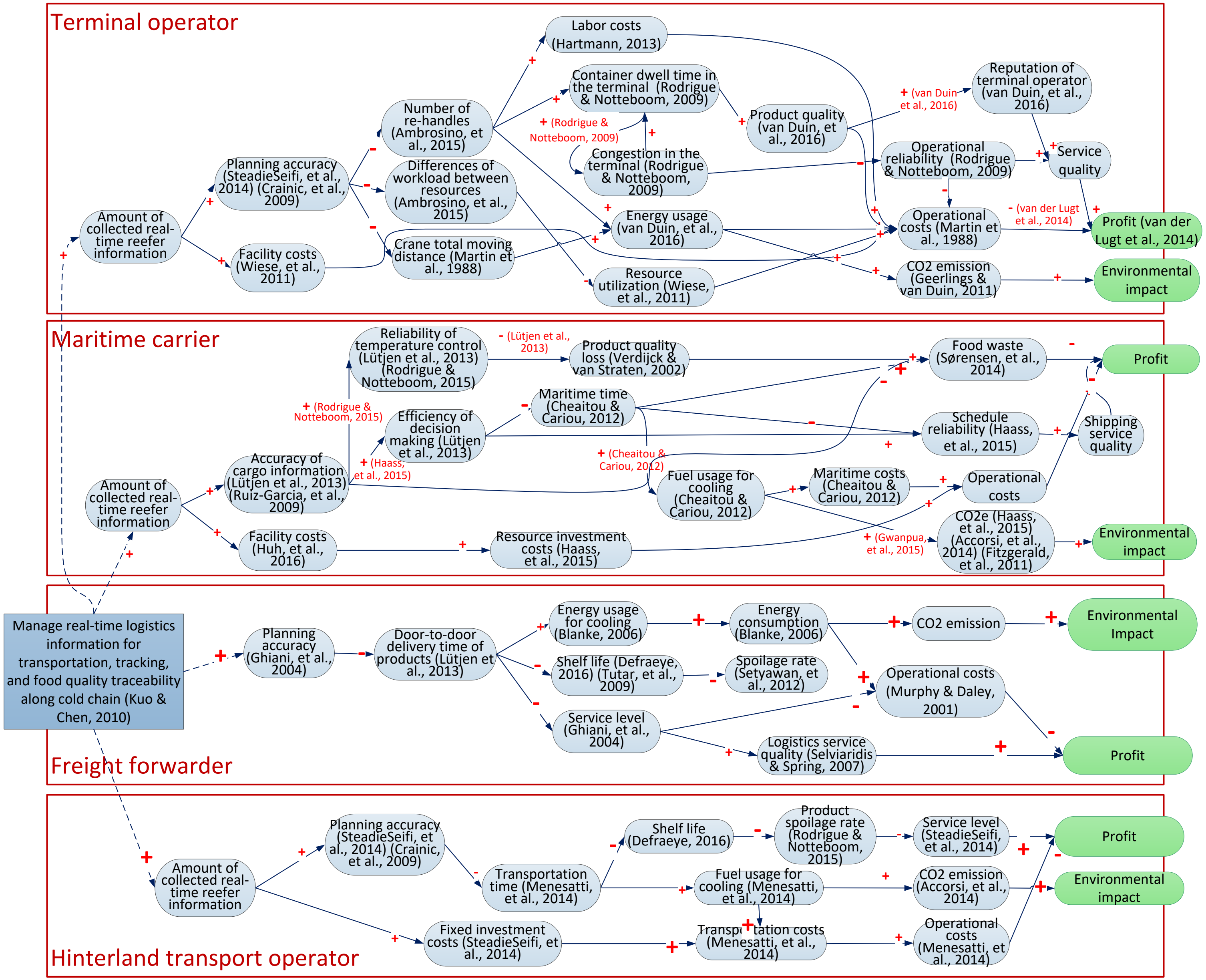


Figure 15: Impacts on other actors if a freight forwarder requests information

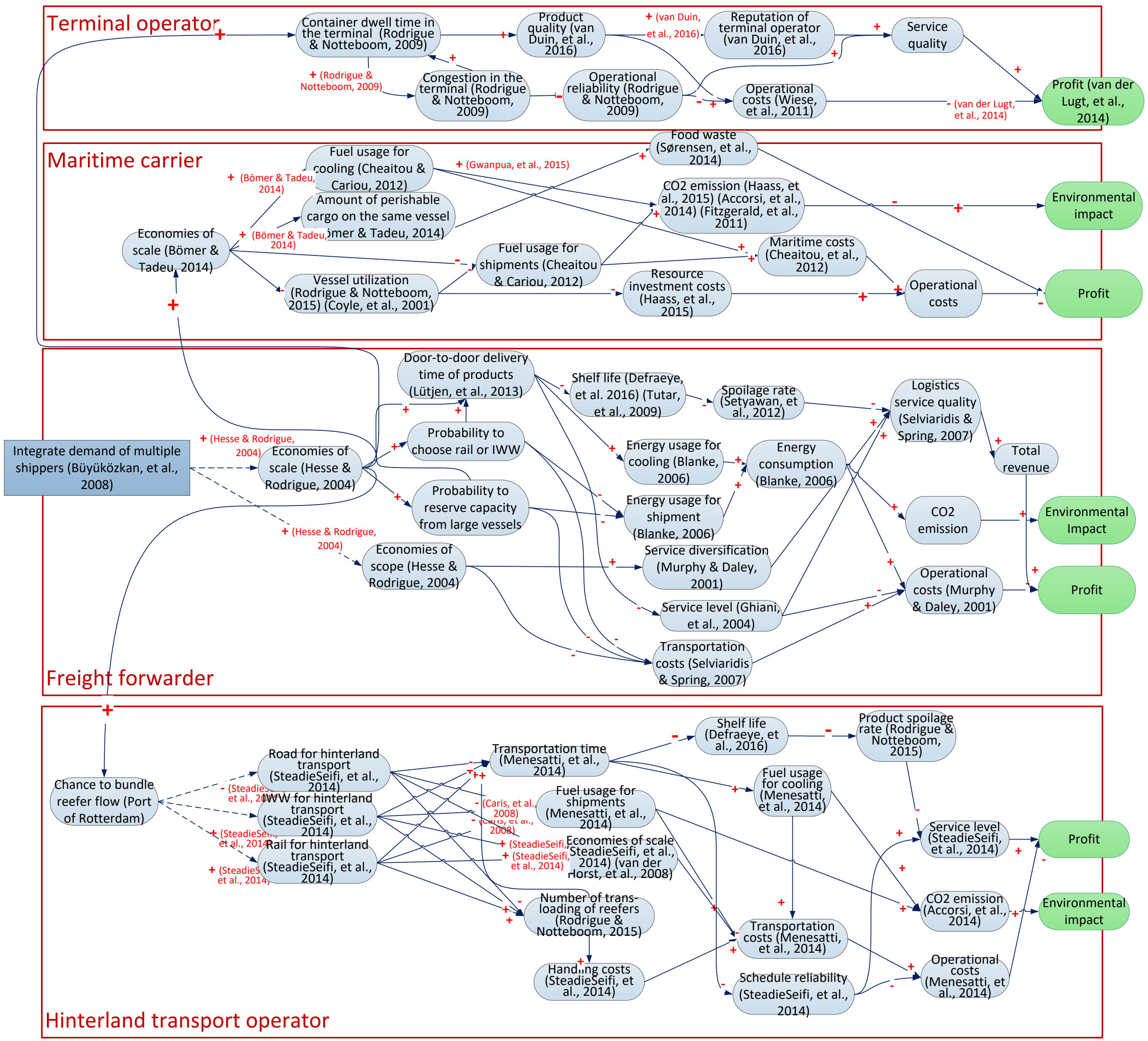


Figure 16: Impacts on other actors if a freight forwarder synchronizes demand of multiple shippers

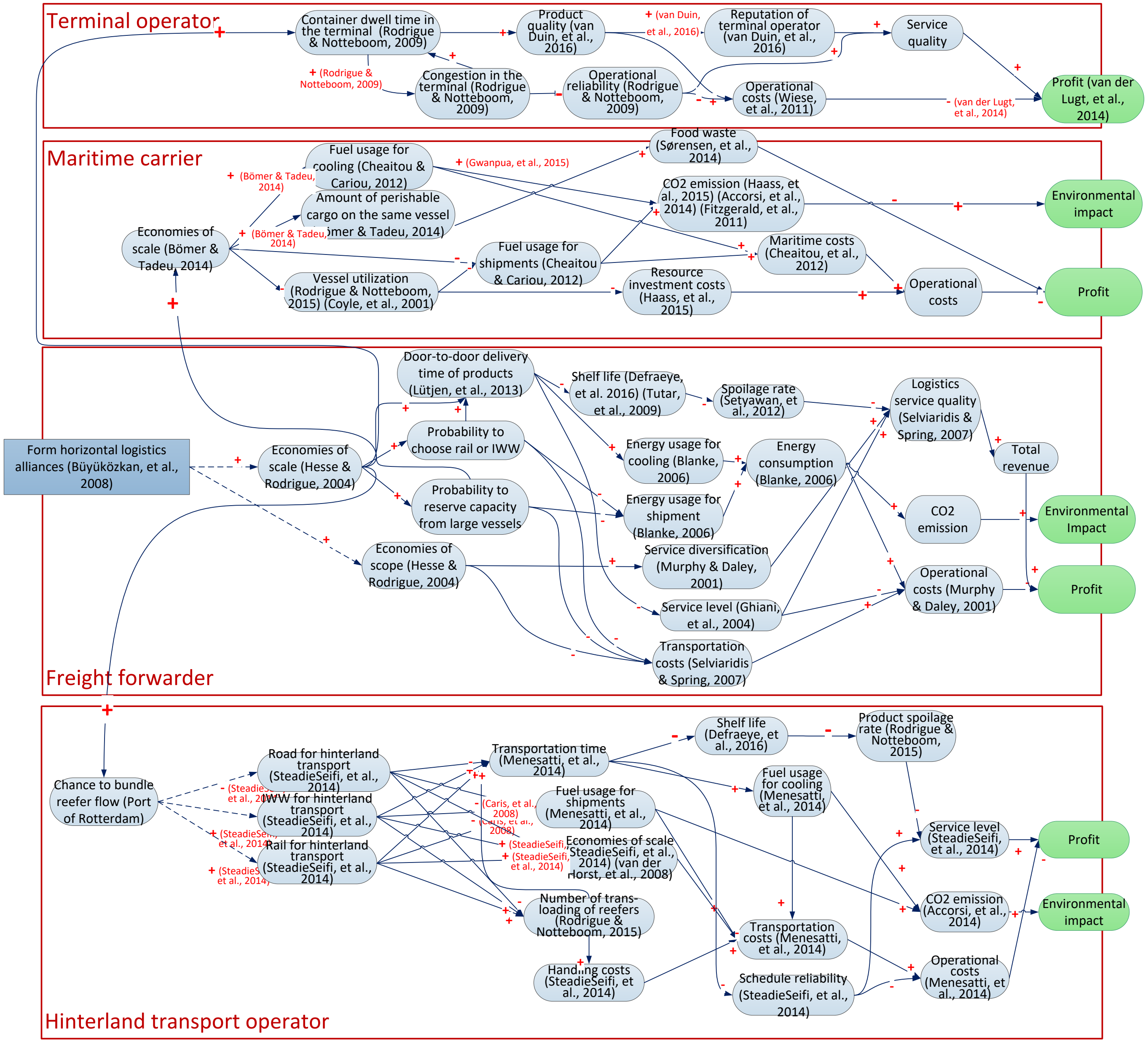


Figure 17: Impacts on other actors if a freight forwarder forms horizontal logistics alliances

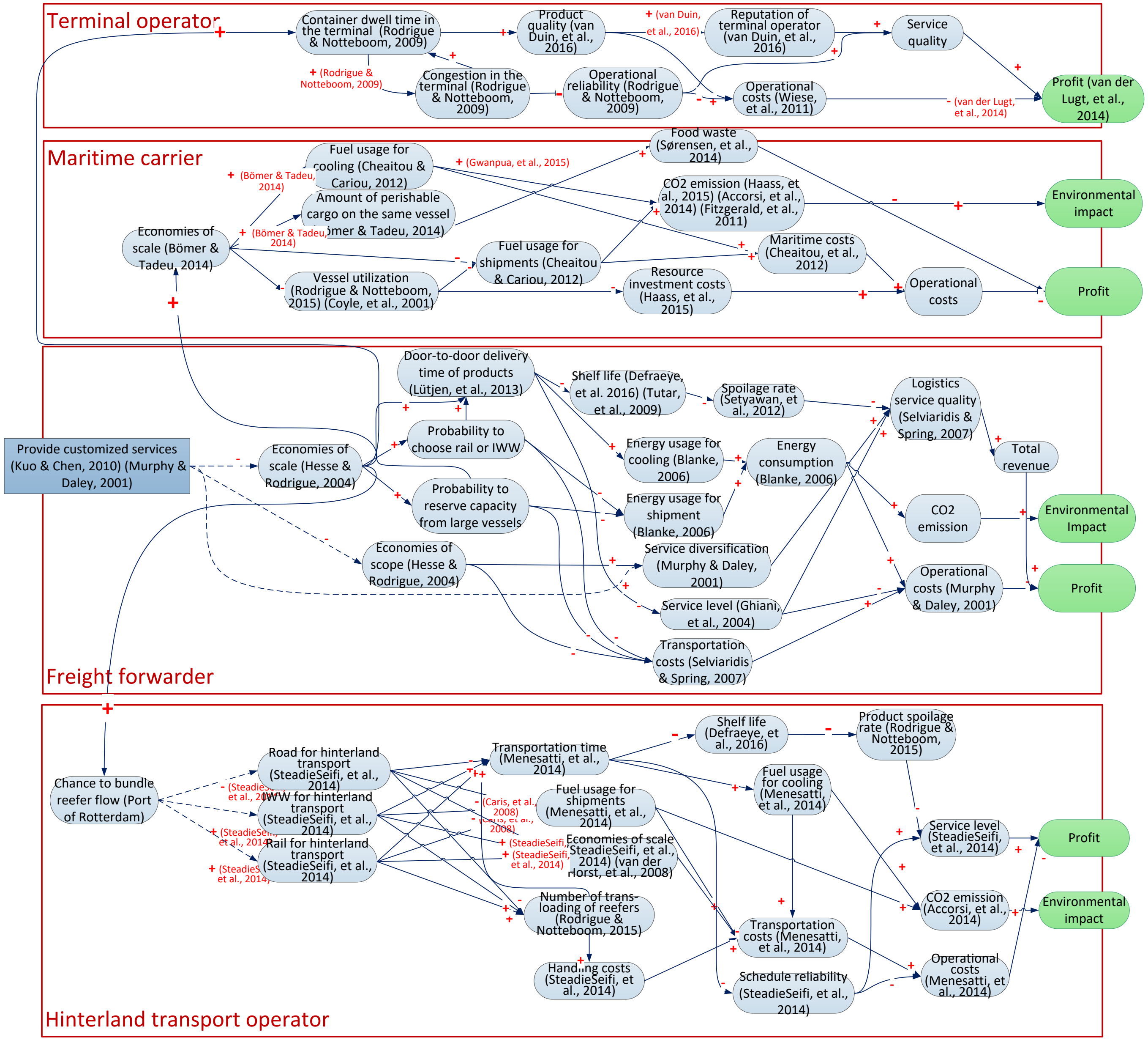


Figure 18: Impacts on other actors if a freight forwarder provides customized services

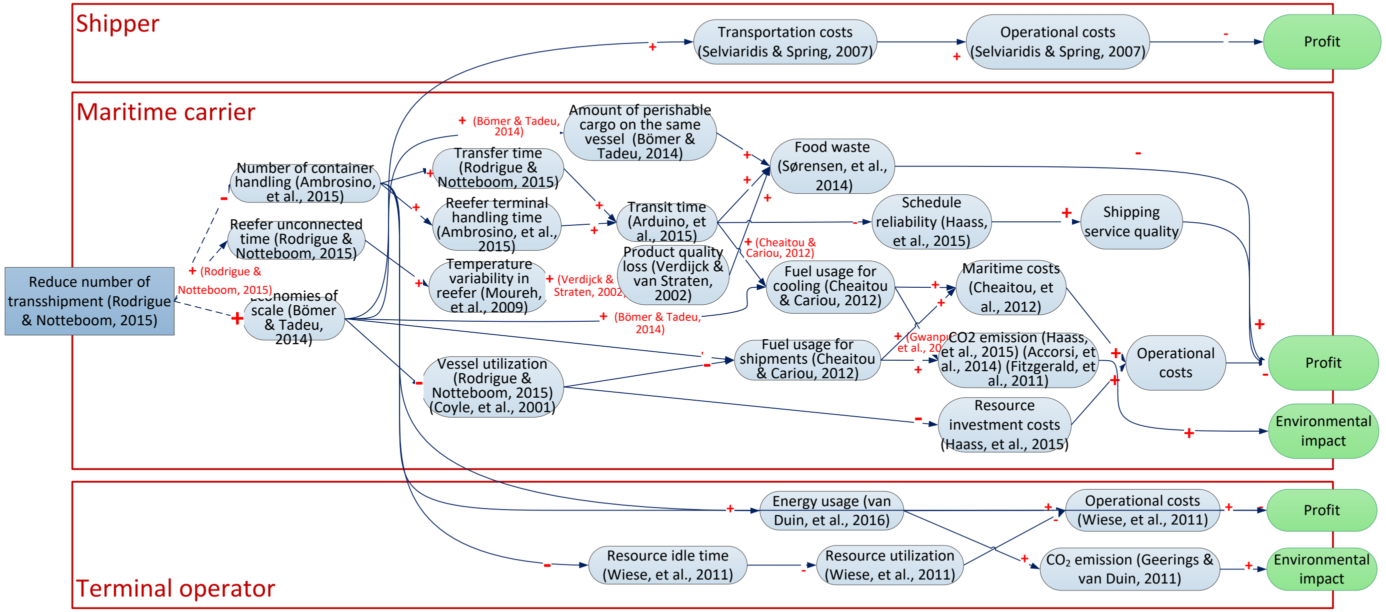


Figure 19: Impacts on other actors if a maritime carrier reduces number of transhipment

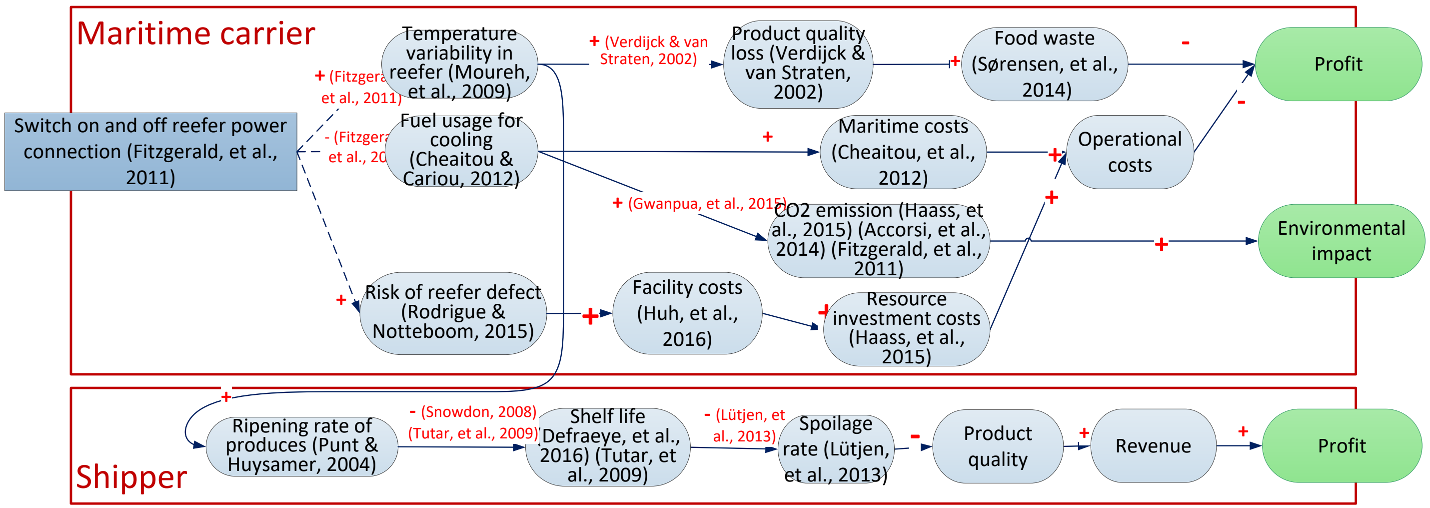


Figure 20: Impacts on other actors if a maritime carrier switches on and off reefer power connection

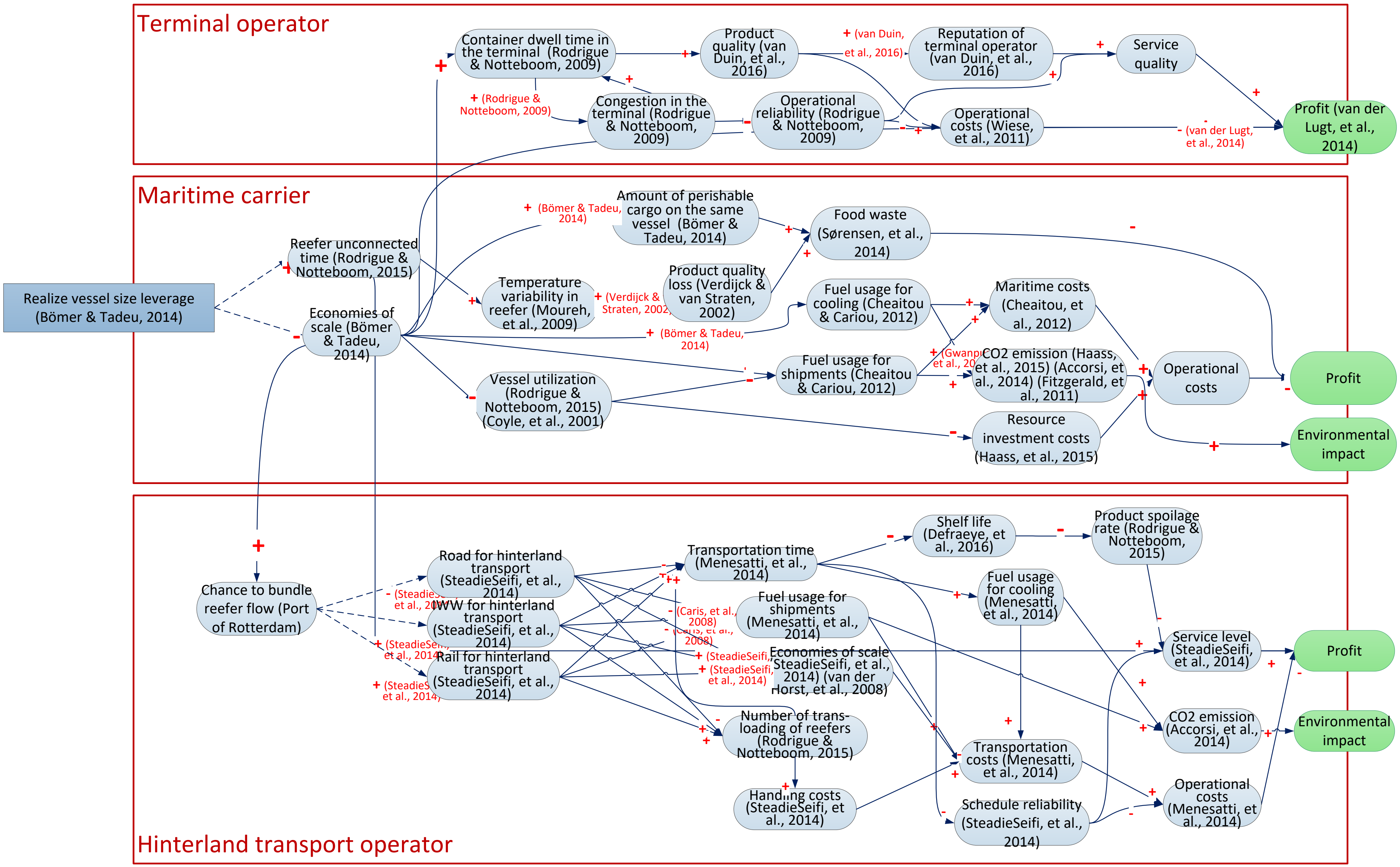


Figure 21: Impacts on other actors if a maritime carrier realizes vessel size leverage

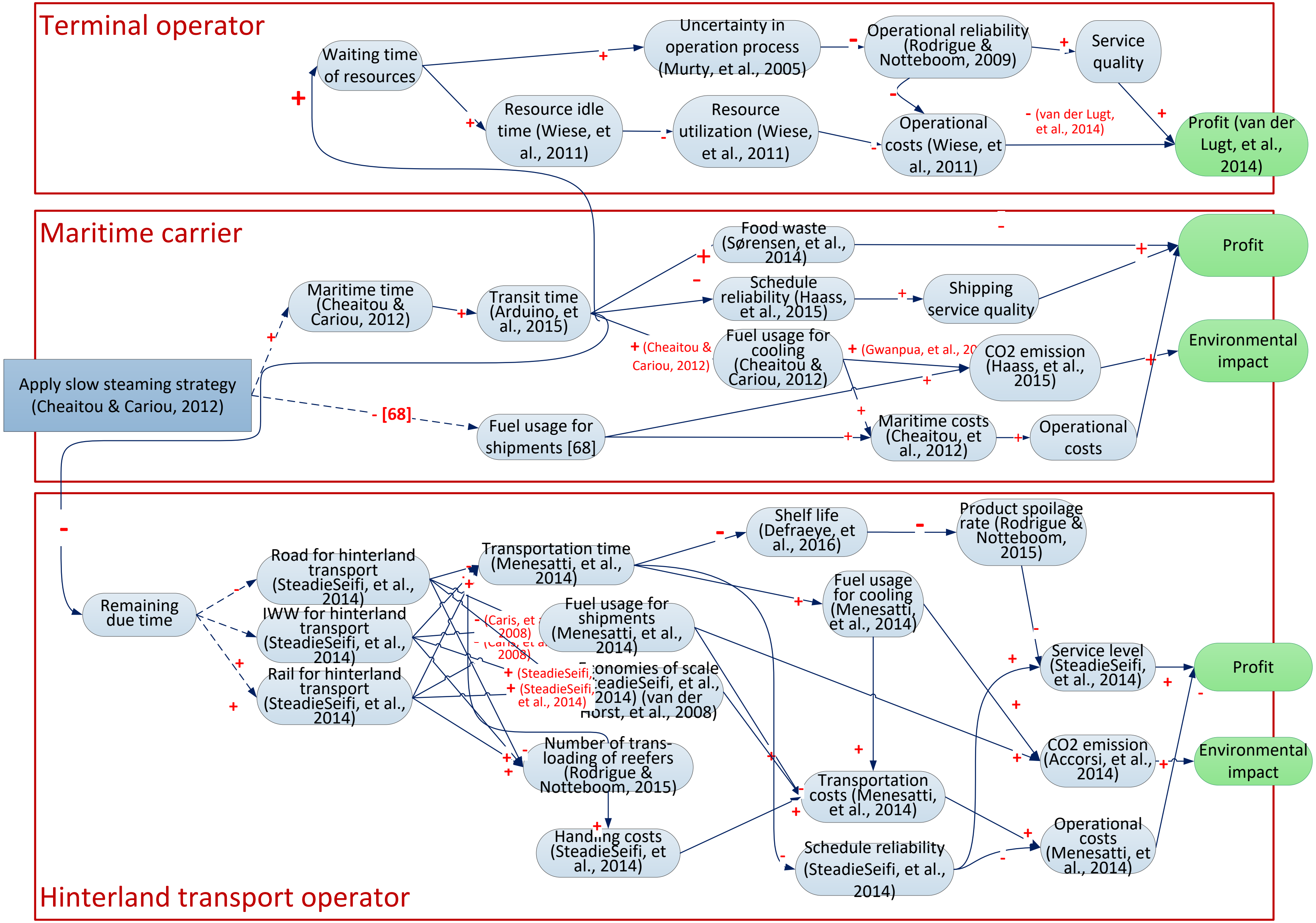


Figure 22: Impacts on other actors if a maritime carrier applies slow steaming strategy

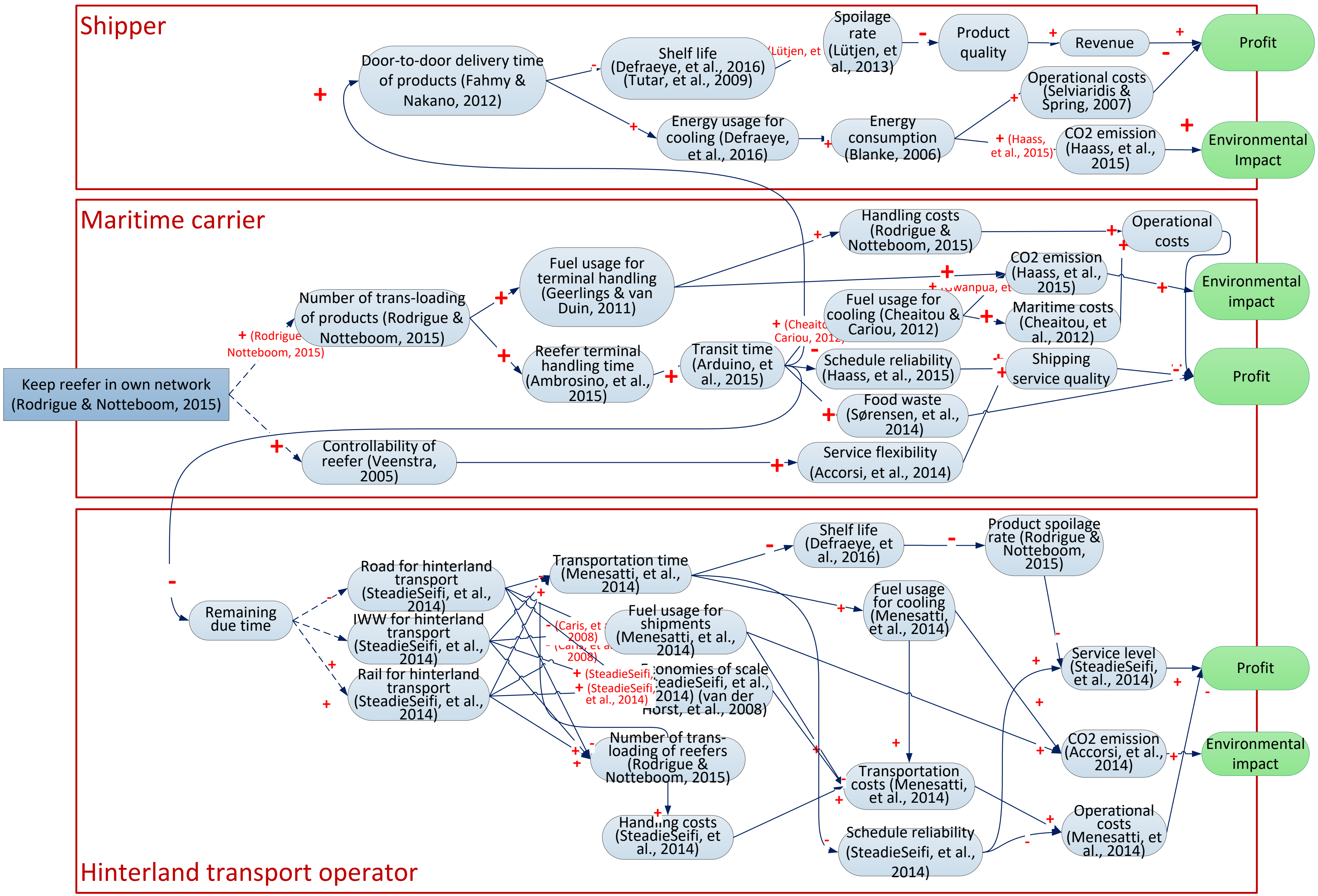


Figure 23: Impacts on other actors if a maritime carrier keeps reefer in own network

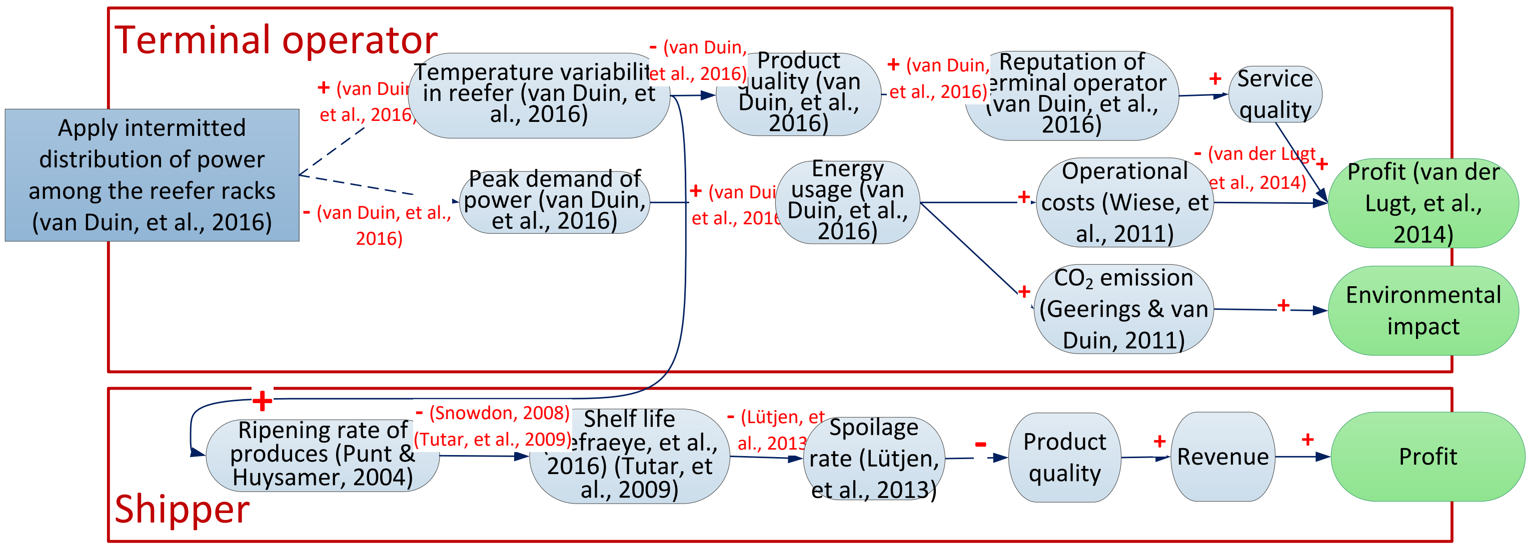


Figure 24: Impacts on other actors if a terminal operator uses intermitted distribution of power among the reefer racks

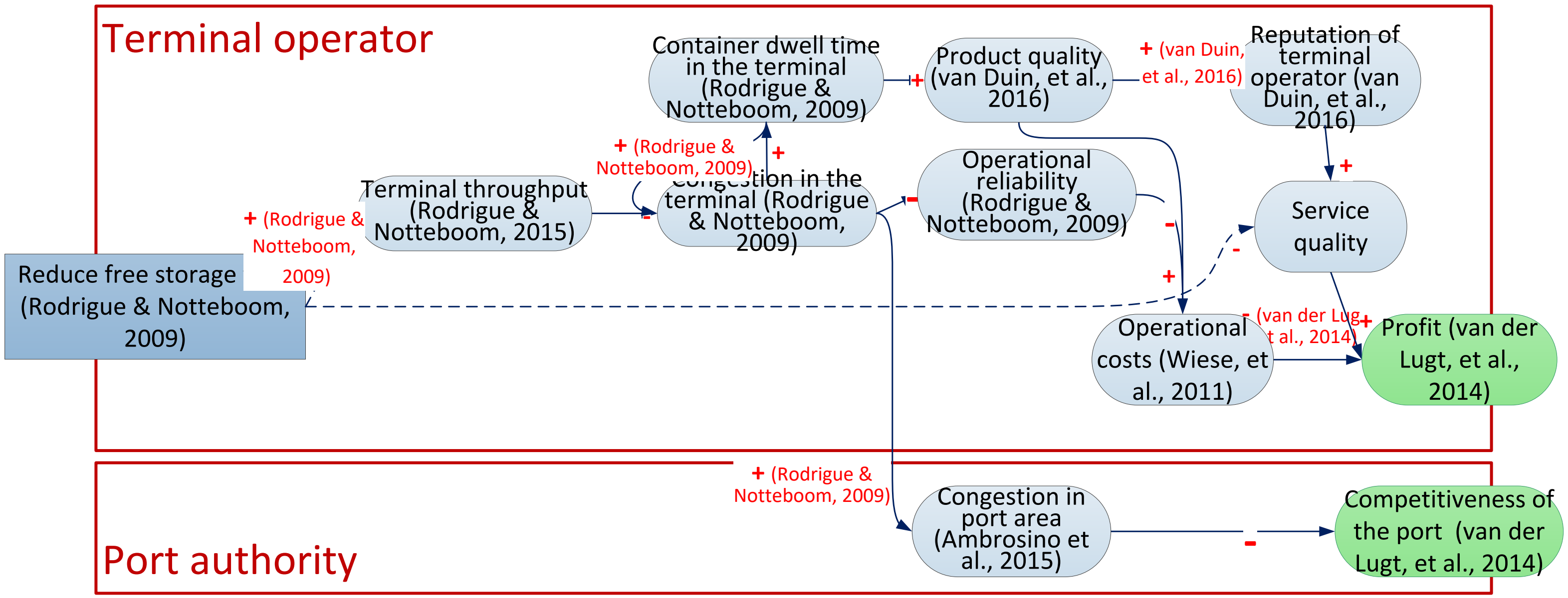


Figure 25: Impacts on other actors if a terminal operator reduces free storage time

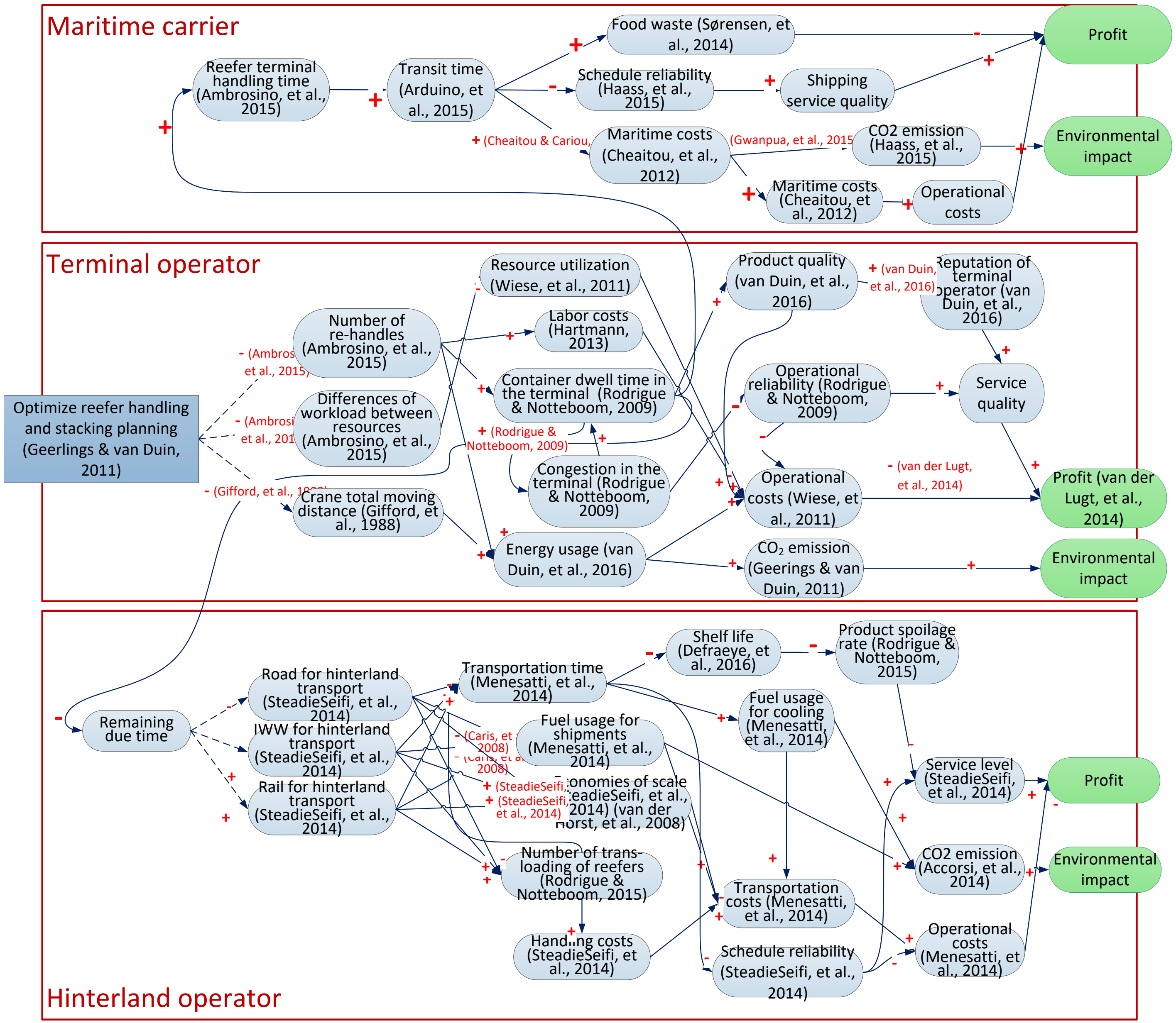


Figure 26: Impacts on other actors if a terminal operator optimizes reefer handling and stacking planning

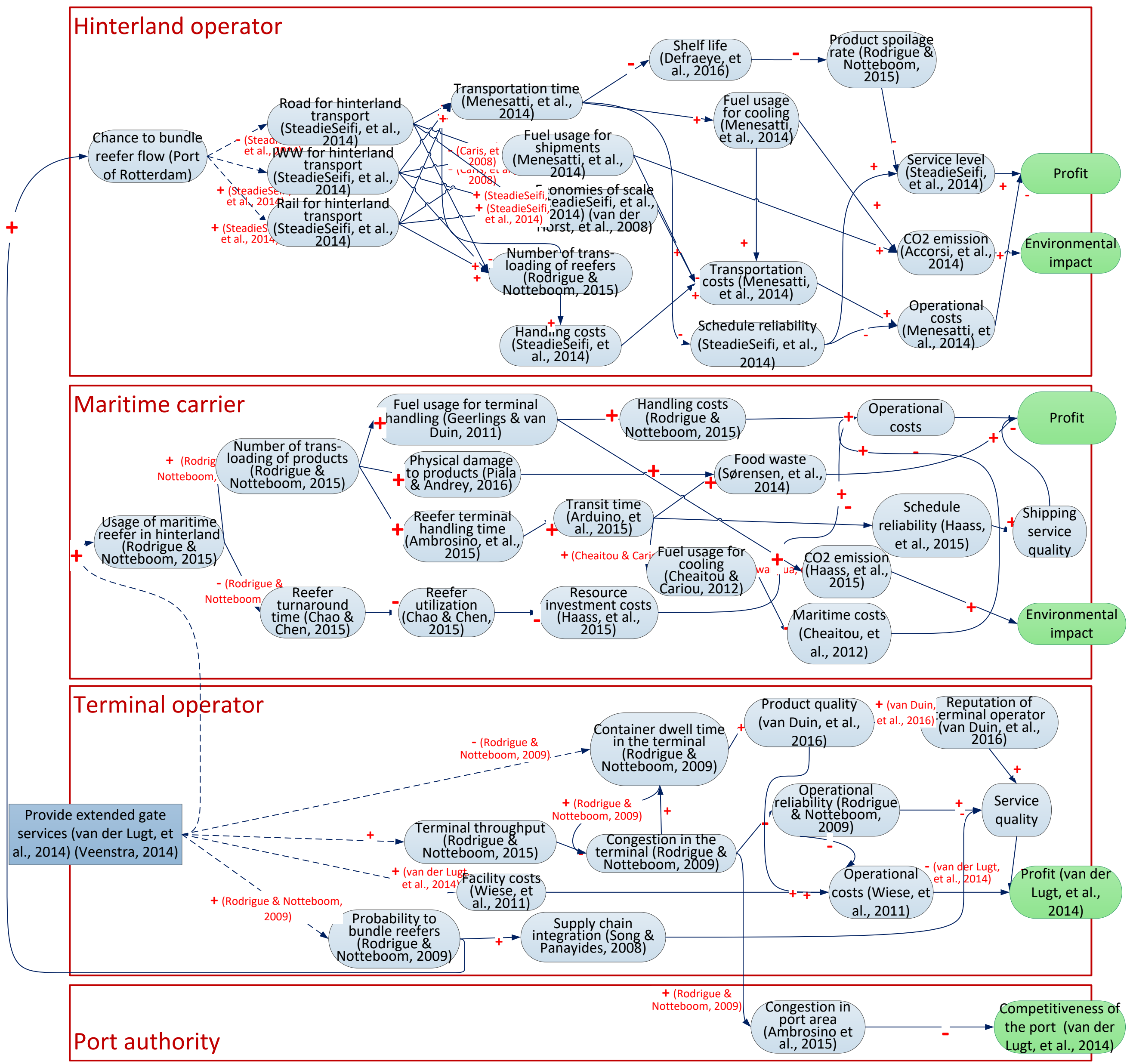


Figure 27: Impacts on other actors if a terminal operator provides extended gate services

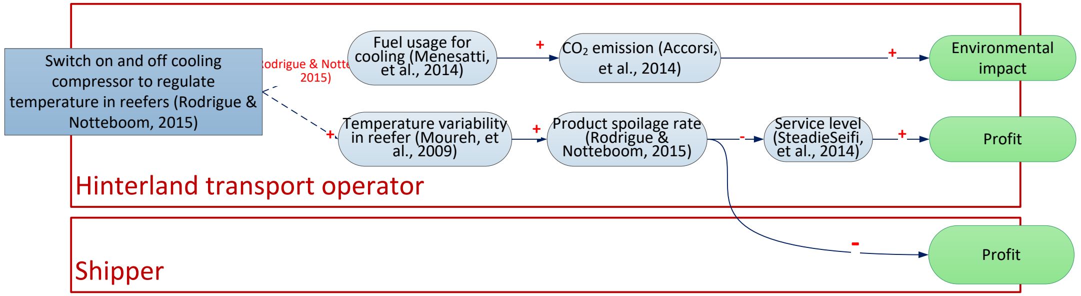


Figure 28: Impacts on other actors if a hinterland transport operator switches on and off cooling compressor

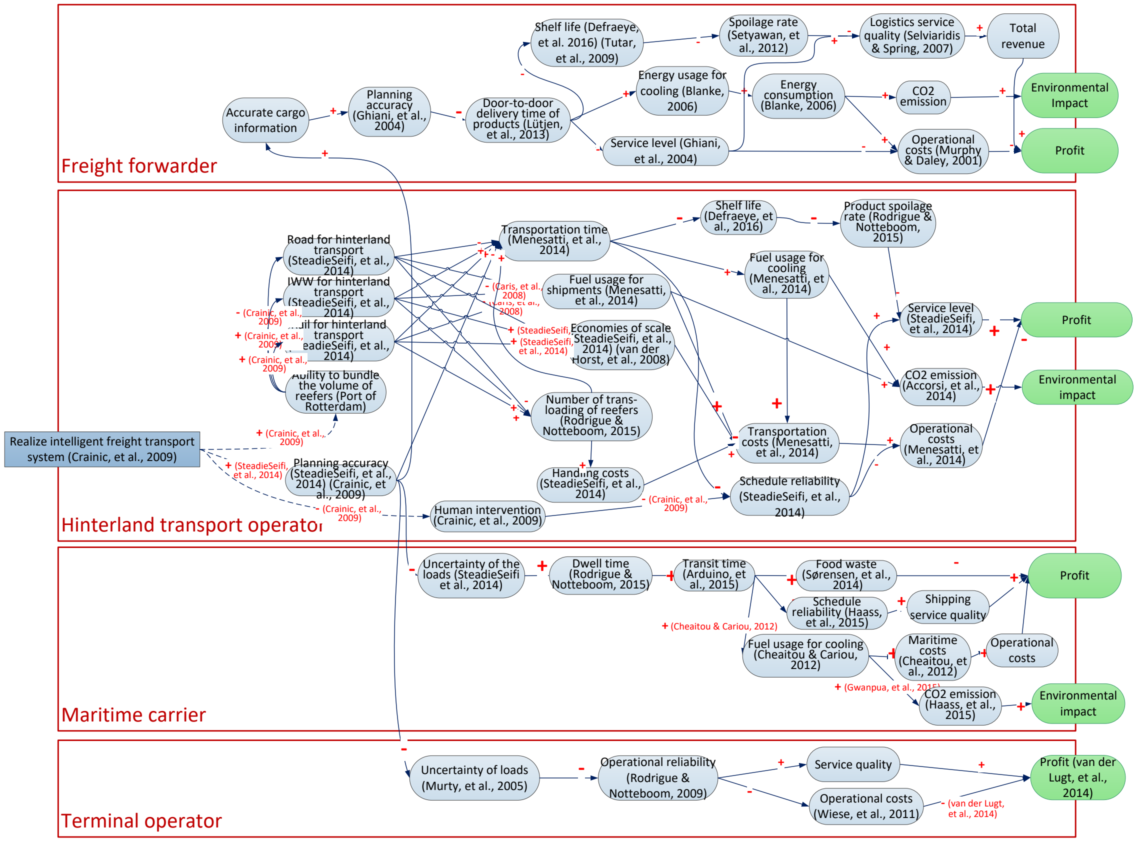


Figure 29: Impacts on other actors if a hinterland transport operator realizes intelligent freight transport system

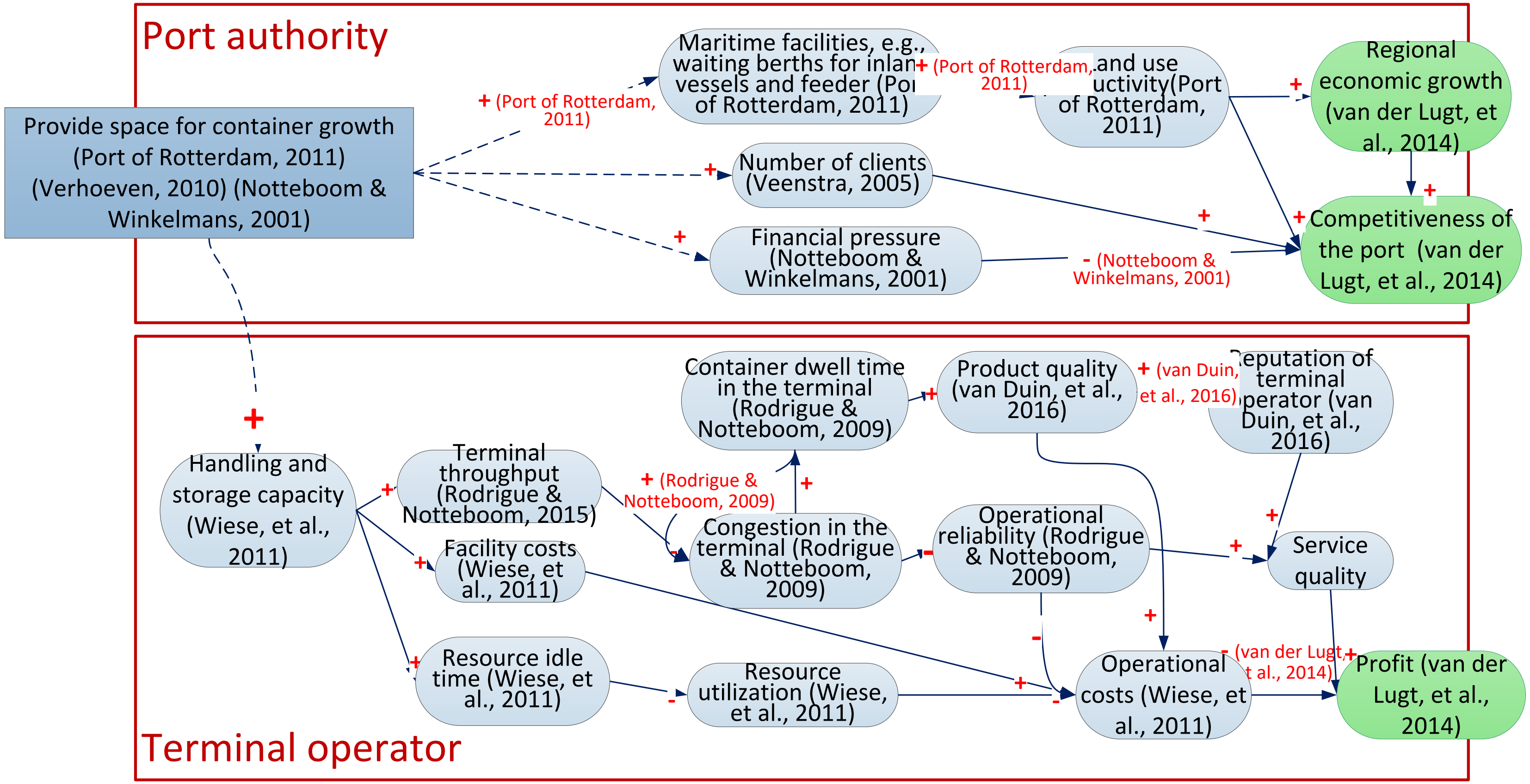


Figure 30: Impacts on other actors if a port authority provides space for container growth

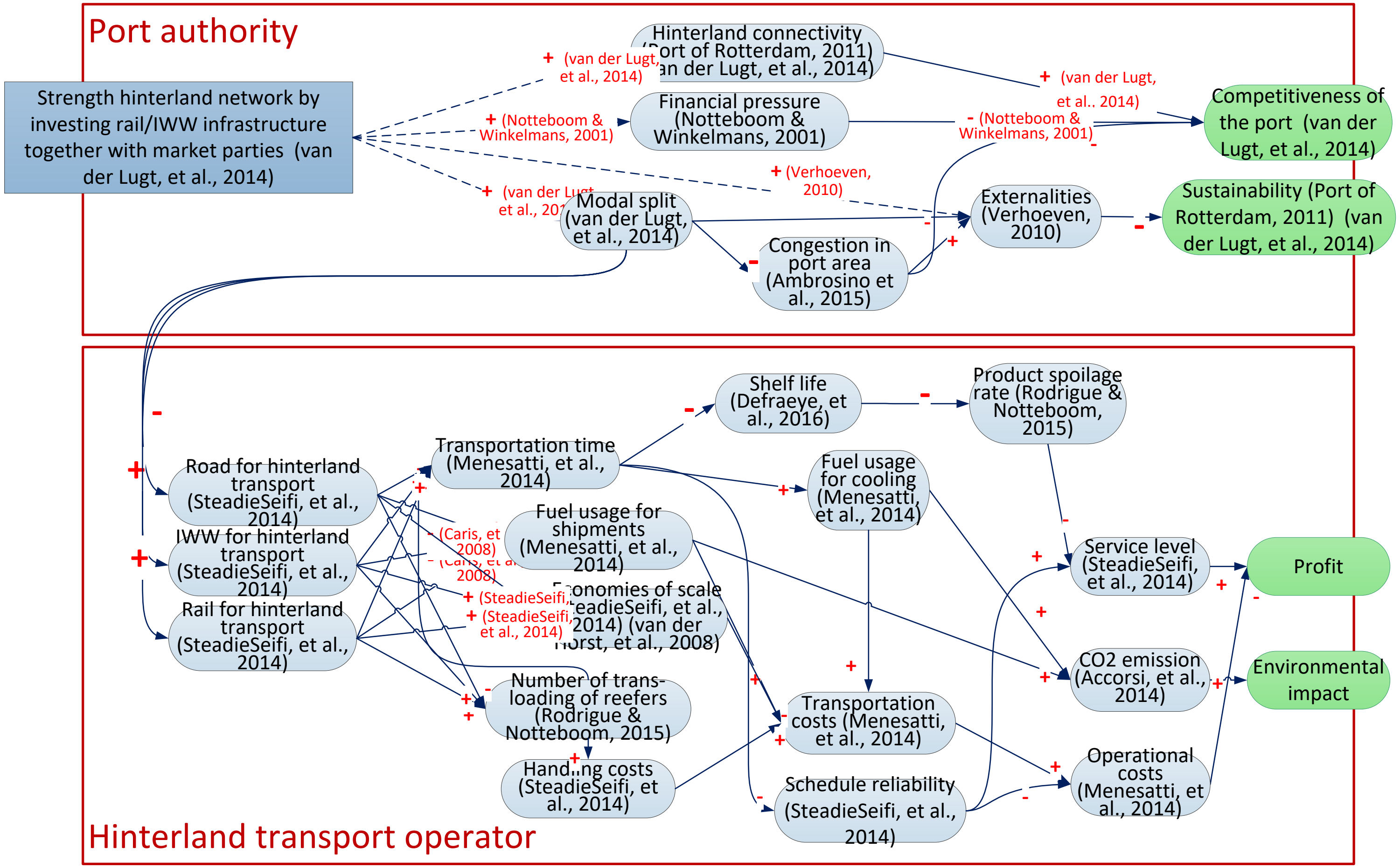


Figure 31: Impacts on other actors if a port authority strengthens hinterland network

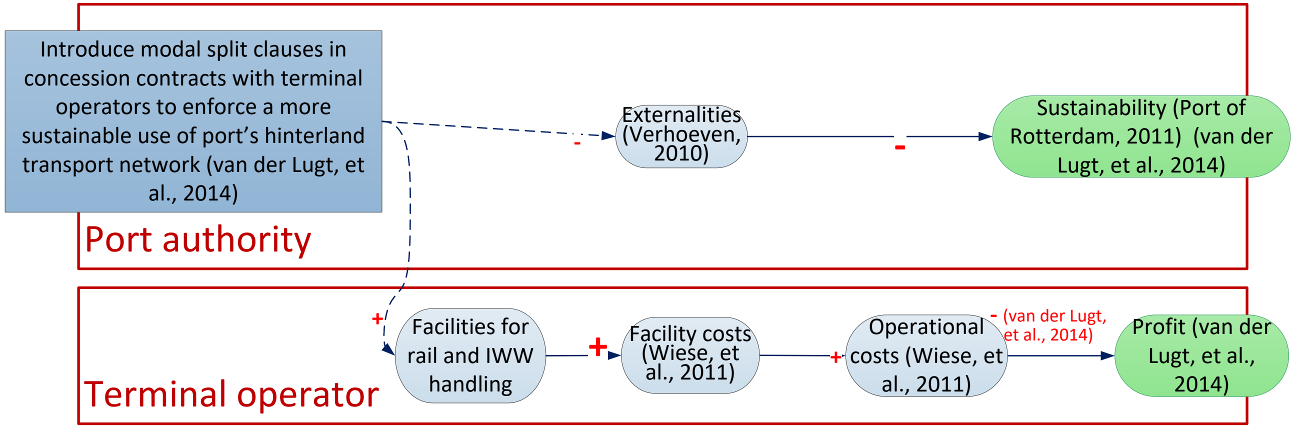


Figure 32: Impacts on other actors if a port authority introduces modal split clauses in concession contracts

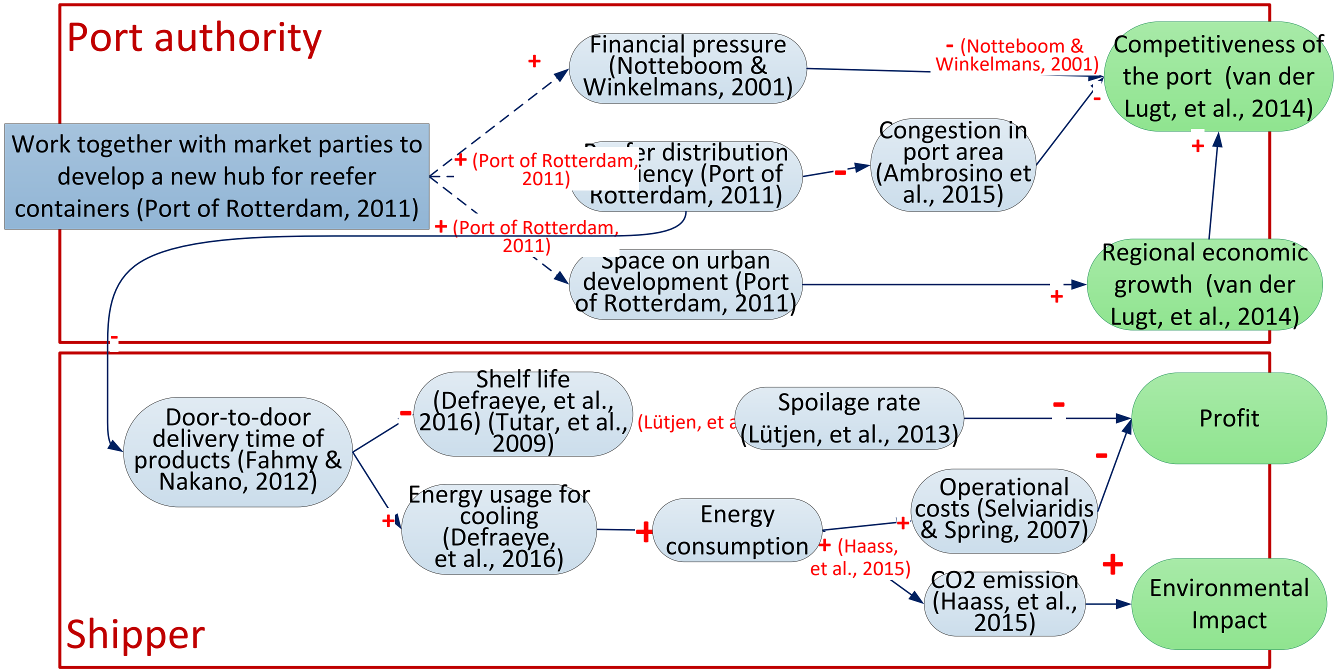


Figure 33: Impacts on other actors if a port authority works together with market parties to develop a new hub for reefers

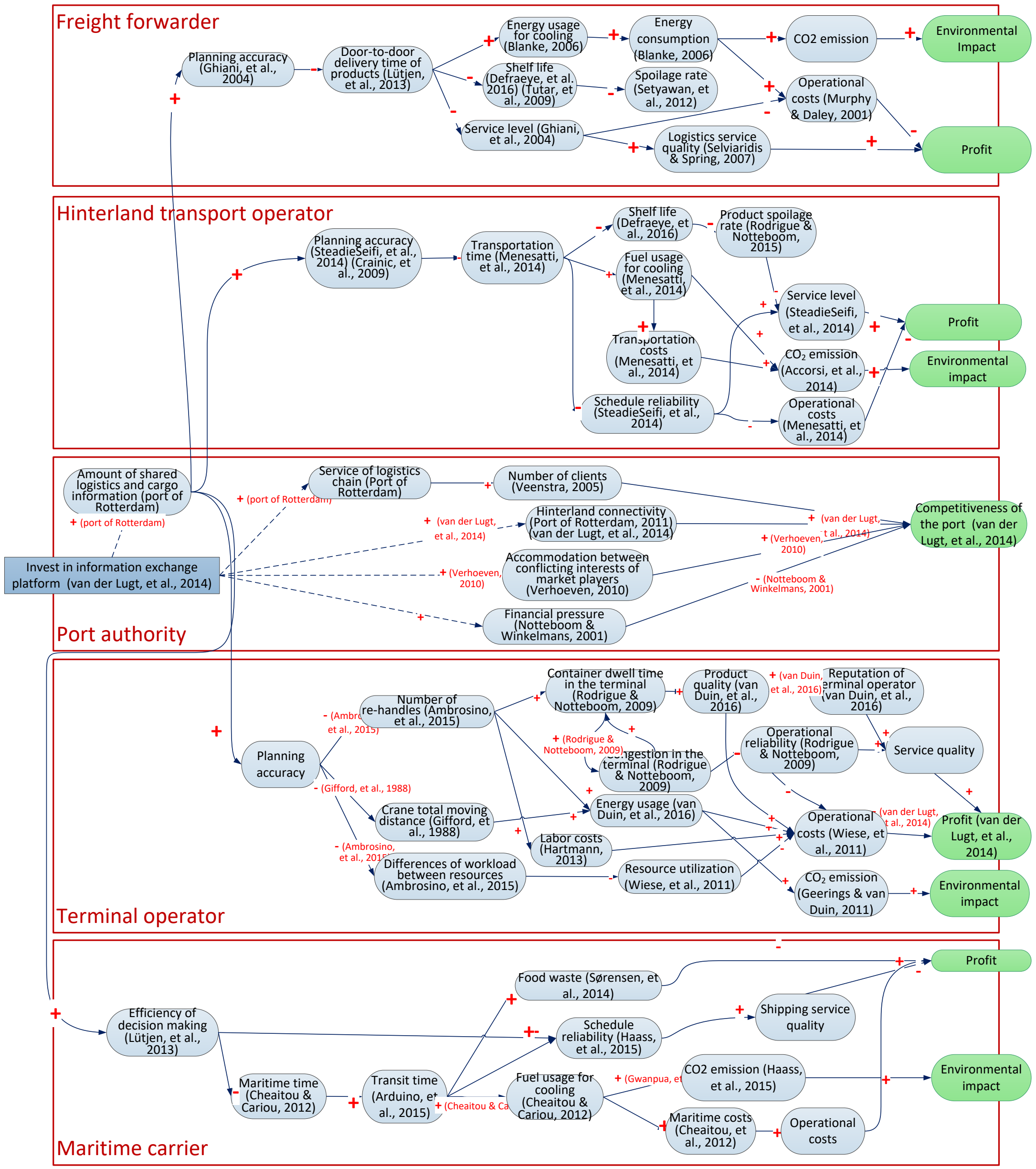


Figure 34: Impacts on other actors if a port authority invests in information exchange platform

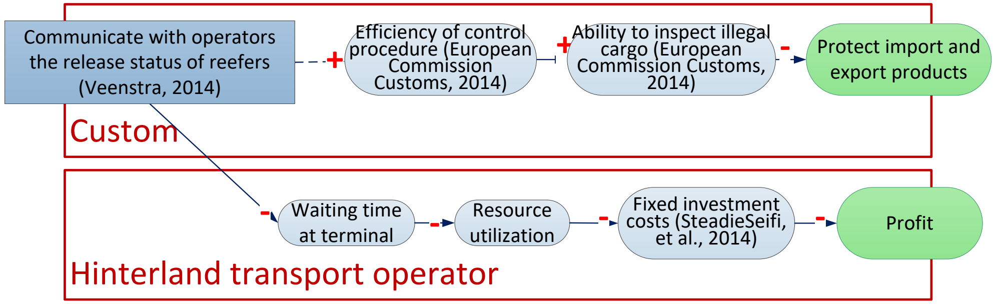


Figure 35: Impacts on other actors if a custom communicates with operators the release status of reefers

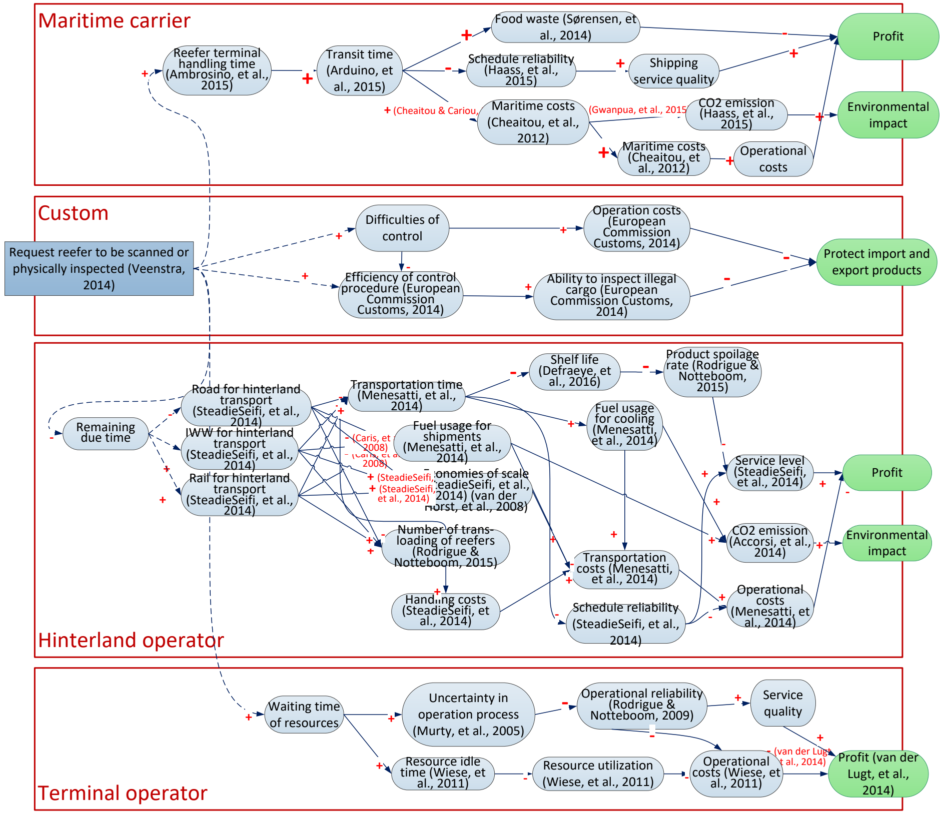


Figure 36: Impacts on other actors if a custom request reefers to be scanned or physically inspected

Study on Vulnerability of Hazardous Materials Road Transport Network Based on Gravity Model: A Case Study of Guangzhou's Highway Road Network

Huiling Zhong[a], *Jun Wang*[b], *Tsz Leung Yip*[c] *and Yimiao Gu*[d*]

[a]Department of Logistics Engineering, School of Economic and Commerce, South China University of Technology, Guangzhou, China. Email: hlzhong@scut.edu.cn
[b]Department of Logistics Engineering, School of Economic and Commerce, South China University of Technology, Guangzhou, China. Email: 201620136623@mail.scut.edu.cn
[c]Department of Logistics and Maritime Studies, The Hong Kong Polytechnic University, Hung Hom, Kowloon, Hong Kong. Email: t.l.yip@polyu.edu.hk
[d]Department of Logistics Engineering, School of Economic and Commerce, South China University of Technology, Guangzhou, China. Email: guymcheers@scut.edu.cn

[*]*Correspondence Author*

Abstract

The transportation of hazardous materials (hereinafter referred to as Hazmats) is different from general cargos. Once the Hazmats road transportation accident occurs, it will not only cause significant casualties and road network damage, but also threaten the safety of life and property along the residents. Therefore a quantitative vulnerability analysis method of Hazmats road transportation network is developed to access the vulnerability of each link, which can help improve the road transportation risk management level. Firstly, we propose an indicator to measure the relevance between two links based on the comprehensive analysis of its road transportation network topology and Hazmats road transportation risk characteristics. Secondly, we discover that we cannot identify the road vulnerability only based on its topology and risk characteristics alone. Thus, an Impact Strength model is developed to assess the Hazmats road transportation vulnerability. It is based on classical Gravity model considering its topology and risk characteristics together. Relevant algorithms are proposed accordingly. Thirdly, we use Guangzhou's Hazmats highway transportation as a case study to verify our Impact Strength model. The related statistics data are collected and handled then ArcGIS software is employed. By using this model, we can calculate the Impact Strength of each link in the whole transportation network. The empirical results support and verify that this innovative Impact Strength model can help to identify the links with significant vulnerabilities, which can help to reduce road transportation risk in advance and build the road transportation risk early-warning mechanism. This innovative model can be used to support the relevant decision-making process for further analysis as well.

Keywords: Road Transportation; Road Vulnerability; Hazardous Materials Transportation; Gravity Model

1. Introduction

According to the definition of Hazmats by United Nations, they are those whose physical and chemical properties are potentially harmful to human life and to environment (UNECE 2011). With the rapid development of China's economy, Hazmats have become indispensable materials for its industry, agriculture, national defence and people's daily life. In China, more than 1 million tons of Hazmats are transported every day and the annual Hazmats transportation burden is over 400 million tons (Zhang and Zhao 2007). With rapid expansion of Chinese chemical industry, the number of enterprises related to Hazmats reaches more than 300 thousands. In most cases, the regions of Hazmats consumption and Hazmats production are different and far apart. More than 95% of Hazmats are transported between different regions, and more than 80% of Hazmats transportation depend on road (Wu and Sun 2006). In recent years, many accidents involving Hazmats road transportation have resulted in catastrophic losses to human beings and the environment in China. Meanwhile, the damaged road transportation networks are heavily blocked or even paralyzed. According to historical statistics, there is an annual average of 36 serious and social-impact accidents involving the Hazmats road transportation in China.

These accidents have attracted great attention from the Chinese public, Chinese governments at all levels, and various non-governmental organizations/ communities (Yang, Li et al. 2010).

In an attempt to ensure the public and environment' safety and to reduce the occurrence of Hazmats accidents, Chinese governments at all levels have made rules and regulations for Hazmats transportation. There are many ways in which governments can regulate the Hazmats transportation activity, for instance, setting standards for the vehicles which are used in carrying Hazmats, designating the roads which are used for Hazmats transportation. Both technology and management instruments are applied simultaneously (Erkut and Verter 1995).

Despite the increasing demands and significance of Hazmats transportation, after going through a comprehensive literature review of Hazmats transportation by Erkut et al. (2007), it can be identified that vulnerability of Hazmats transportation network has not been studied yet. This paper develops an innovative model to effectively identify road vulnerability in Hazmats transportation network. It can help the related transport authorities to recognize the most vulnerable links in the traffic network, to build the risk early-warning mechanism and to elevate their management capabilities. It can assist governments at all levels making related policies in various forms (e.g. Regulations and rules) for Hazmats transportation as well.

The remainder of this paper is organized as follows. In Section 2, a literature review about Hazmats road transportation is provided. Section 3 presents the innovative vulnerability assessment model per se and related explanations. Section 4 proposes the algorithms according to the model in Section 3. Section 5 deals with a case study of Guangzhou's Hazmats highway road transportation. Finally, Section 6 is dedicated to conclusions and implications.

2. Related Literature

Going through two classical and state-of-the-art literature reviews by List et al. (1991) and Centrone et al.(2008), it is not difficult to find that Hazmats transportation literatures can be classified into three major branches: risk analysis, routing/scheduling, facility location, and the combination of these three. About the transport risk, there does not seem to be any consensus on how to define transport risks and how to model the associated transport risks. Through Erkut and Verter (1998) empirical analysis on the U.S. road network, it can be uncovered that different risk models usually select different optimal paths (routing) for a Hazmat transportation between a given origin-destination pair. Therefore, how to select the road transport risk model is crucial and tricky. As early as 1995, Alp (1995) proposed the Traditional Risk (TR) model to minimize the expected consequence of Hazmats road transportation, which is a non-linear binary integer program. In 1997, Jin and Batta (1997) simplified and approximated Alp (1995)'s Traditional Risk model to the Approximated Traditional Risk (ATR) model as follows:

$$R^r = \sum_{(i,j)\in L^r} P_{ij} C_{ij} \qquad (1)$$

In this model, Hazmats road transport risk on link (i, j) is the product of accident probability (P_{ij}) on link (i, j) and accident consequence (C_{ij}) on link (i, j) . Thus there exist two approaches to minimize the Hazmats road transport risk: minimizing accident probability, minimizing accident consequence and the combination of these two factors. This Approximated Traditional Risk (ATR) model is easier to optimize than Alp (1995)'s Traditional Risk (TR) model. That is why several other risk models have been developed based on ATR model from different perspectives over the past years. For example, in Kara et al. (2003)'s paper, they define the transport risk is the product of the incident probability and the affected population. Here they use the "affected population" to present the "accident consequence".

Now let's return to the question that what vulnerability is. As early as 1994, Laurentius (1994) proposed the definition of it as "vulnerability is a susceptibility for rare, though big, risks, while the victims can hardly change the course of events and contribute little or nothing to recovery". Unfortunately, to date there is still no internationally accepted definition of "vulnerability" in road transport research. From the road network point of view, vulnerability is a susceptibility to incidents that can lead to considerable reductions in road network serviceability (Berdica 2002). Taylor and D'Este (2003) suggested that vulnerability studies could substantially utilize the existing research basis on the risk analysis of road network, as vulnerability analysis concepts are related to risk analysis concepts. Husdal (2004) extended the Approximated Traditional Risk (ATR) model to include the "vulnerability" factor as follows:

$$R^r = \sum_{(i,j)\in L^r} P_{ij} V_{ij} \qquad (2)$$

where the Hazmats road transport risk on link (i, j) is the product of the "probability of an external circumstance or threat occurring (P_{ij}) on link (i, j)" and the "vulnerability to the occurrence of an external circumstance or threat (V_{ij}) on link (i, j)".

Berdica and Mattsson (2007) studied the road network of Stockholm and pointed out that identifying the critical components of the network (e.g. Network topology structure analysis) is a very important issue in vulnerability analysis. For instance, it can help us to know where the weakest links (vulnerable elements) are and what we can do about it in advance.

In this research paper, we refer and combine the concepts of "vulnerability" in Husdal(2004) and Berdica and Mattsson (2007) papers. Here we concern the vulnerability on the basis of both road transport risks and road network topology structure. In other existing literature about Hazmats road transportation, they only concern associated road transport risks without analyzing the network topology structure. However, it is a very crucial issue to make the network topology structure analysis to help us identifying the critical components (vulnerable elements). By using the information from vulnerability analysis, we can build-up the early-warning mechanism in Hazmats road transport network which can helps us to reduce the catastrophic losses to economics, human beings, and environment.

3. Model Formulation

Based on the definition of road network vulnerability and the characteristics of Hazmats transportation, we uncover that the vulnerability of Hazmats road transport network, impacting the entire network when an accident happens, is highly related to transport network topology and transportation risks.

3.1 Transport network topology analysis

Edge number represents the influential power of an edge in the whole network, and is often used to analyse the topology characteristics of the traffic network. In practice, there will be traffic interaction among different road links. The more traffic interactions, the greater influences exist among the different links. However, edge number cannot indicate the interrelationship among the different links. Interrelationship means traffic interaction here. According to the definition of edge number, we define a Link Correlation Coefficient to measure the correlation degree between two links.

(1) Edge number

Edge number is the sum of the all ratio of the number of shortest paths between node a and node b that crossing link i to the shortest path number in the entire network (Holme, Kim et al. 2002).
For link i, the edge number $ED(i)$ is

$$ED(i) = \sum_{a,b\in N(a\neq b)} \frac{N_{ab}(i)}{N_{ab}} \qquad (3)$$

where N_{ab} is the number of the shortest paths between node a and node b; $N_{ab}(i)$ is the number of the shortest paths between node a and node b passing through link i; N is the set of all nodes.

(2) Link Correlation Coefficient

Link Correlation Coefficient is the number of the shortest paths between node a and node b passing through link i and link j simultaneously, which is expressed as follows:

$$CC(i,j) = \sum_{a,b \in N(a \neq b)} N_{ab}(i,j) \tag{4}$$

where $CC(i,j)$ is the correlation coefficient of link i and link j; $N_{ab}(i,j)$ is the number of shortest paths between the node a and node b passing through link i and link j.

3.2 The development of Approximated Traditional Risk (ATR) model

According to the Approximated Traditional Risk (ATR) model, the risk of link is used to represent its transport network vulnerability. The risk of traffic accidents is the product of the probability of an accident and the outcome of an accident (Lepofsky, Abkowitz et al. 1993; Alp 1995; Erath, Birdsall et al. 2009). Thus, the risk of Hazmats transportation vehicles passing through link i can be calculated as follows:

$$R_i = P(R)_i C_i \tag{5}$$

where $P(R)_i$ is the probability of accident on link i; C_i is the outcome of accident on link i.

The probability of Hazmats accident on link i ($P(R)_i$) is related to conditional leakage probability and vehicle accident rate on link i. It can be calculated as follows:

$$P(R)_i = TAR_i \times P(R \mid A)_i \times L_i \times n_i \tag{6}$$

where TAR_i is the vehicle accident rate on link i, and the unit is the number of accidents per kilometer-year; $P(A)_i$ is the Hazmats accident rate per year which is given, and $P(R \mid A)_i$ is the conditional leakage probability of the Hazmats accident; L_i is the length of link i, and the unit is kilometer; n_i is the number of vehicles that transport Hazmats on link i.

It is assumed that the outcome of the accident is only related to the population of the affected area. The affected area of the link is a strip-shaped area with fixed width. The affected area is divided into two parts: the population in the link and the population out of the link. Therefore, the outcome of accident on link i can be expressed as follows:

$$C_i = (\pi\lambda^2 + 2\lambda L_i - W_i L_i)\rho + n_i + \sum_k x_{ik} N_{ik} \tag{7}$$

where λ is the impacted radius of the accident, and the unit is km; L_i is the length of link i,and the unit is kilometer; W_i is the width of link i,and the unit is kilometer; ρ is the population density in the around of link i,and the unit is number of people per km^2; n_i is the number of vehicles that transport Hazmats on link i; x_{ik}

is the amount of vehicles that the k class non-Hazmats is transported on link i; N_{ik} is the seats of the k class vehicles that non-Hazmats is transported on link i.

From the above Eq. (5) to (7), the risk of vehicles that transport Hazmats on link i can be expressed as follows (Ren 2007):

$$R_i = TAR_i \times P(R|A)_i \times L_i \times n_i \times [(\pi\lambda^2 + 2\lambda L_i - W_i L_i)\rho + n_i + \sum_k x_{ik} N_{ik}] \tag{8}$$

3.2 Traditional vulnerability assessment without analyzing the network topology structure

(1) Hub-and-spoke network

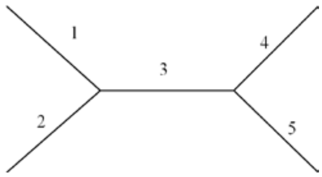


Figure 1: Hub-and-Spoke Topology Network

Figure 1 is a typical road traffic network, which is called hub-and-spoke topology. It is assumed that the amount of traffic flow and the number of vehicles are the same in the gravity model. Thus the traffic flow of each link in the model can be set to 1. The length, risk and edge number of each link are listed in the Table 1. The detailed information is shown in Table 1.

Table 1: Traditional Vulnerability Assessment Model for Hub-and-spoke Network

Link	Link 1	Link 2	Link 3	Link 4	Link 5
The Length of Link (km)	1.3	1.3	1.3	1.3	1.3
The Risk of Link	4.5830E-04	1.1608E-04	2.3529E-04	2.4279E-04	4.2772E-04
Edge Number	0.174	0.174	0.304	0.174	0.174

Sources: compiled by authors

From the above Table 1, it can be uncovered that the risk of Link 3 is ranked 4th only. However, from the topology structure of Figure 1, it can be easily found that the Link 3 is the most important link in the whole network. The edge number of Link 3 is 0.304 which is the highest value among all the links, which means Link 3 plays a very important role in topology. If only concerning the risk of link, Link 1 is the link with the highest risk, while if only concerns edge number, Link 3 is the link with the highest edge number. So now comes the question, which link has the highest vulnerability in the network? Link 1 or Link 3?

In traditional risk assessment model, the risk of each link is used to assess road vulnerability of Hazmats transportation network. The significance of network topology structure cannot be reflected in the traditional risk assessment model. Therefore, a new innovative model is needed to reflect the importance of the network topology structure in Hazmats road transportation network.

(2) Peer-to-Peer network

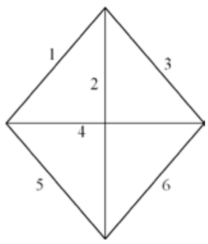


Figure 2: Peer-to-Peer Topology Network

Figure 2 is a typical road traffic network as well, which is called peer-to-peer topology. We assume that the amount of traffic flow and the number of vehicles are the same in the gravity model as well. The traffic flow of each link in the model can be set to 1. The specified information is shown in Table 2.

Table 2: Traditional Vulnerability Assessment model for peer-to-peer network

Link	**Link 1**	**Link 2**	**Link 3**	**Link 4**	**Link 5**	**Link 6**
The length of link (km)	1.2	2.08	1.2	1.2	1.2	1.2
The risk of link	1.5982E-01	5.4253E-03	8.5560E-02	3.5924E-03	6.3453E-02	7.5354E-04
Edge number	0.1667	0.1667	0.1667	0.1667	0.1667	0.1667

Sources: compiled by authors

From the above Table 2, it can be easily found that there are five links with the same length of 1.2 km. Only the length of Link 2 is different (2.08 km). From the view of the topology structure, the edge numbers of all links are the same with the value of 0.1667. If we compare the links with the same length and edge number, the link with higher risk is the link with higher vulnerability. Thus, Link 1 is the link with the highest vulnerability among these five links (Link 1, Link 3, Link 4, Link 5, and Link 6). However, when considering the vulnerability of the network, we are required to calculate the distances from the accident link to the affected links. Usually the distance from the accident link to the affected link is measured between the middle points of each link. Therefore the length of each link matters. It is indispensable to introduce a new innovative model which considers the length (distance) factor into the vulnerability assessment model.

3.3 An innovative vulnerability assessment model

In order to get the vulnerability of Hazmats road transportation network, we define "Link Impact Strength" (S_i) to measure the vulnerability of the link. The "Link Impact Strength" means the consequence is caused by the evacuation of the population and the traffic flow in the affected area when the accident occurs on the entire road network.

In the Hazmats road transportation network, vehicle transportation exists high risk. When an accident occurs in a certain link, it is necessary to evacuate the population around the link. In the study of emergency evacuation, it is assumed that the population using the vehicles to escape (Yamada 1996). The affected population around the accident link will be the traffic flows in the road network, which is similar to the process of traffic distribution and population migration. In the study on traffic flow and population migration, the gravity model is regarded as a common method to evaluate the strength of the flow. The classical gravity model drawing on analogy with Newton's Law of Gravitation is shown as follows:

$$T_{ij} = k\frac{P_i P_j}{D_{ij}^{\;2}} \tag{9}$$

where T_{ij} is the he expected strength of the traffic flow; P_i is the quantity of traffic generation; P_j is the quantity of traffic attraction; D_{ij} is the distance between different traffic zones; k is the gravity constant, which is usually set to 1 (Jung, Wang et al. 2008; Anderson 2011).

In the process of evacuation, the expected impact of the accident link i on the affected link j is related not only to the risk of link i and traffic flow of link j, but also related to the distance and the exchange traffic flow between them. In reality, if there is frequent exchange traffic flow between two areas when population migration and traffic flow, the strength of traffic flow will be affected. However, this point is not considered in the classical gravity model.

In order to accurately measure the impact of traffic exchange on the strength of traffic flow between two links, we introduce the parameter $C(i, j)$, called "Link Correlation Coefficient" in Section 3.1, to modify the classical gravity model. Accordingly an innovative vulnerability assessment model is constructed based on the classical gravity model, and the formula is expressed as follows:

$$S_{ij} = a\frac{R_i H_j}{{d_{ij}}^2}C(i,j) \tag{10}$$

where S_{ij} is Link Impact Strength, which means the expected impact of the accident link i on the affected link j; a is the gravity constant and usually set to 1; R_i is the risk of link i when a vehicle carrying Hazmats passes through; H_j is the traffic volume of link j; d_{ij} is the distance between link i and link j, which means the shortest distance between the midpoint of the link i and the midpoint of the link j; $C(i,j)$ is the Link Correlation Coefficient.

Therefore, the total expected Link Impact Strength of the accident link i on the entire Hazmats transportation network could be expressed as follows:

$$S_i = \sum_j a\frac{R_i H_j}{{d_{ij}}^2}C(i,j) \tag{11}$$

S_i can mirror the potential impact of the accident link i to the entire Hazmats transportation network. The value of S_i is greater, the potential impact of link i to the entire network is greater, which means the vulnerability of link i is stronger.

3.4 The related proof procedure

In order to illustrate the feasibility of the application of the classical gravity model to derive the Link Impact Strength S_i, the following proof procedure is given based on Chen and Liu (2002)'s research paper. The basic hypotheses are as follows:

- The expected Link Impact Strength of Hazmats transportation network is subjected to link risk, traffic flow, distance between the accident link and the affected link and the Link Correlation Coefficient in between.
- Different links are independent obviously.

The first hypothesis is self-evident and the second hypothesis is logically self-consistent. According to the first hypothesis, we obtain:

$$I = a \bullet f(\mathrm{x}_1, \mathrm{x}_2, \mathrm{x}_3, \mathrm{x}_4) \tag{12}$$

where I is the expected Link Impact Strength of Hazmats road transportation network, x_1 is the risk of Hazmat vehicle passing through link i, x_2 is the traffic flow of the link j, x_3 is the distance between link i and link j, x_4 is the correlation coefficient of link i and link j, and a is the scale factor. We make a total differential to the Equation (12) and get as follows:

$$dI = a\sum_{i=1}^{4}\frac{\partial f}{\partial x_i}dx_i = \sum_{i=1}^{4}\frac{\partial I}{\partial x_i}dx_i \tag{13}$$

Both sides are divided by I, then $\frac{dI}{I} = \sum_{i=1}^{4}\delta_i \frac{dx_i}{x_i}$ (14)

According to the second hypothesis, we can get $\delta_i = \frac{\partial I}{\partial x_i} \frac{x_i}{I}$ (15)

δ_i is a constant and actually it is an elasticity coefficient.

Making an integral to the equation (15), $\int d \ln I = \sum_{i=1}^{4} \int \delta_i d \ln x_i$ (16)

Then the result is as follows: $I = u \prod_{i=1}^{4} x_i^{\delta_i}$ (17)

This is a specific form of the spatial interaction model, where $u = \exp \sum C_i$ is gravitational coefficient (C_i is an integral constant).

According to Eq. (15), $\partial \ln I = \delta_i \partial \ln x_i$, then we have $I = C_i x_i^{\delta_i}$ (18)

which means that: $I = C_1 x_1^{\delta_1}$, $I = C_2 x_2^{\delta_2}$, $I = C_3 x_3^{\delta_3}$, $I = C_4 x_4^{\delta_4}$.

We can form a new equation as follows: $I = K x_1^{\alpha} x_2^{\beta} x_3^{\gamma} x_4^{\chi}$ (19)

where $K = (\mathrm{C_1 C_2 C_3 C_4})^{1/4}$, $\alpha = \delta_1 / 4$, $\beta = \delta_2 / 4$, $\gamma = \delta_3 / 4$, $\chi = \delta_4 / 4$

By using parameter replacement handling, $a = K$, $R_i = x_1$, $H_j = x_2$, $d_{ij} = x_3$, $C(i, j) = x_4$,

we can get the formula as follows: $S_{ij} = a \frac{R_i^{\alpha} H_j^{\beta}}{d_{ij}^{\gamma}} C(i, j)^{\chi}$ (20)

The total Link Impact Strength of the accident link i on the entire Hazmats transportation network could be expressed as follows: $S_i = \sum_j a \frac{R_i^{\alpha} H_j^{\beta}}{d_{ij}^{\gamma}} C(i, j)^{\chi}$ (21)

Regression method is used to determine the parameter values (α、β、γ、χ). According to Hu et al. (2015)'s regression results, we can set the parameter values as α=1、β=1、γ=2、χ=1. Therefore, the equation (21) can be simplified to: $S_i = \sum_j a \frac{R_i H_j}{d_{ij}^{2}} C(i, j)$ (22)

4. Algorithms

The key point of "Link Impact Strength" (S_i)'s calculation is to get the Link Correlation Coefficient ($CC(i, j)$). Thus first, we design an iteration algorithm to calculate the correlation coefficient of links ($CC(i, j)$), and then develop a step by step algorithm to get Link Impact Strength S_i according to Eq. (22).

4.1 The algorithm to get "Link Correlation Coefficient"

It is needed to build a matrix BB to record “Link Correlation Coefficient”. Because the traffic network is a sparse network (Newman 2010), the nodes connected with links are rare among all the nodes in the network. If using the maximum link number $m = \frac{1}{2}n(n-1)$ to build a $m \times m$ matrix BB, the BB matrix will become extremely large. Therefore, this paper builds a mapping matrix “S_Name”. In this “S_Name” matrix, the sequence number of the row and column represent the name of the node, while the value in the matrix represents the name of links between the node pair. Using the links which are actually existent in the mapping matrix “S_Name” to develop the “Link Correlation Coefficient” matrix BB can help to reduce the scale of matrix BB greatly.

The detailed algorithm is as follows:

- Step 1: Set “start” = 0;
- Step 2: Check whether the “start” has visited all the nodes. If yes, stop the iteration;
- Step 3: According to the Dijkstra (1959) algorithm, calculate the shortest path from node “start” to each other node, and record the shortest path index from node “start” to each other node.
- Step 4：Backtrack the obtained shortest path index to find out all the links in each shortest path, and count out the total number that each shortest path from node “start” to each other node passing through link i and link j simultaneously.
- Sub-step 4.1: Check whether the node i has traversed all the nodes on the shortest path index, if so, set start = start + 1, go to Step 2;
- Sub-step 4.2: Check whether node i is connected to node “start” directly or node i is node “start”, if yes, set $i = i + 1$, go to Sub-step 4.1;
- Sub-step 4.3: Find out all the nodes on the shortest path from node “start” to node i, and find out all the link names on the shortest path from node “start” to node i according to the mapping matrix “S_Name”, then record and store these link names in the one-dimensional array called “Bpath”.
- Sub-step 4.4: Make permutations and combinations of all the links in the one-dimensional array “Bpath”. Add 1 ($i = i + 1$) to the corresponding position of matrix BB to record every link combination, and then go to Sub-step 4.1.

4.2 The algorithm to get “Link Impact Strength”

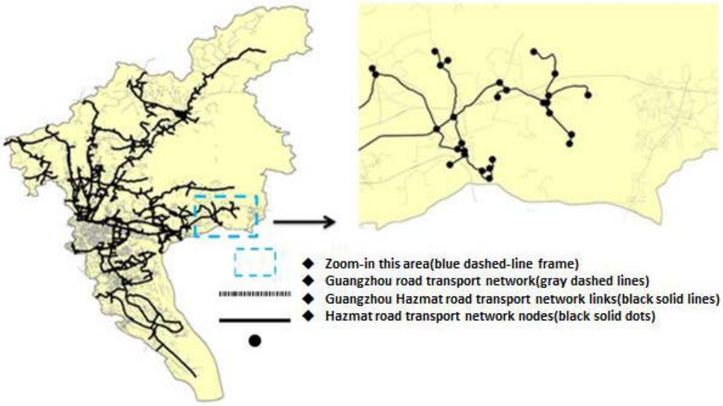
We firstly utilize the ArcGIS software to analyse the road network which can help us to get three tables: the spatial relation table about links and nodes (Relation), the midpoint distance table between two links (Distance), and the link information table (Link). The “Relation” table contains the information about link name, node name, link length; the “Distance” table provides the information about link i and link j, the midpoint distance between these two links; the “Link” table includes the information about link name, population density around the link, link length, the vehicle number on the link.

The detailed procedures are as follows:

- Step 1: Initialization. Through reading the data from these three tables (“Relation”, “Distance” and “Link”), we can generate the weight matrix between nodes, the distance matrix between links, the mapping matrix between node name and link name, and the information matrix about links.
- Step 2: Calculating the Link Correlation Coefficient. By using the iteration algorithm in Section 4.1, we calculate the Link Correlation Coefficient, and record such information in the BB matrix.
- Step 3: Calculating the Link Impact Strength. According to Eq. (8) above, we calculate the Hazmat transport risk of each link. Then we put all the obtained data from previous steps in Eq. (22) to calculate the Link Impact Strength of each link.

5. Case Study

The Hazmats transportation network in GuangZhou can be made as an example, which is a two-way network that contains 3,930 nodes and 5,062 links (in Figure 3). For simplicity, only two types of non-Hazmats vehicles are considered in the network. One is the 55-seat bus and the other is the 5-seat car. Based on the GPS data of the vehicles that transport Hazmats or passengers and the traffic data of the highways in 2015 in Guangdong Province, the total number of vehicles of each type per hour on each link can be calculated. And the Guangzhou Statistical Yearbook of 2015 can be referred to acquire the density of the population around the related links. According to the statistics of Hazmats transport tasks from September 2014 to August 2015 in Guangzhou, the main transported Hazmats are cyanide and toluene-2 isocyanate. Therefore, it is assumed that only the Hazmats transportation of cyanide and toluene-2 isocyanate is considered in this research. According to Frank et al. (2000)'s research, the impact scope of these Hazmats accidents is 8km. Referring to Ren (2007)'s PhD thesis, the accident rate of the transport vehicle is $TAR_i = 1.35E-6$ on the highway link and the conditional leakage probability is $P(R|A)_i = 0.062$. Referring to Berdica (2002)'s paper, we set $\alpha = 1$.



(a) A Global View (b) A Partial View

Figure 3: Hazmats Road Transport Network on the Highway Network of Guangzhou

According to the above formulas, we calculate the Impact Strength (S_i), the Risk (R_i), the Edge Number ($ED(i)$) and the total Correlation Coefficient ($CC(i, j)$) for each link i. The results are normalized and shown in Table 3. In order to make the horizontal comparison about the four indicators, the top ten links with high indicator values are selected and ranked in Table 4. In Table 4, Column 1 represents the links with top ten high value of Impact Strength, Column 2 represents the links with top ten high value of Risk, Column 3 represents the links with top ten high value of Edge Number, and Column 4 represents the links with top ten high value of the total Correlation Coefficient.

Table 3: The Four Main Indicators of Each Link (Normalized)

Link ID	Impact Strength S_i	Risk R_i	Edge Number $ED(i)$	The Total Correlation Coefficient $\sum_{j\neq i}\sum_{a,b\in N(a\neq b)} N_{ab}(i,j)$
1	3.84833E-04	4.58303E-04	4.52888E-04	3.33051E-04
2	4.13257E-05	3.55806E-07	1.25270E-04	1.52922E-04
3	1.41032E-05	9.38307E-08	4.83201E-05	1.24146E-04
4	1.42476E-04	1.16083E-04	2.46005E-04	2.10757E-04
5	3.08512E-05	2.88998E-07	8.71835E-05	1.49075E-04
6	9.75155E-06	9.04340E-06	1.24233E-04	1.70158E-04
7	1.21597E-05	2.78114E-07	1.01563E-04	1.40600E-04
8	2.80823E-05	4.16158E-07	1.17627E-04	1.66526E-04
9	2.48958E-04	1.28317E-04	3.59875E-04	2.81199E-04
10	6.28842E-05	4.27718E-05	2.23724E-04	1.97081E-04
11	1.42814E-05	5.94511E-07	1.48717E-04	1.75073E-04
12	6.43318E-06	1.71147E-07	7.34518E-05	1.31554E-04
13	1.80591E-05	2.55219E-07	1.05579E-04	1.30699E-04
14	3.48868E-04	2.73529E-04	3.60911E-04	2.86755E-04
15	2.94514E-05	4.03547E-07	1.05579E-04	1.35685E-04
16	3.55830E-05	1.26739E-06	1.00656E-04	1.37252E-04
17	6.55303E-05	1.66400E-05	2.09474E-04	2.18449E-04

18	3.12403E-05	1.82737E-06	1.08040E-04	1.34901E-04
19	2.41887E-04	1.32918E-04	4.27886E-04	3.28564E-04
20	6.32091E-05	1.15367E-06	1.60635E-04	1.70942E-04
⋮	⋮	⋮	⋮	⋮
⋮	⋮	⋮	⋮	⋮
5060	3.27773E-06	1.49365E-07	1.04802E-04	1.38819E-04
5061	2.61016E-05	1.01399E-07	1.80844E-04	1.87039E-04
5062	7.09699E-06	2.85704E-08	8.95153E-05	1.43947E-04

Sources: Compiled by Authors

Table 4: The Top Ten Links with High Indicator Values Respectively

Index/ Link ID/ Ranking	**Impact Strength** S_i	**Risk** R_i	**Edge Number** $ED(i)$	**The Total Correlation Coefficient** $\sum_{j\neq i}\sum_{a,b\in N(a\neq b)} N_{ab}(i,j)$
1	3104	3460	2396	2396
2	2636	2636	1775	2636
3	2463	2105	2636	1775
4	3460	2463	3104	3104
5	2105	2980	2080	2080
6	2380	4480	4060	2380
7	2980	1540	2380	1770
8	2140	3187	1770	1720
9	3340	3340	3410	4060
10	3160	3104	1720	3410

Sources: Compiled by Authors

The next step is to build Table 5 to exhibit the link coincidence ratio between different indicators. In Table 5, Column 1 is the link coincidence ratio of Impact Strength to Risk in the top N links; Column 2 is the link coincidence ratio of Impact Strength to the total Correlation Coefficient in the top N links; Column 3 is the link coincidence ratio of Impact Strength to Edge Number in the top N links; Column 4 is the link coincidence ratio of Edge Number to the total Correlation Coefficient in the top N links.

Table 5: The Link Coincidence Ratio between Different Indicators

Comparison Scope	**The Link Coincidence Ratio of Impact Strength to Risk**	**The Link Coincidence Ratio of Impact Strength to The Total Correlation Coefficient**	**The Link Coincidence Ratio of Impact Strength to Edge Number**	**The Link Coincidence Ratio of Edge Number to The Total Correlation Coefficient**
Top 10	70.0%	30.0%	30.0%	100.0%
Top 30	86.7%	30.0%	30.0%	100.0%
Top 50	90.0%	34.0%	34.0%	100.0%
Top 70	92.9%	40.0%	40.0%	97.1%
Top 100	95.0%	48.0%	47.0%	99.0%
Top 150	92.7%	56.0%	55.3%	98.0%
Top 200	91.0%	61.0%	60.0%	98.0%
Top 300	89.7%	66.3%	65.7%	97.7%
Top 400	86.5%	72.0%	73.3%	96.0%
Top 500	84.6%	74.6%	74.8%	95.8%
Top 600	83.3%	76.7%	77.3%	95.8%
Top 700	81.1%	77.3%	77.4%	95.0%
Top 800	79.6%	77.0%	78.6%	94.6%
Top 900	78.4%	76.8%	77.6%	93.3%
Top 1000	77.4%	76.4%	77.0%	92.4%
Top 1500	71.6%	72.6%	74.1%	90.3%
Top 2000	69.8%	72.1%	73.3%	89.6%
Top 2500	71.6%	75.6%	75.6%	90.0%
Top 3000	74.2%	78.4%	79.2%	92.2%

Top 3500	78.9%	82.2%	82.7%	94.2%
Top 4000	84.1%	86.5%	87.2%	94.6%
Top 4500	90.9%	92.0%	92.6%	96.4%
Top 5000	98.8%	98.9%	99.3%	99.3%
Total 5062	100.0%	100.0%	100.0%	100.0%

Sources: Compiled by Authors

Based on the above tables, some comparative analyses are as follows:

- From Table 4, we can uncover that 7 links appear simultaneously in Column 1 (Impact Strength) and Column 2 (Risk) which are Link 3104, Link 2636, Link 2463, Link 3460, Link 2105, Link 2980, Link 3340. When concerning the links with top ten high values of "Impact Strength" and "Risk", 70% of links are same. It means that 70% of links with high "Impact Strength" are with high "Risk" as well. When concerning the top 500 links, 423 links have high "Impact Strength" and "Risk" simultaneously (Ratio=423/500=84.6%). When concerning top 1000 links, the ratio is 77.4%. From the second column of Table 5, we can find that all the ratios are above 70% and some ratios are even more than 90%, which means that the identification of "Impact Strength" can be used to identify the links with high risks in the Hazmats transport network.

- In Table 4, Link 2380 is not presented in "Risk" column, but it is appeared in other three columns. Link 2380 is ranked in "Edge Number" 7th and in "Total Correlation Coefficient" 6th which means it has an important topological characteristic. Due to its topological characteristic, Link 2380 has high "Impact Strength" value (means a high vulnerability). However, Link 2380 does not have a high transport risk. Because "Impact Strength" (vulnerability) is determined by many factors, such as traffic flow, transport risk, topological characteristic, hence the link with a low transport risk can also have a high vulnerability (impact strength). In the third column of Table 5, the link coincidence ratio of Impact Strength to the Total Correlation Coefficient is growing while the comparison scope is growing (increasing from 30% to 100%). The fourth column (the ratio of Impact Strength to Edge Number) of Table 5 has the same situation (increasing from 30% to 100%) as the third column. On a large comparison scope, the "Impact Strength" can identify the links with important topological characteristics.

- In Table 4, all the links in the "Total Correlation Coefficient" column exist in the "Edge Number" column as well. In Table 5, the ratios of "Edge Number to the Total Correlation Coefficient" in the fifth column are mostly more than 90%. Therefore, we can say that the "Total Correlation Coefficient" indicator can be used to recognize the links with important topological characteristics (e.g. Edge Number) in the Hazmats transport network.

- In Table 4, we can discover that the links in the four different indicator columns have great differences. Thus we cannot identify the vulnerable links barely on the topology structure of Hazmats transport network. For example, Link 2396 is ranked 1st in the "Edge Number" column and "Total Correlation Coefficient" column in Table 4. However, its "Impact Strength" ranking is 1,954th, because it has a low transport ranking (1200th), a low traffic flow, and is far from other links, and so on. In reality, Link 2396 exists less threat which means less vulnerability (less "Impact Strength").

According to the data in Table 3, it can be drawn out of the cumulative distribution of four indicator values, as showed in Figure 4.

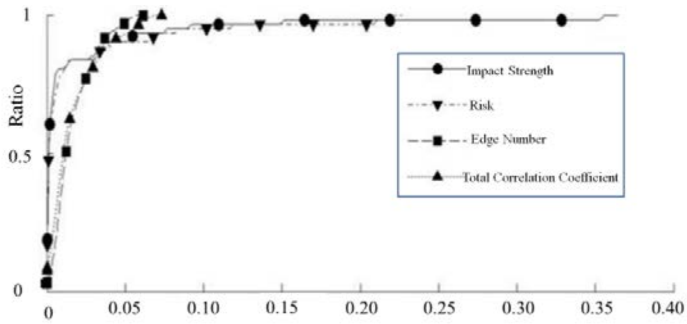


Figure 4: The Cumulative Distribution

From Figure 4, the cumulative distribution curves of Impact Strength and Risk are similar and they are overlapped in many areas, which indicate that the links with a high vulnerability identified by the "Impact Strength" model have the high transport risk characteristics. In Figure 4, the cumulative distribution curve of Risk is reaching 1 faster than the curve of Impact Strength, because there exists a small amount of links with high risks and important topology structures which means they have high vulnerabilities. Due to these links' existence, the cumulative distribution curve of Impact Strength is reaching 1 with a slow speed in the later stage. This phenomenon indicates that Impact Strength is affected by the topology structure of Hazmats network. In Figure 4, the cumulative distribution curves of Edge Number and Total Correlation Coefficient are very similar. And these two curves are almost overlapped. The main reason lies in the fact that they are both from network topological structure perspectives to measure the link vulnerabilities.

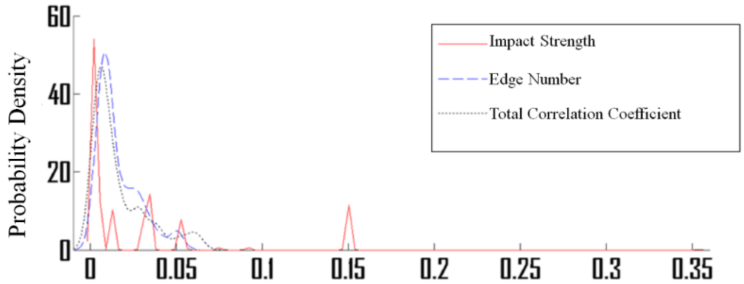


Figure 5: The Probability Density Distribution of Impact Strength, Edge Number and the Total Correlation Coefficient

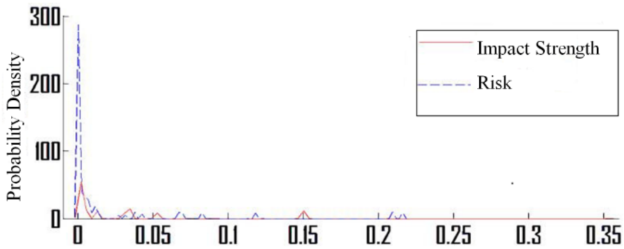


Figure 6: The Probability Density distribution of Impact Strength and Risk

From Figure 5, we can uncover that the probability density curves of Edge Number and the Total Correlation Coefficient are very similar, which shows that the Total Correlation Coefficient can reflect the characteristics of Edge Number--recognizing the "important" links (from topological structure perspective) in the entire road transport network. From Figure 6, we notice that the probability density curve of Risk (approaching 300) is far greater than the curve of Impact Strength (around 55) in the interval of 0~0.05. This phenomenon is mainly due to Impact Strength is related to not only Risk but also topological characteristic, traffic flow, and length of link. For example, some links have high transport risks but are "unimportant" links (topological characteristic), having low traffic flow, and far from other links and densely populated areas. Actually these links only with high risks have low Impact Strength values to the whole Hazmats road transport network. From a practical point of view, we can state confidently that the indicator "Impact Strength" can take over the indicator "Risk" to identify the vulnerability of Hazmats road transport network.

6. Conclusion and Implications

Through the analysis of transport network topology and Hazmats transport risk, the combination of these two, and on the basis of Gravity model, this paper develops an innovative Impact Strength model to assess the vulnerability of Hazmats road transport network. Then we use Guangzhou's Hazmats highway transportation as a case study to verify the Impact Strength model, and make a comparative analysis on the four indicators of each link: Impact Strength, Risk, Edge Number and Total Correlation Coefficient. These analysis results indicate that the characteristics of Impact Strength and Risk are very similar. That is to say we can use Impact Strength model to identify the links with high risks in Hazmats transport network. Meanwhile, Impact Strength of links are affected by the topological structures as well. By combining the transport risk and network topological structure factors, we can calculate the Impact Strength of each link and identity the links with high vulnerabilities (high Impact Strength values). In other previous studies, vulnerability identification of Hazmats transportation is only concerning the transport risk which is not comprehensive. Here we use the Impact Strength model to assess the vulnerability of Hazmats transportation, which is an innovative approach due to its comprehensive considerations. This research contributes to Hazmats road transportation management, e.g. improving the capabilities of emergency relief materials' distribution &scheduling and building the risk early-warning mechanism by using vulnerability identification for Hazmats transportation network.

References

Alp, E. (1995). "Risk-based Transportation Planning Practice: Overall Methodology and A Case Example." INFOR: Information Systems and Operational Research 33(1): 4-19.

Anderson, J. E. (2011). "The Gravity Model." Annual Review of Economics 3(1): 133-160.

Berdica, K. (2002). "An Introduction to Road Vulnerability: What Has Been Done, Is Done and Should Be Done." Transport Policy 9(2): 117-127.

Berdica, K. and L.-G. Mattsson (2007). Vulnerability: A Model-Based Case Study of the Road Network in Stockholm, Springer.

Centrone, G., R. Pesenti, et al. (2008). Hazardous Materials Transportation: a Literature Review and an Annotated Bibliography, IOS Press. 45.

Chen, Y. and J. Liu (2002). "Derivation and Generalization of the Urban Gravitational Model Using Fractal Idea with an Application to the Spatial Cross-correlation Between Beijing and Tianjin (in Chinese)." Geographical Research 21(6): 742-752.

Dijkstra, E. W. (1959). "A Note on Two Problems in Connexion with Graphs." Numerische Mathematik 1(1): 269-271.

Erath, A., J. Birdsall, et al. (2009). "Vulnerability Assessment Methodology for Swiss Road Network." Transportation Research Record: Journal of the Transportation Research Board 2137: 1-17.

Erkut, E., S. A. Tjandra, et al. (2007). "Hazardous Materials Transportation." Handbooks in Operations Research and Management Science 14(Chapter 9): 539-621.

Erkut, E. and V. Verter (1995). "A Framework for Hazardous Materials Transport Risk Assessment." Risk Analysis 15(5): 589-601.

Erkut, E. and V. Verter (1998). "Modeling of Transport Risk for Hazardous Materials." Operations Research 46(5): 625-642.

Frank, W. C., J.-C. Thill, et al. (2000). "Spatial Decision Support System for Hazardous Material Truck Routing." Transportation Research Part C: 8(1-6): 337-359.

Holme, P., B. J. Kim, et al. (2002). "Attack Vulnerability of Complex Networks." Physical Review E 65: 1-14.

Hu, P., B. Shuai, et al. (2015). "Model and Simulation for the Robustness of Hazardous Goods Transportation Network under Emergency (in Chinese)." Journal of Transportation Systems Engineering and Information Technology 15(2): 109-115+141.

Husdal, J. (2004). Reliability and Vulnerability Versus Cost and Benefits. Second International Symposium: Transportation Network Reliability (INSTR), Christchurch, New Zealand.

Jin, H. and R. Batta (1997). "Objectives Derived from Viewing Hazmat Shipments as a Sequence of Independent Bernoulli Trials." Transportation Science 31(3): 252-261.

Jung, W.-S., F. Wang, et al. (2008). "Gravity Model in The Korean Highway." Europhysics Letters 81(4): 6.

Kara, B. Y., E. Erkut, et al. (2003). "Accurate Calculation of Hazardous Materials Transport Risks." Operations Research Letters 31(4): 285-292.

Laurentius, G. (1994). The Vulnerability of the City, Planning a High Resilience Society (Swedish Agency).

Lepofsky, M., M. Abkowitz, et al. (1993). "Transportation Hazard Analysis in Integrated GIS Environment" Journal of Transportation Engineering 119(2): 239-254.

List, G. F., P. B. Mirchandani, et al. (1991). "Modeling and Analysis for Hazardous Materials Transportation: Risk Analysis, Routing/Scheduling and Facility Location." Transportation Science 25(2): 100-114.

Newman, M. E. J. (2010). Networks: An Introduction, Oxford University Press.

Ren, C. (2007). Hazardous Materials Transportation by Road: Risk-analysis-based Optimal Routing Methodology (in Chinese). Environmental Science and Engineering Department, Nankai University PhD Thesis: 167.

Taylor, M. and G. D'Este (2003). Concepts of Network Vulnerability and Applications to the Identification of Critical Elements of Transport Infrastructure. The 26th Australasian Transport Research Forum. Wellington, New Zealand.

UNECE (2011). Recommendation on the Transport of Dangerous Goods--Model Regulations, 17th revised edition, Volume I. New York and Geneva.

Wu, Z. and M. Sun (2006). "Statistic Analysis and Countermeasure Study on 200 Road Transportation Accidents of Dangerous Chemicals (in Chinese)." China Academy of Safety Science and Technology 2(2): 3-8.

Yamada, T. (1996). "A Network Flow Approach to A City Emergency Evacuation Planning." International Journal of Systems Science 27(10): 931-936.

Yang, J., F. Li, et al. (2010). "A Survey on Hazardous Materials Accidents During Road Transport in China from 2000 to 2008." Journal of Hazardous Materials 184(1-3): 647-653.

Zhang, J. and L. Zhao (2007). "Risk Analysis of Dangerous Chemicals Transportation." Systems Engineering - Theory & Practice 27(12): 117-122.

A Mathematic Identification Model of Risk Factors for Marine Casualties and Incidents

Tian-Hang Gao and Jing Lu

Transportation Management College, Dalian Maritime University, Dalian, Liaoning, 116026, China
Email: lujing@dlmu.edu.cn

Abstract

Because of the huge share of maritime transportation in the international transportation market, more and more governments and companies begin to pay high attention to the maritime safety. In order to identify the risk factors of marine casualties and incidents, an identification model of risk factors for marine casualties and incidents is constructed. This model is based on a determining nonadditive set functions, and considers the geographic features. The solution algorithm references the genetic algorithm. The proposed method is successfully applied in a case study, and the results show the single risk measures and double risk measures of the 6 risk factors.

Keywords: Identification of risk factors, Marine casualties and incidents, Determining nonadditive set functions, Geographic feature,Genetic algorithm

1. Introduction

Nowadays, the maritime transportation is the most important transportation mode for international commodity exchange. More than 80% international commodity is transported by ships from one country to the other. Therefore the safety of shipping at sea impacts the global economy, the ships are frequently threatened by both natural and human agents. The risk factors mainly includes weather, hydrogeology and ship factors. Every year these risk factors result in casualties and incidents which cause losses of property and life. It is quite necessary to find out which risk factor is more risky, only then can ships make targeted measures.

About the maritime safety, classical mathematics is used widely to assess the maritime risk. Hashemi and Le Blanc (1995) develops three models to predict vessel accidents on the lower Mississippi River. These models are a neural network, multiple discriminant analysis and logistic regression. According to the percent of "grouped" cases correctly classified, the neural network is proved to be better than the other two. Beside that, Ting-rong et al (2008) discusses the intrinsic essence and manageability of the risk, and points out FSA method is the appIication of the Risk Management in maritime safety which is drawn accordingly. In addition to the classical mathematics, Balmat et al (2011) proposes a fuzzy approach based on the decision-making system to evaluate the maritime risk assessment applied to safety at sea and more particularly, the pollution prevention on the open sea. Eleyedatubo et al (2008) proposes a fuzzy-Bayesian network to enable a bridge to be made into the possibilistic integration and that of vital inputs of linguistic nature. This implementation is demonstrated in a maritime performance case study that utilizes performance-shaping factors as the input variables of this groundbreaking risk model. These researches show that fuzzy mathematics are applied to the maritime safety, which have significant implications for identification of risk factors for marine casualties and incidents.

In the research of identification of risk factors, scholars have experimented with different methodologies. Campbell and Smith (2007) creates a prototype safety tool hosted via Microsoft Access program. This tool completes classification of work tasks using a system based on RIDDOR categories, and then searches a database to retrieve a selection of control measures and hazard mitigations that have been used in similar work tasks before. Kroger (2008) presents a selection of system weaknesses and a number of policy options that have been identified and highlights issues for further investigation and dialogue with stakeholders. Cagno et al (2011) presents an integrated approach for societal risk analysis of the failures of underground services for an urban area, an identification method of risk factors based on the check-lists. These researches about identification of risk factors in other domains all have the inspiration significance to this paper.

Because of the huge transportation volume, it is very necessary to make a systemic approach to find out the risk factors for marine casualties and incidents. Recent researches on the risk factors for maritime transportation have addressed various approaches to the problem. Trucco et al (2008) presents an innovative approach to integrate Human and Organisational Factors (HOF) into risk analysis, and a Bayesian Belief Network is developed to model the Maritime Transport System by taking into account its different actors and their mutual influences. Goerlandt and Montewka (2015) applies a classification of risk definitions, an overview of elements in risk perspectives and a classification of approaches to risk analysis science to focus on applications addressing accidental risk of shipping in a sea area.

On the basis of previous researches, a mathematic identification model of risk factors for marine casualties and incidents considering the risk factors' interaction is proposed in this paper. The mathematical tool, fuzzy measures, or more generally, nonadditive set functions and a filiation of fuzzy mathematics are used to indicate the interaction. Beyond that, Choquet integral, a nonlinear integral can be used to calculate the risk level under different risk conditions.

This paper is organized as follows: A qualitative analysis and selection of risk factors of marine casualties and incidents are demonstrated in section 2. The proposed model and the solution algorithm are shown in Section 3. In section 4, the proposed model is applied in a case study. In section 5, a detailed analysis based on the results in section 4 is given. Finally, the conclusions are given in Section 6.

2. Risk Factors of Marine Casualties and Incidents

Before identifying the risk factors in case study, it is necessary to construct a risk factors set which is waited to be identified. In the actual transportation process, the safety of the transportation ships is influenced by many factors. They are environment factors, ship factors and human factors.

Considering the human factors are difficult to be quantized and lack of data statistics, the human factors are not involved in this case study. Only the environment factors and ship factors are considered. According to a qualitative analysis, the following quantifiable risk factors are selected to form the risk factors set.

i. Surface wind speed

Wind strength influences the safety of the maritime transportation all the time. For modern ships, strong wind can make the crews get out control of the ship on the sea. In practical, besides stall and growth, wind can also cause deflection of sailing direction. Therefore, wind is selected to be one risk factor. After selecting risk factor, it needs to find the quantitative measure. Surface wind speed is a common quantitative data to measure whether wind is strong or weak in practice. The higher the surface wind speed, the stronger the wind strength. From the above, surface wind speed is chosen as the first risk factor variable.

ii. Rain Rate

Rain rate is the rainfall per unit time. The bigger amount of rainfall at sea usually means a bad weather and poor visibility, it adds to the difficulty of ship steering. In this case, collisions and standings are more likely to happen because of the poor visibility. Therefore, rain rate is an important parameter needs to be focused on for navigation.

iii. Significant wave height

Ships usually sway around the center of gravity under the stress of waves on the sea. This swing is affected by several factors, such as the strength of the waves, the cycle of the waves and the characteristics of ships. The major influences of the waves to the ships are the threats to the security of the ships, the reduction of the ships' speed and the impacts to the crews. In order to consider the influences of the waves, the significant wave height is selected to be the risk factor variable on behalf of the waves' influences.

iv. Water depth

When the water depth is shallow, the ratio between the water depth and ship draught is small. With the smaller of the ratio, the ship's speed is slower. On the other hand, there will be occurrence of ship's sinking and trim. If the water depth is serious shortage, the ship will strike on rock. Therefore, water depth is also an important risk factor variable. Beyond that, the water depth deeper than 100 meters is regarded as the same in the paper considering the impact is not no longer obvious.

v. Ship density

Ship density represents the amount of the ships in a certain area. When the amount of the ships in this area is enormous, the navigation environment is very complicated. That is why the driving difficulty is increased. Many marine casualties and incidents happened in this circumstance. In this paper, the amounts of the ships within 15 nautical miles of the marine casualties and incidents' the locations are counted to represent the ship density. This is a reasonable area in which the crews can have clear observations, so the ships in sight can impact the crews' operation.

vi. Ship deadweight

Almost all the ships sailing on the sea have met severe weather. In this case, the ships which have larger deadweights are safer. That is because the anti-risk capability of the bigger ships is stronger. The same wind strength may cause damage to the ship whose deadweight is smaller, but no damage to the bigger one.

3. Methodology

3.1. 1st Nonadditive set functions

The traditional tool of aggregation for identification of risk factors is linear integral, and it is based on the assumption that the factors involved are noninteractive and their weighted effects are viewed as additive ones. This assumption is not realistic in many applications, such as the maritime transportation. To overcome this defect and describe the interaction among various risk factors, the fuzzy measures, or more generally, nonadditive set functions can be used. Regarding a nonlinear integral as a multi-input ingle-output system, the values of the nonadditive set function can be determined from the input-output data of the system. In this paper, the values of the nonadditive set function correspond to the degree of the risk factors.

Let X be a measurable space, and μ:F $\rightarrow [0, \infty)$ be a set function satisfying $\mu(\emptyset)$ =0，$\mu(X)$ =1, μ is regular. Assumed that there are two risk factors x_1, x_2 needed to determine the degree of the risk. If $\mu(\{x_1, x_2\}) > \mu(\{x_1\}) + \mu(\{x_2\})$, it indicates that the joint contribution of andx_1, $x_2$to the degree of the risk is larger than the sum of their individual contributions. This means that there is some interaction between them, in other words, x_1 and $x_2$enhance each other. On the contrary, if $\mu(\{x_1, x_2\}) < \mu(\{x_1\}) + \mu(\{x_2\})$, it indicates that they restraining each other.

The classical Lebesgue integral is not applicative for nonadditive set function because of the nonadditivity. So it is necessary to define a new type of integral. A common and reasonable nonlinear integrals with respect to nonnegative monotone set functions is the Choquet integral.

Let f be a nonnegative real-valued measurable function defined on X, and μ be a nonnegative monotone set function. The *Choquet integral* of f on X with respect to μ, $(c) \int f \, d\mu$ is defined by the formula

$$(c) \int f \, d\mu = \int_0^{\infty} \mu(F_\alpha) d\alpha \qquad (1)$$

where $F_\alpha = \{x \mid f(x) \geq \alpha\}$ for any $\alpha \in [0, \infty)$.

3.2. 2nd Data processing

- *1st Risk data processing*

A risk is an uncertain event or condition that, if it occurs, will have a negative or positive effect on one or more objectives. It is a function of the probability and consequence of the uncertain event or condition. Assumed that the risk is R, the probability of the uncertain event is P, the consequence of the uncertain event is E, the function is $R = f(P, E)$. In order to simplify the model, the function in this paper is assumed to be $R = P \times E$.

In order to identify the risk factors for marine casualties and incidents, the historical casualties and incidents data are the best samples because of their specificity. In the other historical data, the risk can't be measured because there are no casualties and incidents.

In a historical casualty or incident, the risk factors data like sea surface wind speed, wave height and depth of water and so on can be obtained from the professional website. The consequence of the uncertain event, the accident, can be obtained from the accident report, but the probability of the accident can't be obtained directly. So there need to be some data processing to get the probability of the accident.

From a casualty or incident report, the geographical coordinate of the casualty or incident location is known. Then the risk factors data in this location can be summarized from various websites and reports. According to the risk factors data in this location, the geographic area who has the same data is delimitated. After delimitating the area, the quantity of the ships sailing in this area is counted. The probability of the accident can be obtained by dividing the number of accidents to the total number of ships sailing in the area, that is, the total number of ships sailing under the same condition.

- *2nd Risk factors data processing*

Each unstandardized risk factor has its own characteristics and range, and the specific dimension and distribution of the datum of each unstandardized risk factor is different. It is difficult to compare the characteristics of different risk factors or incorporate them together into one model. So it is necessary to make dimensionless by range transformation by normalization.

Different risk factors influence the maritime safety in different directions. For example, the faster the sea surface wind speed is, the more dangerous the ships are at sea. The deeper the water is, the safer the ships are. So if the higher value for each unstandardized risk factor means more dangerous navigation environment, the maximum normalization method is applied.

$$f = \frac{x - \min x}{\max x - \min x} \tag{2}$$

To the contrary, the minimum normalization method is applied.

$$f = \frac{\max x - x}{\max x - \min x} \tag{3}$$

After normalization transforming, the risk factors data is continuous variable. But the delineation area can't be delineated base on the continuous variable. And this also enlarges the calculation work remarkably. In order to solve these problems, keep one decimal place of the normalization risk factors data.

3.3. 3rd Solution Algorithm

The identification of risk factors in this model is to determine the measure μ. Let $X = \{x_1, x_2, \dots, x_n\}$ be set of risk factors. The nonlinear integral *Choquet integral* of f with respect to μ can be viewed as a system with n inputs and one output. The input-output data of the system can be given in this form:

$$
\begin{array}{lllll}
f_{11} & f_{12} & \cdots & f_{1n} & E_1 \\
f_{21} & f_{22} & \cdots & f_{2n} & E_2 \\
\vdots & & & & \\
f_{l1} & f_{l2} & \cdots & f_{ln} & E_l
\end{array}
$$

where l is the size of the risk factors data, E_j is the risk data, $j = 1,2,\cdots,l$. The job of the solution algorithm is to find a suitable nonnegative monotone set function μ such that

$$E_j = \int f^{(j)} d\mu \quad \forall j = 1,2,\cdots,l \tag{4}$$

where $f^{(j)}(x_i) = f_{ji}, j = 1,2,\cdots,l; i = 1,2,\cdots,n$. There may be many such measures μ exist, but which one is the most suitable. The least-square method can be used to determine the best solution μ. Find μ such that:

$$e = \sqrt{\frac{1}{l}\sum_{j=1}^{l}(E_j - \hat{E}_j)^2} \tag{5}$$

is minimized, where $E_j = \int f^{(j)} d\mu, \forall j = 1,2,\cdots,l$.

The genetic algorithm can be used to search the optimal μ. This algorithm has been successfully used to obtain the approximate optimal regular λ-fuzzy measure nonlinear integral system. The genetic algorithm is a mature algorithm, so the algorithm mechanism is not explained in detail. But there are two additional explanations. The first one is that, the bit string length of each chromosome depends on the precision. So the determination of the precision is very important, it has an influence on the calculation efficiency and the results precision. The specific precision should be indicated in the cast study. The second one is the function of the fitness of chromosomes. According to Wang's (1999) paper, the fitness of chromosomes is defined by

$$\frac{1}{1+e} \tag{6}$$

it has been proved to be a rational fitness function.

4. Case Study

To illustrate the benefit of the proposed model, a case study is presented in this section. The case is the 24 marine casualties and incidents in the shipping line from China to the Middle East in the last 5 years. The 6 selected risk factors waiting to be identified are introduced in section 2. The surface wind speed data and rain rate data is produced by Remote Sensing Systems (http://www.remss.com), the significant wave height data is produced and distributed by AVISO (http://www.aviso.oceanobs.com). The water depth data and ship density data is got from the http://www.shipxy.com. The real-time ships' locations are used to replace the ships' location when the marine casualties and incidents happen because of the lack of historical data. This processing is reasonable because the ships distribution on the earth is regular at most time. The details of the ship and the reports of the marine casualties and incidents are both got from the GISIS (Global Integrated Shipping Information System) database, which is public in IMO (International Maritime Organization) website. The marine casualties and incidents in this database are divided into 3 levels: very serious, serious and less serious. According to this, the quantitative consequence of marine casualties and incidents can be also divided into 3 levels: 3(very serious), 2(serious) and 1(less serious). And the risk data is the result of dividing the quantitative consequence of marine casualties and incidents by the total number of ships sailing under the same condition. The details are shown in Table 1.

Table 1: Original risk factors

Risk factors	Normalization	Data sources
Surface wind speed	+	http://www.remss.com
Rain rate	+	http://www.remss.com
Significant wave height	+	http://www.aviso.oceanobs.com
Water depth	-	http://www.shipxy.com.
Ship density	+	http://www.shipxy.com
Ship deadweight	-	GISIS database

+: maximum normalization
-: minimum normalization

The algorithm is implemented in Matlab R2012a, and the crossover probability is 0.8, the mutation probability is 0.1. The population size is 500, the number of generations is 200. The precision is 0.001, so the bit string length of each chromosome is 10. After running the program, the convergence figure of the algorithm and the fitting figure of the model are firstly demonstrated to illustrate the applicability of the algorithm and the reasonability of the proposed model. Figure 1 shows the convergence curves of 5 algorithm operations. These 5 convergence curves indicate that this algorithm can converge rapidly and get virtually equal solutions. The algorithm has been proven to be applicative.

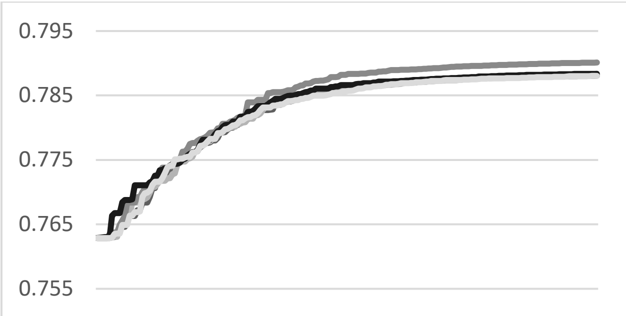


Figure 1: Convergence curves figure

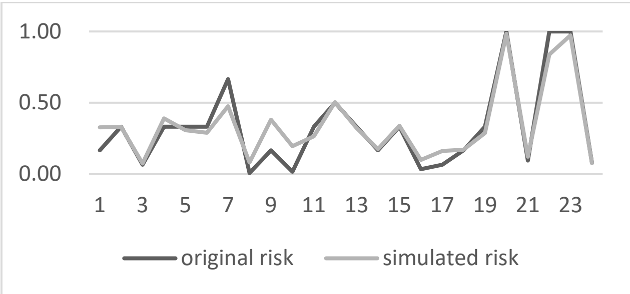


Figure 2: Simulated risk fitting curve figure

The fitting curve in Figure 2 indicates that the Chouqet integral values simulated with the risk measure values are very similar to the actual risk values, *e*=0.0850. This also explains the risk measures values calculated by this method are reasonable. Only single risk measure values and double risk measure values of the 6 risk factors are demonstrated considering the total number of the risk measures values are huge:

Table 2: Risk measure values of risk factors sets

risk factors set	risk measure values	risk factors set	risk measure values	risk factors set	risk measure values
$\{x_1\}$	0.998	$\{x_1, x_3\}$	0.981	$\{x_2, x_6\}$	
$\{x_2\}$	0.990	$\{x_1, x_4\}$		$\{x_3, x_4\}$	0.730
$\{x_3\}$	0.129	$\{x_1, x_5\}$		$\{x_3, x_5\}$	
$\{x_4\}$	0.248	$\{x_1, x_6\}$	0.011	$\{x_3, x_6\}$	0.994
$\{x_5\}$	0.800	$\{x_2, x_3\}$		$\{x_4, x_5\}$	0.126

$\{x_6\}$	0	$\{x_2, x_4\}$	0.996	$\{x_4, x_6\}$	0.492
$\{x_1, x_2\}$		$\{x_2, x_5\}$		$\{x_5, x_6\}$	0.860

The black parts in the Table 3 means that the measures of these risk factors sets can't be calculated with the data. Each historical marine casualty and incident needs 6 measures of risk factors set to calculate the Chouqet integral. The data is irregular in a real-world situation, so it can't guarantee every risk factors set involved.

5. Discussions

In this section, the features and analysis of the above results are described:

- Among the 6 risk factors, surface wind speed, rain rate and ship density these 3 risk factors' single risk measure values are high. This illustrates that if there is only one risk existing, surface wind speed, rain rate or ship density will have greater impact on the safety of the ships in the shipping line from China to the Middle East. Significant wave height and water depth have small impact on the safety of the ships.

- The single risk measure value of the ship deadweight in the Table 2 is 0. This means the ship deadweight has no impact on the safety if there is no other risk existing. This phenomenon conforms to the actual situations. Smaller ships' anti-risk capability is weaker, so they are more dangerous when facing with other risks. But once there are no other risks, the ship deadweight is not a risk factor any more.

- The double risk measures values of $\{x_3, x_6\}$, $\{x_4, x_6\}$ and $\{x_5, x_6\}$ are higher than the sum of the two single risk measure value. It means that the smaller ships face greater risks than the larger ships under these 3 circumstances, in other words, the risk factor ship deadweight has a positive coupling interaction with significant wave height, water depth and ship density.

- There are also negative coupling interactions between the 6 risk factors, like $\{x_1, x_3\}$ and $\{x_2, x_4\}$. At first, strong wind often accompanies with giant waves, the impacts of them to the safety of the ships are resemblances, so there is a negative coupling interaction between surface wind speed and significant wave height. In addition, strong rainfall has a serious impact on visibility at sea, which results in reduction of ship speed. Such operation reduces the risk of the water depth, too. Therefore, $\mu(\{x_2, x_4\}) < \mu(\{x_2\}) + \mu(\{x_4\})$.

6. Conclusions

In this paper, a mathematic identification model of risk factors for marine casualties and incidents based on determining nonadditive set functions and geographic feature is constructed. And a case study in the shipping line from China to the Middle East is presented. At last, the features and analysis of the contrast results are described.

The main conclusions of this work are as follows. First, surface wind speed, rain rate and ship density are the main three risk factors to the safety of the ships in the shipping line from China to the Middle East. Second, the single risk measure of ship deadweight is 0 in the case study, but it has a positive coupling interaction with significant wave height, water depth and ship density. Third, the double risk measures of $\{x_1, x_3\}$, $\{x_1, x_6\}$, $\{x_2, x_4\}$ and $\{x_4, x_5\}$ are smaller than the sum of two single risk measures.

On the basis, the future researches can be focused on the improvement and perfection of model, at the same time, more factors can be considered to make the model closer to the reality. In addition, it is hoped that this work can increase the number of the case data to reduce the imponderable risk measure values and improve the accuracy of the model.

7. Acknowledgements

This research was funded by Chinese National Natural Science Foundation (71473023).

References

Balmat. J.F., Lafont. F., Maifret. R., Pessel. N. (2011), A decision-making system to maritime risk assessment, Ocean Engineering 38(1):171-176.

Cagno, E., De Ambroggi, M., Grabde, O. et al. (2011), Risk analysis of underground infrastructures in urban areas, Reliability Engineering and System Safety 96(1): 139-148.

Campbell, J.M., Smith, S.D. (2007), Safety, hazard and risk identification and management in infrastructure management: A project overview, Proceedings of 23rd Amual ARCOM Conference, Belfast, UK.

Eleyedatubo, A.G., Wall, A., & Wang, J. (2008), Marine and offshore safety assessment by incorporative risk modeling in a fuzzy-Bayesian network of an induced mass assignment paradigm, Risk Analysis 28(1), 95-112.

Goerlandt, F., Montewka, J. (2015), Maritime transportation risk analysis: Review and analysis in light of some foundational issues, Reliability Engineering and System Safety 138:115-134.

Hashemi, R.R., Le Blanc, L. A., Rucks, C. T.,& Shearry. (1995), A neural-network for transportation safety modeling, Expert Systems with Applications 9(3):247-256.

Kroger, W. (2008), Critical infrastructures at risk: A need for a new conceptual approach and extended analytical tools, Reliability Engineering and System Safety 93(12): 1781-1787.

Murofushi, M., Sugeno, M. (1989), An interpretation of fuzzy measure and the Choquet integral as an integral with respect to a fuzzy measure, Fuzzy Sets and Systems 29(2):201-227.

Murofushi, M., Sugeno, M., Machida, M. (1994), Non-monotonic fuzzy measures and the Choquet integral, Fuzzy Sets and Systems 64(1):73-86.

Ting-rong, Q., Wei-jiong, C., & Xiang-kun, Z. (2008), Risk management modeling and its application in maritime safety, Journal of Marine Science Applications 7(4):286-291.

Trucco, P., Cagno, E., Ruggeri, F., Grande, O. (2008), A Bayesian Belief Network modelling of organisational factors in risk analysis: A case study in maritime transportation, Reliability Engineering and System Safety 93(6):823-834.

Wang, Z., Leung, K., Wang, J. (1999), A genetic algorithm for determining nonadditive set functions in information fusion, Fuzzy Sets and Systems 102(3):463-469.

Using Meta-Frontier Approach to Measure the Efficiency of Global Liner Shipping Companies: An Aspect of Joining E-Commerce Alliances

Shih-Liang Chao and Ssu-Yu Cheng*

Department of Shipping and Transportation Management, National Taiwan Ocean University, Keelung, Taiwan, ROC. Email: alexchao@ntou.edu.tw

**Corresponding author*

Abstract

Developing e-commerce is a commonly used strategy for the liner shipping companies (LSCs) to increase their service quality. Some LSCs prefer to join large strategic alliances to promote the e-commerce but some LSCs promote e-commerce by themselves. This study divided major LSCs into several groups according to their strategies and then used data envelopment analysis (DEA) meta-frontier approach to measure the scores of efficiency and technology gap of LSCs. The result showed that LSCs joined two e-commerce alliances held the leadership in the industry in 2014 and 2015.

Keywords: Liner shipping, E-commerce, Strategic alliance, Efficiency evaluation, Data Envelopment Analysis (DEA)

1. Introduction

Liner shipping has become an important mode for carrying cargo globally because containers can be exchanged between ships, truck and even trains. To maintain fixed schedules and service routes, liner shipping companies (LSCs) have to deploy a large number of ships and containers, or even setup dedicated terminals at important ports. These huge investments built up significant entry barriers for new comers to enter this industry. As a result, the global liner shipping market is dominated by a few large LSCs (Heaney, 2008). Since the core service of liner shipping is to carry containers between ports, in which the difference are not so significant. Therefore, enhancing peripheral service has become an important strategy for LSCs to increase their competitiveness in the market. For example, it is a common strategy to provide so-called "door to door" service to handle a shipment before it arrives at a terminal from shipper's premise, and after it leaves a terminal to consignees' warehouse. That's the reason why most large LSCs have established dedicated logistics companies to provide customers with more tailored service rather than just carrying containers for them. Another widely used strategy is to facilitate the shipment via information technology, especially based on the internet. In other words, promoting e-commerce has become a must for large LSCs to increase their service quality. In terms of liner shipping, typical services of e-commerce include documentation management (bill of ladings), container tracking, on-line booking and payment. In addition to these basic services, many LSCs have formed strategic alliances to further increase the scope of e-commerce service. Therefore, it's an interesting and important issue to investigate the effect of joining strategic alliances of e-commerce for LSCs. Given that most LSCs had joined at least one e-commerce alliance, in this study we divided major LSCs into two groups. LSCs in the first group joined one e-commerce alliance and LSCs in the other group joined two e-commerce alliances. After that, the score of efficiency and technology gap were measured by applying the meta-frontier approach. Lastly, statistical tests were conducted to examine if the difference in scores is significant between different groups.

2. Literature Review

Measuring the efficiency of LSCs is an important issue which has been investigated in many prior studies. For example, Lun and Marlow (2011) measured the efficiency of major global LSCs by a data envelopment analysis (DEA) model. Capacity and cost were used as input variables and the output variables include profit and revenue. Bang et al. (2012) used DEA to measure the scores of operational and financial efficiencies of major LSCs. The difference in financial efficiency between alliance member LSCs and non-member LSCs was proved significant. Gutierrez et al. (2013) also evaluated the efficiency of major LSCs by DEA models. The bootstrap approach was applied to determine the scores. Chao (2014) decomposed the production process of an LSCs into three stages by a multi-stage DEA model to identify the scores of division and overall efficiency. Based on the above discussed studies, it is suitable to apply the DEA approach to measure the efficiency of LSCs.

3. Methodology

In this study, the distance function (DF) was used to determine the contemporaneous efficiency of an LSC. A DF is the maximal ratio that its output is projected to the frontier curve but still in the possible production set. Extending the idea of DF, Oh and Lee (2010) proposed an index to measure the change of efficiency with a metafrontier approach. As Figure 1 shows, for the same decision making units (DMUs) in different periods, the change of efficiency can be measured by DFs benchmarking the global frontier curve formed by all DMUs over all periods. Let P^G be the global frontier curve, $P^I_{R_j}$ be the frontier curve of group j over all periods, $P^i_{R_j}$ be the frontier curve of group j in period i and (x^t, y^t) be the observed the input and output in period t, then the metafrontier Malmquist productivity index (hereafter called MMPI) can be defined with Eq. (1), which is the ratio between two DFs measured by P^G.

$$\mathrm{MMPI}=M^G\left(x^t, y^t, x^{t+1}, y^{t+1}\right)=\frac{D^G(x^{t+1},y^{t+1})}{D^G(x^t,y^t)} \qquad (1)$$

The MMPI in Eq. (1) can be further deconstructed by Eq. (2) into the product of three indexes. The first is named efficiency change (EC), showing the change in the DFs between different periods. The second item is called the best practice change (BPC), representing the change in the gap between the contemporaneous frontier curve and the group frontier curve. The last item, technical gap change (TGC), measures the gap between the group frontier curve and the global frontier curve.

$$\begin{aligned}
\mathrm{MMPI} &= \frac{D^G(x^{t+1},y^{t+1})}{D^G(x^t,y^t)} \\
&= \frac{D^{t+1}(x^{t+1},y^{t+1})}{D^t(x^t,y^t)} \times \left\{\frac{D^t(x^t,y^t)}{D^{t+1}(x^{t+1},y^{t+1})} \times \frac{D^G(x^{t+1},y^{t+1})}{D^G(x^t,y^t)}\right\} \\
&= \frac{D^{t+1}(x^{t+1},y^{t+1})}{D^t(x^t,y^t)} \times \left\{\frac{D^t(x^t,y^t)}{D^{t+1}(x^{t+1},y^{t+1})} \times \frac{D^I(x^{t+1},y^{t+1})}{D^I(x^t,y^t)}\right\} \times \left\{\frac{D^I(x^t,y^t)}{D^I(x^{t+1},y^{t+1})} \times \frac{D^G(x^{t+1},y^{t+1})}{D^G(x^t,y^t)}\right\} \\
&= \frac{D^{t+1}(x^{t+1},y^{t+1})}{D^t(x^t,y^t)} \times \left\{\frac{\frac{D^I(x^{t+1},y^{t+1})}{D^{t+1}(x^{t+1},y^{t+1})}}{\frac{D^I(x^t,y^t)}{D^t(x^t,y^t)}}\right\} \times \left\{\frac{\frac{D^G(x^{t+1},y^{t+1})}{D^I(x^{t+1},y^{t+1})}}{\frac{D^G(x^t,y^t)}{D^I(x^t,y^t)}}\right\} \\
&= \frac{TE^{t+1}}{TE^t} \times \frac{BPG^{I,t+1}}{BPG^{I,t}} \times \frac{TGR^{t+1}}{TGR^t} \\
&= EC \times BPC \times TGC
\end{aligned} \qquad (2)$$

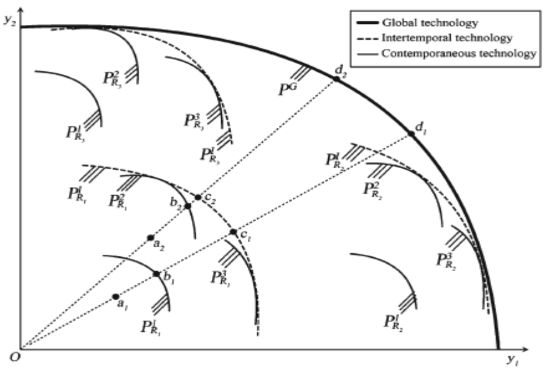


Figure 1: The concept of MMPI

Source: Oh and Lee (2010)

4. Empirical study

4.1 Input and output variable

Considering the characteristics of running an LSC, this study selects total capacity and number of employees as input variables, and the operating revenue as output variable. Table 1 shows input and output variables used in this study.

Table 1: Definition of input and output variable

	Variable	Unit	Definition
Input	Total capacity	TEUs*	The total fleet capacity deployed for carrying containers.
	Employees	Person	The number of employees served in a liner shipping company.
Output	Operating revenue	US dollar	The operating revenue obtained from running liner shipping service.

Note: TEU stands for twenty-foot equivalent unit.

4.2 Intertemporal efficiency and technology gap measurement

This study applies MMPI to determine the intertemporal efficiency of global LSCs. After that, the technology gap ratios (TGR) of each LSC were determined to compare the efficiency between LSC groups that adopt different e-commerce development strategies. Currently, *CargoSmart* and *GT Nexus* are two major e-commerce alliances for LSCs. Therefore, we classified major global LSCs into two groups in which LSCs in group 1 joined only one e-commerce alliance and LSCs in group 2 joined both. Table 2 indicates the result of intertemporal efficiency for the period 2014-2015. It is found that the average of EC score of group 2 were larger than 1, reflecting these LSCs improved their relative efficiency comparing to their peer LSCs in group 2. The average BPC scores of both groups were less than 1, reflecting both groups enlarged the gap between the contemporaneous frontier curve and the group frontier curve. The decrease rate of group 1 was larger than that of group 2 because group 1 had a lower average BPC score. Similarly, both groups enlarged the gap between the group frontier curve and the global frontier curve. The decrease rate of group 2 was larger than that of group 1 because the average TGC score was lower. The scores of TGR are summarized in Table 3. The average TGR scores of group 2 were larger than those in group 1 in 2014 and 2015, indicating that group 2 held the technology leadership in these two years.

Table 2: Result of intertemporal efficiency measurement

		2014-2015			
Group	Carriers (DMU)	EC	BPC	TGC	MMPI
1	Evergreen	1.0694	0.9437	1.0000	1.0092
	Hanjin	0.9984	0.8811	1.0028	0.8822
	OOCL	0.9723	0.8580	1.0000	0.8343
	APL	0.7528	0.6643	1.0000	0.5001
	HMM	1.0000	0.9031	0.9879	0.8922
	ZIM	0.9348	0.8249	1.0000	0.7711
	Average	0.9546	0.8459	0.9985	0.8148
2	Maersk	0.9599	0.8801	0.8448	0.7137
	CMA CGM	0.9523	0.8801	0.8382	0.7025
	COSCO	0.9371	0.8801	0.8247	0.6802
	Hapag-Lloyd	1.4992	0.8801	1.3195	1.7412
	MOL	1.0000	1.0000	1.0000	1.0000
	YML	0.8022	0.8801	0.7061	0.4985
	NYK	1.0735	0.9153	0.9825	0.9653
	K-LINE	1.0000	0.8948	0.8948	0.8006
	Average	1.0280	0.9013	0.9263	0.8878

Table 3: The value of TGR (2014 and 2015)

Group	Carriers(DMU)	2014	2015
1	Evergreen	0.9844	0.9870
	Hanjin	0.9844	0.9870
	OOCL	0.9844	0.9870
	APL	0.9844	0.9870
	HMM	1.0000	1.0000
	ZIM	0.9844	0.9870
	Average	0.9870	0.9891
2	Maersk	1.0000	1.0000
	CMA CGM	1.0000	1.0000
	COSCO	1.0000	1.0000
	Hapag-Lloyd	1.0000	1.0000
	MOL	1.0000	1.0000
	YML	1.0000	1.0000
	NYK	0.9652	0.9843
	K-LINE	1.0000	1.0000
	Average	0.9956	0.9980

4.3 Mann–Whitney U test

To compare the difference in TGR scores between the two groups, we conducted Mann–Whitney U tests to examine the difference statistically. Tables 4 to 5 show the results of Mann–Whitney U tests on TGR from 2014 to 2015. We found that the difference in TGR scores between the two groups in 2014 and 2015 were both significant at P=0.05. These results show that the TGR scores between the two groups were significant in 2014 and 2015.

Table 4: The result of Mann–Whitney U test of TGR (2014)

	Group 1	Group 2
Group 1	1	0.033*
Group 2	0.033*	1

Note: *significant at the P<0.05

Table 5: The result of Mann–Whitney U test of TGR (2015)

	Group 1	Group 2
Group 1	1	0.033*
Group 2	0.033*	1

Note: *significant at the P<0.05

5. Conclusions

There are a number of studies adopting DEA to measure the efficiency of LSCs, but few of them discussed the efficiency from the view of joining the e-commerce alliance. In this study, we divided major global LSCs into two groups. LSCs in the first group joined one e-commerce alliance and LSCs in the other group joined two e-commerce alliances. Based on the result of our empirical study, the TGR scores of LSCs in the second group were larger than those of LSCs in the first group in 2014 and 2015. This result shows that LSCs that joined two e-commerce alliances (i.e. *CargoSmart* and *GT Nexus*) held the leadership in terms of production technology in the liner shipping industry because their group frontier curves were closer to the global frontier curve in 2014 and 2015. Given that most LSCs have joined at least one e-commerce alliance, future studies may investigate the development on e-commerce of liner shipping and global logistics, and evaluate the efficiency of LSCs by appropriate categorization. In addition, due to time constraints, only three variables were taken into account in this study. Future studies may include more LSCs and variables to measure and compare the difference between LSCs using different strategies for developing e-commerce.

6. Acknowledgements

The authors would like to thank the Ministry of Science and Technology of the Republic of China, Taiwan for financially supporting this research under contract no. MOST 103-2410-H-019-025. Our deepest appreciation is also extended to Mr. Wei-Fan Hsieh and Ms. Wan-Rung Tsai for their assistance in data collection and analysis.

References

Bang, H. S., Kang, H. W. and Martin, J. (2012), The impact of operational and strategic management on liner shipping efficiency: a two-stage DEA approach, Maritime Policy and Management 39(7): 653-672.

Battese, G. E. and Rao, D. S. P. (2002), Technology gap, efficiency, and a stochastic metafrontier function, International Journal of Business and Economics 1(2): 87-93.

Caves, D. W., Christensen, L. R. and Diewert, W. E. (1982), Multilateral comparisons of output, input, and productivity using superlative index number, Economic Journal 92(365): 73-86.

Chao, S. L. (2014), Combining Multi-Stage DEA and Fuzzy AHP to Evaluate the Efficiency of Major Global Liner Carriers, International Forum on Shipping, Ports and Airports(IFSPA) 2014: 162-169.

Färe, R., Grosskopf, S., Lindgren, B. and Roos, P. (1992), Productivity Change in Swedish Pharmacies 1980-1989: A Nonparametric Malmquist Approach, Journal of Productivity Analysis 3(1): 85-101.

Gutiérrez, E., Lozano, S. and Furió, S. (2013), Evaluating Efficiency of International Container Shipping Lines: A Bootstrap DEA Approach, Maritime Economics & Logistics 16(1): 55-71.

Heaney, S. (2008), Top 20 container lines, American shipper 50(9): 67-70.

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.

Malmquist, S. (1953), Index numbers and indifference surfaces, Trabajos de Estadistica 4(2): 209-242.

Oh, D. H. and Lee, J. D. (2010), A metafrontier approach for measuring Malmquist productivity index, Empirical Economics 88: 47-64.

An Overview of the Hinterland Operations at Cochin Port

Vidya G Mohan, Naseer Muhammad Abdurahman, Archana Vinod and Amrutha Meera Asokan

Department of Architecture and Planning, NIT, Calicut, India
Department of Civil Engineering, ACE College of Engineering, Trivandrum, India
Email: vidyagmohan@gmail.com

Abstract

India, with around 7517 km of natural peninsular coastline strategically located on the crucial East-West trade route, has a vast potential in the shipping sector. Seaports are critical in international trade. They provide linkages between international and domestic production and distribution networks. India still lacks in proper planning when shipping and port sector is concerned besides framing of various Maritime Agendas. India has in all 13 major and 199 other minor and intermediate ports. On the East coast, bulk cargo dominates cargo traffic with a share of 51% and on the West coast of India; containers drive the traffic with 69%. This paper is an attempt to review the various aspects of Cochin Port which is a major port in the West Coast of India. The paper attempts to glance through the history, the socio economic and demographic changes that have occurred to the Cochin port. It also includes the performance of the port and what are the real problems that need to be addressed indicators that need to improve for the improvisation of the business in the port.

Keywords: ICD, IFS, hinterland, Cochin port

1. Introduction

India is endowed by around 7517 km of natural Coastal line across nine coastal states, namely Gujarat, Maharashtra, Karnataka, Goa, Kerala (West coast) and Tamil Nadu, Andhra Pradesh, Orissa and West Bengal (East coast). It has 13 major ports (Mumbai, Kandla, JNPT, Cochin, Goa & New Mangalore on the west coast. Chennai, Ennore, Tuticorin, Vizag, Paradip, Haldia and Kolkota on the East coast) and 199 other minor and intermediate ports. One of the major port in India is the Cochin port in the southern tip state of Kerala and it occupies a prominent position in the international trade of the country.

1.1 Indian Port Sector

India located on the world shipping routes prominent maritime commerce space of Indian Ocean (Raja Mohan, 2010). The Jurisdiction of Major ports in India is the Ministry of Surface Transport (MoST) and is governed by the Major Ports Trust Act (MPTA) (MoS, 1963). The non major ports which includes minor and intermediate ports are controlled by the Indian Ports Act (IPA) of 1908 and it is controlled by the State. In mid 2005 as an agenda in the 11th 5-Year plan of Government of India (GoI) and the Department of Shipping (DoShip) set up the National Maritime Development Plan (NMDP). Indian Ports caters to about 95% of India's international trade by volume and 77% by value (De, 2006). A Crisil research report on Indian ports and maritime transport estimates (Kurup et al., 2010) that ports will grow by 160 per cent over the 2011-2020 period A total tonnage is 963 MT for 2009-10 and is projected to be 3130 MT by the year 2019-20 of this 1460MT is projected for the Major ports. The traffic projection is 2521MT by the year 2019-20 out of which 1241MT (50%) is to be carried out by the Major Ports (J.K. Panigrahi, A. Pradhan, 2012) .The traffic handled and capacity of all major ports in India for the last five years is given in Fig 1 shown below and it is clear that even though the capacities of different ports has been improved. The major ports are not able to divert the traffic towards them. The Utilization % shown in Table 1 of all major port gives a clear idea regarding this. The % Utilization has been coming down over the years This may be due to various reasons like: 1.) insufficient infrastructure, 2.) inability to handle mother vessels of larger capacity, 3.) no proper governance and 4.) no proper channeling of the freight.

1.2 Shipment Trends in India

The major ports in India still do not have facilities to handle the modern container ships. The goods have to be handled in the regional ports of Singapore, Dubai and Colombo. The Govt. of India has now started taking initiatives to modernize the ports of JNPT and Chennai. The shipment trends in India shows that Singapore and Colombo are the regional ports which handle the transshipment traffic from India. The others include ports of Dubai and Hong Kong. These ports have developed sufficient modern infrastructure to handle transshipment this decline will further continue in view of the following reasons:

- Indian ports are developing necessary infrastructure to service bigger mainline ships
- Direct shipment of container cuts transit time and cost
- The direct shipment from Indian ports at present is 65% and transhipment is 35%

As we understand the need for a hub port and the need to provide infrastructure for handling containerized cargo needed for the capacity building was identified and a new container terminals was proposed in the East and West Coast of Indian peninsular region.

Table 1: % Utilization of major ports in India

Year	% Utilization
2009-10	90.5
2010-11	85.07
2011-12	80.43
2012-13	73.27
2013-14	69.39
2014-15(P)	63.74

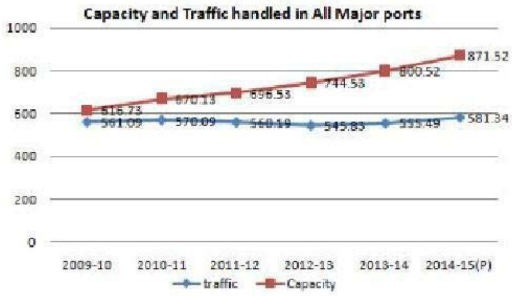


Figure 1: Capacity and traffic handled
Source: Indian Ports Association

1.3 Container Traffic Trend in India

The container freight flows are analyzed with a view to assess both the increase of total traffic of Exim traffic at the ports, and the potential growth that can result. This stream of traffic has increased on an average by 12.6 % percent per year since the1990s .Total cargo handled at Major Indian Ports in 2007-08 was 519,314* thousand tonnes, of which 17.77% of total traffic was containerized. Total traffic handled at intermediate and minor ports was an additional 203,621 thousand tonnes in 2007-08, of which 11,052 tonnes or 5.43% was container traffic. Thus, of total traffic of 722,935 tonnes handled at ports, containerized traffic was 14.3%.

Out of the 13 major ports, only 7 ports have substantial container traffic exceeding 2000 thousand TEUs, and only 2 major ports have a more than 10% share of container traffic of total container traffic handled as shown in the Table 3. These are JNPT and the Chennai JNPT handled 55324 thousand tonnes in 2014-15 (partial data) of a total container handling of 114641 thousand tonnes for all Indian major and minor ports i.e. more than 48% of total container traffic of India. In Chennai, there is 17.46% of total container traffic. Minor ports had a substantial share of container traffic specially the Pipavav and Mundra. In 2007-08, they contributed 10,746 thousand tonnes of container traffic and their combined share of container traffic was 10.4% of total container traffic, and next only to the share of JNPT and Chennai. Container traffic is concentrated in few ports; although most ports handle some container traffic. Table 2 below shows the share of container traffic to total traffic.

Table 2: Share of container traffic to total traffic by major ports

Ports	**Total Traffic (TT)**	**Container Traffic (CT)**	**%Share CT/TOTCT**	**CC/TT**
Vishakhapattanam	64597	113	1.2	1.8
Chennai	57154	18050	19.6	31.6
Kandla	64920	2617	2.8	4
Mumbai	57038	1632	1.8	2.9
Jnpt	55838	51923	56.3	93
Haldia	43588	2397	2.6	5.5
Paradip	42438	54	0.1	0.1
Morugao	35128	135	0.1	0.4
Nmpt	36019	320	0.3	0.9
Tuticorin	21480	5630	6.1	26.2
Cochin	**15810**	**3239**	**3.5**	**20.5**
Kolkota	13741	5139	5.6	37.4
Total	507751	92269	100	

Source: IPA

From the table 2 we can understand that the container traffic is concentrated in few major ports only. The need to compete with the international shipment market requires more facilities like adequate draft and need for a hub port with capacity to handle the modern ships. Hence the potential and most major port in the south –west of India is lacking in factors like1.unavailability of the draft 2.hence more dredging is required 3.more money been spent for maintaining draft there by reducing profit 3.the hinterland is almost very crowded and any intention to improvise will require more acquisition, which is more costly 4. The port has not been planned and hence hindering future development. The Rajiv Gandhi container terminal at the Cochin port was envisaged with a view to handle more containers. These factors contribute and stress the importance of an international port in an ideal location like Cochin or Vizhinjam (220km South of Cochin Port).

2. Cochin Port

The port of Cochin is situated at Northern Latitude 9°47’and 10° 17’ and Eastern longitude 76 °09’ and 76° 47’.Cochin is 12 nautical miles off the international sea route from Europe to the Pacific rim The port is situated on the Willington island which is an artificial island tucked inside the backwaters. An all weather natural port, Cochin is located strategically close to the busiest international sea route. The trend in population, land use and occupation of the corporation of Cochin was assessed.

2.1 Demography

The decennial increase in the urban population was plotted. It is showing a declining trend toward the end of 2001. This may be due to the availability of services in the urban extensions and increase in land price and living cost in the urban area. The decennial population had a very high value in 1931 and in 1971 is due to the fact that the port became functional during this 1930’s and factories i.e. industrialization had started in full swing during 1970s. A lot of people have migrated to the urban areas and to the district as whole. The fact that the catalytic reactions of the port activity ie the industry have also created urban congestion during the period 1971-81 have added to the increase in population during the 70’s.

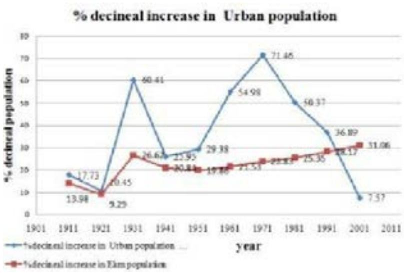


Figure 2:% Decennial increase in population

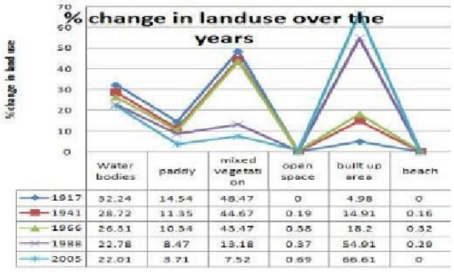


Figure 3:% Change in landuse in 1966,88,2005

Source: Draft Master plan of Cochin Capital region

2.2 Land use

Land use change is shown in Figure 3. Land use data from old map of 1915 and top sheets for 1947 where digitized and brought to the attributes as that in the existing land use map projected by T&CP department for the preparation of Draft plan for Cochin capital region and the data pertaining to the corporation area was taken for analysis. Land use change over years has changed and a tremendous increase in the built up area decrease in mixed vegetation and paddy can be seen.

2.3 Occupational Structure

The Occupational pattern of the people have changed over the years and. The drastic decrease can be seen in agricultural labors, cultivators from 1930's. Increase in HH workers and other workers can be seen after 1961 and is depicted in the table 3 given below tremendous decrease in primary sector jobs. In the second phase increase in industry workers and other workers in larger rate could be seen from the table 4.

Table 3: % total workers in last two decade

SL		**% Of Total Workers**				
NO	**Category**	1981	1991	2001	2011	2021
1	Cultivators	1.22	1.12	0.38	0.26	0.03
2	Agricultural	3.1	2.85	0.52	0.01	0.01
3	HoH Industry Workers	1.52	0.67	1.93	2.4	3
4	Other Workers	82.44	89.42	83.6	84.24	83.7
5	MarginalWorker	11.72	5.94	13.57	13.09	13.27

Source: Draft master plan of Cochin Capital region

3. Hinterland of Cochin Port

Every port has an economic hinterland (area where a port has a monopolistic position (Fageda, 2005) within which there is logistical advantages to attract cargo. For Cochin, the entire State of Kerala, Coimbatore Tirupur belt in Tamil Nadu and the Bangalore Coorg belt in Karnataka. Kerala would be the primary hinterland while other centers are part of the secondary hinterland shown in Figure4 and the location of various ICD/CFS is also shown.

Figure 4: Hinterland of Cochin port; Source: Mapped from top sheet

3.1 Connectivity to the Port

National High Way -2.3 KM and the Rail is 3.4. It has access to Inland Water way II-connecting Alleppey-Kodugaloor and Inland Water way IV, III. The Air connectivity is 27 km which Nedubassery and is only 27Nm from international shipping route.

3.2 Business in Cochin Port

The cargo handled in Cochin port was showing a declining trend before 2010 (Table 4). The traffic is increasing while the ships been called at the port is declining this is mainly due to the fact that Cochin ports incapability to handle modern ships which demand for more draft. The statistics of port operations of cochin port shows the increasing tendency of containerized cargo after the inception of the Rajiv Ghandhi container terminal in 2010 and a slight increase in the performance can be noted.

Table 4: Cargo handled in Cochin port

Year	Container Cargo Handled	Year	Container Cargo Handled
2008-09	3521	2013-14	4785
2007-08	3239	2012-13	4607
2006-07	2949	2011-12	4583
2005-06	2539	2010-11	4299
2004-05	2315	2009-10	3928

Source: Cochin port Trust

3.3 Features of the Container Terminal

It has a land Area of 110Ha.It can handle Vessels up to 8000+TEU capacity and has a dredged depth of 15.95m, Quay length of 600m (Phase 1) and 1800m (Phase 2) with 6 Quay cranes and 2 harbour cranes and storage area and yard equipment as per requirements.

3.4 Modal split of Traffic

The distribution of port container traffic is through road and rail. CONCOR is the main agency involved in transportation of containers by rail. Road movements dominate. Only 14% of the total movement is by rail and 86% is by road. Rail movement is either not cost effective or not convenient. Hence road connectivity is the critical linkage.

3.5 Container Freight Stations CFS/Inland Container Depot ICD

CFS is a warehouse and customs clearance facility. The basic objective of CFSs is to facilitate booking and delivery of containers in the hinterland. The location of ICD/CFS of the Cochin port is given in figure 5. There are 4 in Tamil Nadu (Tondiarpet, Coimbatore, HOM-C, Milavittam) and a major ICD at Whitefield, Bangalore. The ICD/CFS of Cochin port is nearing its capacity can be seen from the table 5 given below and by the year 2020 need to identify new location for ICD/IFS for the smooth transport of freight is to be identified.

Table 5: Showing the capacities of various ICD/CFS of Cochin port

ICD/CFS	Area (ACRES)	Capacity (TE Us)	Throughput (TE Us)
Tondiarpet	80	150000	133242
Hom-C	3.41	75000	69812
Whitefield	125	200000	104223
Coimbatore	2.3	15000	4223
Milavittam	11	350000	10133
Cochin	4.2	20000	11367

Source: Ministry of Commerce, GoI

4. Drawbacks of Cochin Port

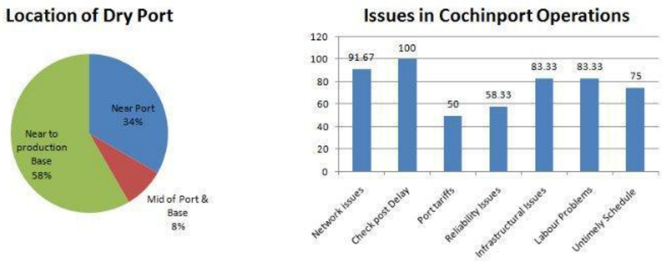
The Unavailability of the draft, so more dredging is required. More money been spent for maintaining draft there by reducing profit. The hinterland is almost very crowded and any intention for expansion will require more acquisition, which is more costly. The CFS/ICD are reaching its capacity due to poor logistics management. The port development has not been planned and hence hindering future development. The mode split of Cochin shows that the freight transport the major share is through roads which are opposite to the statistics shown by other global ports, where they concentrate more on barge and rail.

The importance for locating the CFS and ICD at the optimal location is important rather than locating on the availability of land that has been followed till now has to be taken care. Location Analysis Problem needs to be followed for the better logistic operation of the cochin port in order to get a better performance of the port. The parameters need to be identified at the based on the cost, trade level, infrastructure level, economic level, political level and transportation level for the optimal selection of the location of ICD/IFS.

4.1 Expert Opinion Poll at Cochin port

An expert opinion poll was conducted among the employees of the port trust of Cochin in order to know the poor performance of the port. Total of 3654 employees are working in the port trust as direct employees. The poll was conducted among Class 1 & Class 2 officers that constitute to around 327 and 10% was the sample size collected. The result of the poll is shown below.

Figure 6: Issues in Cochin Port and Opinion on location of dry port



Source: Questionnaire Survey and Analysis

5. Conclusion

Ports are strategic nodes for major trading regions, especially in a world where more than 90% of trade volumes occur by sea. Cochin port is losing its significance and the capacity for calling new panamax vessels with huge draft is a main issue. The further expansion of the port will cause congestion to the urban area. The trend in population, occupation structure and land use show that the port had influenced the development of the city. The land use built up space is 66%, which is above the standards.

The ICDs and CFS are reaching its maximum capacity, which is pointing to more space requirement. The hinterland traffic is not properly addressed as the major freight transport is along the Roads, which again requires widening to avoid congestion. The Container terminal at Vallapadam is not able to act as main hub due to the fact that the draft is less and huge vessels cannot be handled there and there are various issues that are related to the port function as in the expert opinion survey. It is necessary to optimize the location of the ICD/IFS to control the logistic operation by linking all the major ports for getting better performance index for the functioning of the port. The next call is for improvising a methodology for locating the ICD/CFS by understanding the ground conditions.

References

Bird, James. The Major Seaports of the United Kingdom. London: Hutchinson of London, 1963.

Vidya G Mohan and Sheeja K.P (2013)," Impact Assesment -Vizhinjam International Trans-Shipment Hub" , International Journal of Urban planning and Transportation, Recent Science Publication Vol.1, Issue 2, Aug

2013, Mandrid 1001-1004.
Bird, J. "Of Central Places, Cities and Seaports." Geography 58 (1973).
Geetha Kuntojia* and Subba Raob (2015), A Review on Development of Minor Ports to Improve the Economy of Developing Country Aquatic Procedia 4 (2015) 256 – 263 Published by Elsevier Draft Development plan for KCR 2013, Prepared by T&CP dept, GoK, Vol1:study and Analysis.
Jitendra K. Panigrahi, Ajay Pradhan (2012), Competitive maritime policies and strategic dimensions for commercial seaports in India.
De, P. (2006). Total factor productivity growth: Indian ports in the era of globalization. Journal of Maritime Economics and Logistics 8 (4), 366-386.
Haralambides, H.E., Behrens, R., (2000). Port restructuring in a global economy: an Indian perspective. International Journal of Transport Economics XXVII (1), 19-39.
Kurup, N., Prithiani, R., D'souza, A., (2010). Crisil Research Ports Annual Review Report. Crisil Research, Mumbai.
MoS (Ministry of Shipping), 2005. Government of India. National Maritime Development Program.
MoS (Ministry of Shipping), 2010. Government of India. Result framework document (RFD) for shipping ministry.
MoS (Ministry of Shipping), 2011. Government of India. Maritime Agenda 2010-2020 Panchayath level statistics 2006 and Census.
Master plan of Cochin 1971 & Structure plan of 2001, GCDA.
A comparative study of maritime Operations in India, MIT thesis 2005 by Harish Mukundan Impact of Global Hub Port on Hinterland Freight Logistics-Case Study: Kochi, thesis Report CEPT, 2011 by Anna Cherian.
H.M. Shivanand Swamy, Gautam Patel et al (2010). Planning the City around the Port: Maximizing Synergies and Minimizing Conflicts Institute of Town Planners, India Journal 7 - 3, 77 - 87, July - September 2010 D.
Aravind (2012) Problems and Prospects of Shipping Business in India International Journal of Scientific Engineering and Technology (ISSN: 2277-1581) Volume No.1, Issue No.6, pg: 299-300.
Vidya G Mohan et. Al (2013) Scope of Vizhinjam Transhipment Hub-with Focus on Employment.
International Journal of Engineering Research and Technology Vol.2 (11), 2013, ISSN 2278 - 0181 Measuring Inter modalism at European port cities: Employment based study, Cesar Ducreat, Rotterdam University.
Indian Ports Association, Report Coordination of business plans for major ports in India-Consolidated port development plan Volume 1 Main Report, final version Prepared by Port of Rotterdam Authority, September 2007.
Emerging Opportunities in Port Sector by A. K. Mohapatra, Secretary, Department of Shipping, Ministry.

Challenges faced by the Indian Port Sector in the Distribution Mechanism of Containers

Vidya G Mohan[1], Naseer Muhammad Abdurahman[1]and Priya Chandramani Viswanathan[2]

[1]Department of Architecture and Planning, NIT, Calicut, India. Email: vidyagmohan@gmail.com
[2]Department of Civil Engineering, Ace college of Engineering, Trivandrum, India

Abstract

The problems faced by the ports in the developing countries vary from the developed system. The study aims to assess the problems in a Developing economy like India by studying one of its major port, Kochin to understand the lack in infrastructure and the distribution mechanism of the containerized commodities. The first part of this paper deals with the general trend of containerization across the globe and in India. It studies the infrastructure requirement like the Dry ports or consolidation centers in the developed and developing economies. The latter part of the paper focuses on the distribution mechanism of the containers in developed country and the existing pattern followed in followed in developing Country like India with respect the Kochin port in the southern tip of India and other South Indian Ports. The data pertaining to this have been collected from documentation case studies to various port authorities and the meeting various stakeholders in the Port Operations/Users, Dry Port users/owners, Far end users-The Industrial base /exporters and Importers and the People who are benefitted out from the various services. An attempt has been made to bring out the need for optimization of these Dry port locations to be sustainable.

Keywords: Dry Port, Hinterland, Kochin port, Distribution Mechanism

1. Introduction

Ports are engines of economic development and are the linkage between the international economic centers and domestic production and the logistic chain. Globally, 75% of total cargo being shipped is containerized, whereas in India it is around 18% (CONCOR, report). The trade and freight traffic is growing at a greater pace and we are not able control the environmental strain, delay in operation, the increasing logistic cost due to the rise in fuel cost. Non availability of space with the increasing traffic growth calls for an optimized container traffic operation and it stresses the need for an integrated supply chain operation.

1.1 Containerisation

Containerisation, initially started as a method of packaging to save cargoes from damage by weather, pilferage and rough handling ushered in a new era of transportation. In essence, containerisation paved way for a single transport operator by combining different transport modes into a single transaction service under only one bill of lading or combined transport document issued from the origin to destination.

1.2 Global Scenario of Containerisation

An international containerization market trend analysis shows that in 1995 around 9.5 million TEUs were in circulation. The container fleet has almost doubled in the decade from 4.9 million TEUs in 1985 (Containerisation world, 2000). The world container trade growth rate from 2010-14 has increased 127% and from 2005-14 has increased 179%. In the mean time, transhipment also gained significance. Pure transhipment hubs emerged since the late 90s. World total transhipment volume is expected to grow from 85 million TEU in 2005 to 184 million TEU in 2015 and 326million TEU in 2025 (UNCTAD). India with 12 major port and 187 minor ports and no transshipment hubs (only in construction phase) is able to boost container traffic and is growing at a Compounded Annual Growth Rate (CAGR) of 11% (Drewy, 2015). India, is ranked 47th in logistics operations and is far behind many of its Asian counterpart (Report on Freight Logistics and Intermodal

Transport, 2015). Another important fact is in India, 55-60% of the containers are moved through roads while in developed countries it is only 30-35%.

2. Importance of Dry Port Development

Banger (2007) has listed 8 grey areas in port development and that which concerns India among them are Lack of infrastructure/Industrial growth in hinterland/proper connectivity and Complex procedures. The two main reasons for poor connectivity and lack of poor Infrastructure had to be dealt out and is given more priority in this paper. The scale of these issues are much in developing countries than in developed countries. Container transport volume is growing, most seaports are facing the problem of a lack of space at port terminals as well as bottlenecks in the inland transportation system (Roso and Lumsden 2009) and to ease the situation in the hinterland dry ports has become an important node in the supply chain network. These dry ports are termed as ICD/CFS Inland Container Depot/Container Freight stations in India (Gujar, 2009). A dry port emerges as a modern logistics centre located hinterland region.

The first mention of dry ports goes back to 1980 (Munford 1980). A wide range of terminologies are being used in literature for dry ports such as inland clearance depot/inland custom depot (Beresford and Dubey, 1990 inland Container Depot (ICD)/Container Freight Station (CFS) (Gujar, 2009) Inland terminals (UNCTAD, 1982), Inland container depot (Roso, 2005), and inland port (Economic Commission for Europe, 2001). A dry port development was a part of port regionalization process, and is characterized by hinterland accessibility through legal policies and market strategies (Notteboom, Rodrigue 2005). The decision of dry port location is crucial as the location of the dry ports involves a huge amount of investment. It cannot be relocated based on the response to the market demand and the land and capital availability (Gujar, 2009)

A dry port is a logistics node which improves cost-efficiency, environmental performance and the quality of hinterland network connections (Woxenius et.al, 2011). It can nurture manufacturing and service clusters, for example, special economic and export processing zones (Haralambidas, 2011). The location of Dry ports cannot be relocated easily, because of the massive investments required and the location-bound, sunk cost nature of these investments. Therefore, it is pivotal to make reasonable location decisions at the very start of the dry port development process (Gujar, 2011). The advantages of implementing dry port from survey (Roso, 2009) done among dry port managers shows that a dry port can increase port capacity and volume handled, reduce the congestion and environmental impact. It can also cater to regional development and bring in numerous jobs and improve customer service.

2.1 Types of Dry Ports based on location

Based upon the function and the location of a dry port, they can be categorized as distant, midrange and close dry ports (Roso, 2009).

The distant dry port is situated in the vicinity of the market, which might be the consuming area in import-based supply chains, or a core production location in export-based supply chains. This type of dry port plays an imperative role in the logistics system of landlocked countries to connect to international markets. In this case, the seaport will benefit from the connection to this type of dry port by gaining access to the inland market.

Close dry ports or satellite terminals are located in the proximity of seaports with strong connections to seaports by rail, barge and or trucks. These dry ports are mostly developed as extensions of seaports. The main role of close dry ports is to relieve the seaports from the burden of space shortage, congestion and environmental issues. With abundant land available, all high space-consuming activities, such as warehousing or sorting, are shifted from seaports to dry ports. The customs clearance procedures could be carried out in these close dry ports.

Mid-range dry ports work as intermodal hubs to consolidate or deconsolidate cargo from shippers. It might also work as a transmodal/transloading terminal before the cargo reaches a specific market. Seaports benefits from this type of dry port by increasing hinterland access and getting closer to the customers. Congestion and pollution are tackled by a modal shift from trucks to barges/trains. Additionally, this type of dry ports gives customers more access to maritime services.

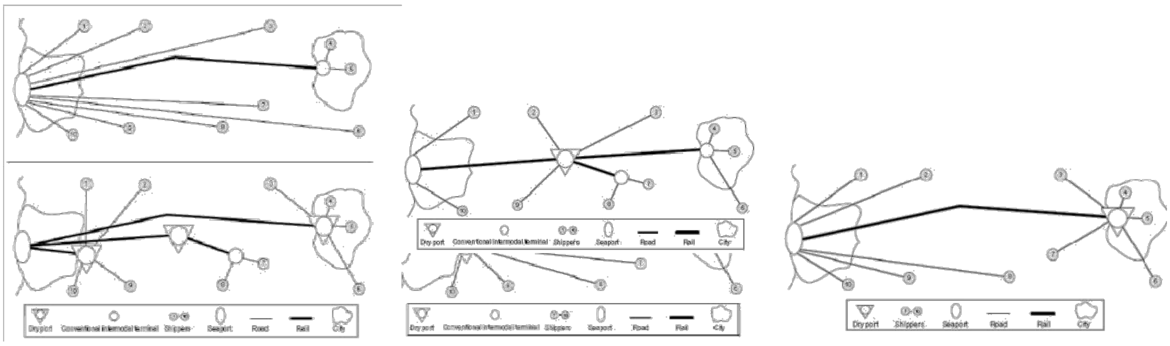


Figure 1: Comparison with and without Dry ports/Midrange, Close Range and Distant Dry port
Source: Roso 2009

2.2 Dry Ports Characteristics in Developing Countries

Dry port services include cargo consolidation, storage, customs clearance, cargo handling for different transport modes; depot function; container maintenance and repair and value added services (Roso et al. 2009). An outside-in or sea-driven dry port means development is driven by a seaport actors, like a port authority or terminal operator. This is mainly the case in developed systems like Europe and North America where seaports have reached the phase of regionalization (Notteboom and Rodrigue, 2005). In contrast, inside-out or land-driven inland terminals are developed by inland parties, such as a local government or transportation companies, mainly in view of serving the local market. Most inland terminals in developing economies are land-driven as they have been established to serve the export-based industrial zones. Thus, inland locations in developing economies are dominated by land-based players interests and generally lack a high level of intermodal integration with seaports through high capacity, reliable trucks train or inland waterway.

Dry ports in developed and developing economies differs in many ways. In developing economies, they are likely to be situated close to production bases, or even inside economic zones, as illustrated in the case studies of India (Ng and Gujar, 2009), South Africa (Cronje et al., 2009). The least-cost model for dry port positioning, will work well for advanced economies will not be sufficient for developing economies, according to (Ng and Cetin, 2012). It can be seen that the nodes in developing countries are cluster-oriented than supply chain-oriented. Dry ports in developing can be located at the end of supply chain or could also be situated in the middle of the chain for trans loading between two transportation networks. Such type of dry port is easily seen at border locations. Inland terminals in close proximity of seaports are rarely found in developing systems as such kind of dry ports are mostly sea-driven.

Production bases in developing nations are numerous but scattered across a large area. This supports the creation of numerous small ICDs which further complicates cargo bundling for intermodal services and results in a high reliance on road transport to transport cargo from/to seaports over mid-range or long distances.

Dry ports in developing countries have more chance of facing lack of trained/experienced human resources and a poor information system support for inland transportation (Garnwa et al., 2009 for a case on Nigeria). Finally, dry ports in developing nations are frequently used by smaller shippers with less experience in global supply chain management. Using the transaction cost theory Williamson (1979), the problem of bounded rationality and reliability lead to a higher transaction cost with distant dry ports. This makes local inland terminals more preferable for shippers. The characteristics of dry ports in developing countries should be used for the dry port location analysis. The study aims to take Cochin as the base port and understand the container flow dynamics to describe the location and requirement of ICD/CFS locations in its vicinity.

3. Indian Port Sector

India has a long coastline extending over 7200 km strategically located on the East-West trade route. Nearly 95 per cent of the countries transportation of goods is by sea, making development of ports critical for nation's progress. India has 12 major ports and187 minor ports. The major ports in India are maintained by the Central government, while all the other ports come under private parties or the state government list.

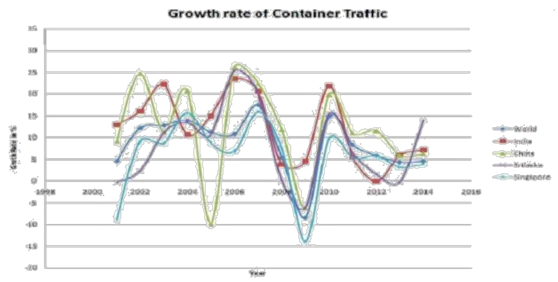


Figure 2: Comparison of Growth Rate of Container traffic in India
Source: JNPT

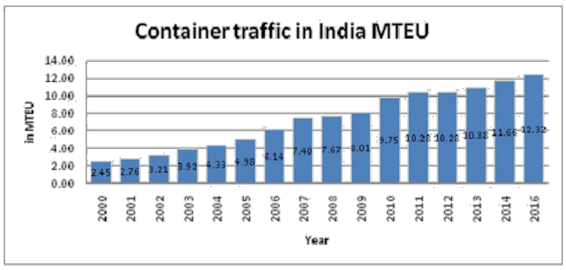


Figure 3: Increasing trend of container traffic
Source: World Bank Data

The yearly growth rate of Indian container trade in comparison with few of the major competitors of the World data is attached above in Fig 2 and 3. India is in the path of containerisation and more and more commodities are getting containerised. India adopted containerisation little late but the growth has been phenomenal as well. The Indian container market is growing at a CAGR of 11% today. In India, west coast dominates the container market size with 69% share. JNPT alone takes 83% share because of relatively better connectivity in 2012-13. It handled 3.7 million TEUs in 2009-10 with respect to 0.04 million in 1989-90 (source: JNPT). With Indian economy growing at a sustained rate of 6% p.a, it is expected that the Indian container trade would grow at a rate of 18% p.a implying the need for a significant expansion.

Indian ports handled 12.32mn TEU container traffic in 2015. Fig 3 shows the growth of Indian container traffic from 2000-2015 (source: World Bank Data). Container traffic has grown at 8 percent over the last decade as the level of containerization also increased from 60 percent in 2004-05 to 67 percent in 2013-14. Going forward, we estimate that container traffic will grow at 6.5 percent rate under business-as-usual and reach 21.5mn TEU by 2025. Including the impact of programs like Make in India and development of industrial corridors, the estimated container traffic can grow to 24-25mn TEU (Final report on cargo traffic projections & logistics bottlenecks, July 2015).

GoI, has planned for two transhipment hub in the Southern tip of India one is at Vizhinjam, Kerala (started working) and the other at Colachel Tamil Nadu. This will further improve the containerisation business and more infrastructure will be required in its Hinterland. This paper further studies the problems in containerisation in India.

3.1 Problems of Container Movement in India

It is a common assumption that cargo moves to the nearest port from the origin because of distance advantage, but it has been seen that in reality, exporters preference for a particular port is governed by efficiency in port operations, freight advantage, connectivity and port tariff. Freight costs by railways/road for containers are exorbitant in India. The ocean freight for bringing cargo from the Far East and South East Asia is much less than the land freight within the country by rail. Proper rationalization of freight structure is required to make the rate more affordable. Ideally, flows should conform to distance advantage.

Consider iron ore transported from Bellary in Karnataka. A comparison of lead distance between the various ports and Bellary reveals that Goa is the closest, followed by Krishnapatnam, Ennore and New Mangalore, respectively. However, connectivity to Goa port is through a mountain road with steep grades, which gives other ports a competitive advantage. The railway freight from Bellary to Goa is Rs 1,936 per tonne whereas the rate per tonne for Ennore is Rs 1,750. In case of New Mangalore and Krishnapatnam, the rail freight is Rs 1,850 per tonne. This railway freight charges are to be seen in conjunction with port handling charges while determining the competitive advantages of each port. Figure 4 shows that New Mangalore is the most favorable destination for iron ore from Bellary despite the distance disadvantage.

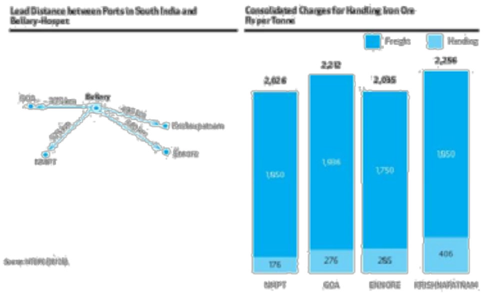


Figure 4: Lead Distance from Port and Industrial Location Source: National Transport Policy in Shipping, 2015

Factor determining the flow of container cargo is the distribution and location of CFSs and ICDs. It is possible to alter hinterland port linkages for ideal flows by changing the CFS locations. ICD/CFS are the common terms used in India for Dry ports (Gujar, 2009). Inland connectivity is the most important cornerstone in port competitiveness (CEMT, 2001).

4. Kochin Port

The port of Cochin is situated at Northern Latitude 9°47 and 10° 17 and Eastern longitude 76 °09 and 76° 47. Cochin is 12 nautical miles off the international sea route from Europe to the Pacific Rim, and is the busiest sea route in the world carrying around 4200 ships in a year. The port is situated on the Willington Island which is an artificial island tucked inside the backwaters.

The International Container Transhipment Terminal (ICTT) have a state-of the art facility with a final capacity of around 3 million TEU. The terminal in its fully developed stage have a berth length of 1800 m with a permissible draught of 14.5 m for deep-sea vessels. The permissible draught of 14.5m will allow for vessels of up to 8000+ TEU capacity.

4.1 Logistics operations

The logistics operations in the ICTT are done through dry port operation. The modal split has shown that the majority is transferred through the roads. The table below shows the functioning Dry ports in the state of Kerala which do the containerisation process. The dry port operated by CONCOR, do all the rail freight operations while others do the Road freight operations. The Dry port in Mathiakam is having around 10ha of land of which 5.2 ha are doing the operations. Rest of the dry ports have less than 2 ha of land.

Table 1: Dry ports in the state of Kerala

Sl. No	Location	Ownership	Name of Dry Port	ICD/CFS	Inception
1	Cochin	Pvt	Sea tech services Asian Terminals, Wellington	CFS	17.03.95
2	Wellington	Pvt	island	CFS	24.10.95
3	Aroor	Pvt	Pace CFS, Aroor	CFS	04.05.97
4	Cochin	Govt	KSWH, Cochin	CFS	05.10.98
5	Kottayam	Govt	Kottayam ports & Containers	CFS	17.05.05
6	Cochin	Govt	CONCOR	CFS	26.07.06
7	Cochin	Pvt	Falcon infrastructure	CFS	26.09.07
8	Mathiakam	Pvt	Transglobal Inland Containers	ICD	23.03.10

9	Kalamassery	Govt	Kerala State Industrial Enterprise	CFS	04.1.11
10	Kannur	Govt	Central Ware Housing	CFS	05.1.11
11	Vallarpadam	Pvt	Gateway Distripark	CFS	9.01.12
12	Vallarpadam	Pvt	MIV Logistics	CFS	16.02.12
13	Kalamassery	Pvt	Periyar Chemicals	CFS	14.06.13
14	Cochin Port	Govt	Cochin Port Trust	CFS	14.06.13

Source: Ministry of Commerce, dt 10/10/16

These location of the dry port are located based on the proximity to the port and was chosen arbitrarily. The apt location of the dry ports will help to optimise the flow thereby improving the business and improving the performance. As more products are getting containerized there is a need to find the optimum location for these facilities. The distribution mechanism that is seen around the vicinity of the Cochin port is explained in the next section.

4.2 Distribution Pattern to Kochin Port

The commodities transhipped through the port and the general problems in the distribution mechanism of the port is discussed in detail. This has been formulated from various site visits to the production bases, service providers, port users.

4.3 Export Mechanism through Cochin Port

From the insights collected the production base and port operators few Export mechanism of Distribution to Cochin Port is perceived as follow.

Case 1: Production Base is Far

This is the case when the production base does not have the facility to containerise at the production and it is containerised at a dry port location which is near to the sea port. The experts in the production base quoted various reasons for this type of transportation of goods even though they are aware of the fact that containerisation at the base is more profitable. The reasons quoted were: 1.) unavailability of infrastructure fork lift, ramp, 2.) not enough competitors for stuffing, de-stuffing of containers, 3.) absence of trailer operators and 4.) labour issues.

Case 2: Production Base is near

If the Production base is less than 100km to the port through which they export. The trailers are rented from an external agency, they do all the containerisation process at the base itself and is sent to the seaport directly, where they are given clearance by the officials in the in house dry port facility. The second type of shipment is the same pattern as followed in the case 1, even though the production base is close, it is bought to the ware house of a private party and stuffed and sent to the Dry port for clearance and then sent to the Seaport or directly to the seaport where clearance is given.

Case 3: Export Direct Shipment

One case is the direct shipment, where the production base have a ware house in the base and its directly containerised to the seaport. But the % of direct shipment to the port is less than 10% as quoted by the port officials.

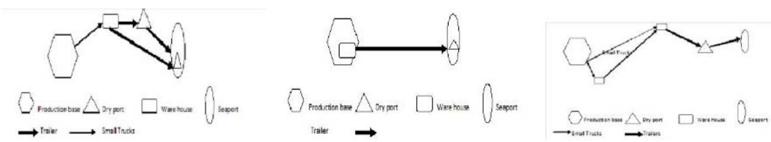


Figure 5: Export Case 1, 2, 3 respectively

Source: Author

4.4 Import through Cochin Port

In the case of import of goods, same patterns are followed but it is normally a reverse flow.

Case 1: Import Production Base is near

In this case, the shipment is sent to dry port for clearance or given clearance in the seaport itself and send through trailers, where they are de stuffed to small trucks and sent to the production base.

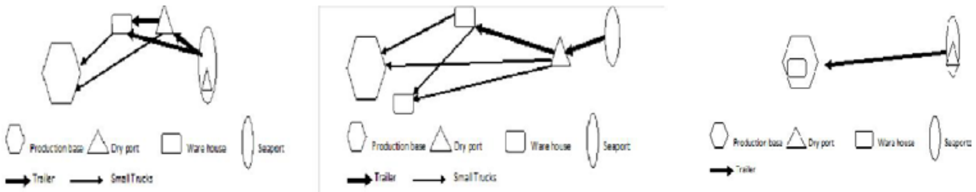


Figure 6: Import Case 1, 2, 3
Source: Author

Case 2: Import Production Base is far

In this case, when the production base is far, the trailers are moved to Dry ports for clearance few of the containers are de stuffed in the dry port itself and sent to either warehouses or to a nearby warehouse and then to the production base.

Case 3: Import Direct Shipment

The percentage of this kind of shipment is there only for few commodities like cars. In this type of distribution, the commodities are moved and cleared from seaport and sent to the ware house of the Production base, this type of trailer movements happens mostly in developed countries and only few production bases in and around cochin has this facility.

5. Conclusion

In this paper, we have discussed the general trend of containerization across the globe and in India. We could learn that in India very smaller amount of Cargo is containerised and the trend is increasing pace. It studied the infrastructure requirement like the Dry ports or consolidation centers in the developed and developing economies. It discussed the problems in Container movements in India. The distribution mechanism of the containers in developed country and the existing pattern followed in developing country like India with respect the Kochin port in the southern tip of India has been discussed. The mechanism in terms of export and import has been detailed out as separate cases. There is a need for sustainable port development in India for reviving the sector. Initiatives are been done to study the flow of commodities through each port in order to make the movement sustainable. New guidelines are to be formulated for the implementation of Dry ports (ICD/CFS) in India. Unless the commodity flow become sustainable there will be numerous number of problems in the port sector. For this we have to take into consideration various stake holders like the port service providers, port users, end users and the common man, initiatives are been done in these direction also.

References

Lam Canh Nguyen, Theo Notteboom (2016). A Multi-Criteria Approach to Dry Port Location in Developing Economies with Application to Vietnam, The Asian Journal of Shipping and Logistics, Vol 32 (1), pp 23-32.

Núñez, S. A., Cancelas, N. G. and Orive, A. C. (2013). Quality evaluation of Spanish Dry Ports location based on DELPHI methodology and Multicriteria Analysis.

KA, B. (2011), Application of fuzzy AHP and ELECTRE to China dry port location selection, The Asian Journal of Shipping and Logistics, Vol.27, pp.331-353.

Padilha, F. and Ng, A. K. (2012), The spatial evolution of dry ports in developing economies: The Brazilian experience, Maritime Economics & Logistics, Vol.14, pp.99-121.

Roso, V. (2005). The Dry Port Concept: Application in Sweden, Logistics Research Network, 2005, pp.379-382.

Roso, V., et.al. The dry port concept: connecting container seaports with the hinterland, Journal of Transport Geography, Vol.17, pp.338-345.

Ng, A. K. and Cetin, I. B. (2012), Locational characteristics of dry ports in developing economies: some lessons from Northern India, Regional Studies, Vol 46, pp.757-773.

Ng, A. K. and Gujar, G. (2009), The spatial characteristics of dry ports in India, Development of dry ports 102.

D. Aravind (2012). Problems and Prospects of Shipping Business in India, International Journal of Scientific Engineering and Technology (ISSN: 2277-1581), Volume No.1, Issue No.6, pp: 299-300.

Vidya G Mohan et. Al (2013). Scope of Vizhinjam Transhipment Hub-with Focus on Employment. International Journal of Engineering Research and Technology, Vol.2 (11), 2013, ISSN 2278 0181.

Notteboom, T. E. and Rodrigue, J. P. (2005), Port regionalization: towards a new phase in port development, Maritime Policy & Management, Vol.32, pp.297-313.

Notteboom, T. (2011), An application of multi-criteria analysis to the location of a container hub port in South Africa, Maritime Policy & Management, Vol.38, pp.51-79.

Bhushan, N. and Rai, K. (2004), Strategic decision making: applying the analytic hierarchy process, Springer Science & Business Media.

Constructing English Medium Instruction Indicators in the Shipping Courses of Taiwan's Higher Education

Po-Hsing Tseng[a*], *Kendall Richards*[b] *and Nick Pilcher*[c]

[a]Department of Transportation Technology and Management, Feng Chia University, No 100, Wenhwa Road, Seatwen, Taichung 40724, Taiwan. E-mail: phtseng@fcu.edu.tw
[b]School of Computing, Edinburgh Napier University, Edinburgh, UK. Email: K.Richards@napier.ac.uk
[c]The Business School, Edinburgh Napier University, Edinburgh, UK; Email: N.Pilcher@napier.ac.uk

[*]*Corresponding Author*

Abstract

English is a common language in the global shipping industry and many countries are now moving towards the use of English as a Medium of Instruction (EMI) to deliver their courses. Such a medium increases students' proficiency in the common language used and also allows institutions to recruit students from different parts of the world. Yet, delivering such instruction using EMI is not without its challenges. This paper uses a fuzzy AHP (Analytic Hierarchy Process) to identify key indicators influencing English Medium Instruction (EMI) in the shipping courses of Taiwan's Higher Education. Based on literature reviews and expert interviews, an evaluation model with four indicators and thirteen sub-indicators is developed. Questionnaire participants include three groups: university English teachers (8), university shipping teachers (9), and shipping practitioners (8). Using 25 effective samples, the results found that Teachers' Characteristics is the most important indicator, followed by Syllabus Design, University Resources, and Students' Characteristics. Such a finding could provide valuable references (e.g. curriculum adjustment) for EMI design in the university and industry sectors.

Keywords: *English Medium Instruction, Shipping, Courses*

1. Introduction

Taiwan, located in Asia-Pacific (between southwest of Japan and the north of Philippines), is an island with around 36,193 square kilometer (total population is around 23 millions). Over 90% international trades cargoes in Taiwan are carried by shipping.[i] Shipping development and education have always occupied a central and key place in the university education in Taiwan. However, Chinese is the first language and English is a second or other language in Taiwan. Although introducing English learning into the Taiwanese education system has been conducted and emphasised for decades,[ii] there are continual attempts to improve English learning. For Taiwanese universities, purposes of introducing English Medium Instruction (EMI) course are to (1) improve students' English abilities and strengthen international mobility and employability, (2) attract more international students to attend such a course. However, there still exist a number of implementation barriers and challenges due to a range of factors such as environment culture, learning skills, curriculum design and exam-based learning approach.

In the shipping industries, qualified shipping practitioners (e.g. seafarers, staff in shipping companies, shipping forwarders, shipping agents, ship-broker, port authorities, etc.) must have 'good' English abilities (including listening, speaking, reading, writing) (Pallis and Ng, 2011). Therefore, high proficiency in English is a prerequisite for employment in the shipping industries. In Taiwan, there are around 12 universities that provide shipping management related courses. Shipping courses in shipping management related departments can categorised into foundation courses and specialist courses. Generally, the former include introductory type courses such as 'introduction to maritime management or shipping management', 'introduction to trade and shipping', and 'introduction to shipping and logistics. The latter covers topics such as 'liner shipping management', 'bulk shipping management', 'port planning and management', 'shipping economics', 'maritime insurance', 'maritime law', 'shipping finance', 'management of maritime organisations', 'shipbroker and chartering management', 'shipping and the environment', and also 'maritime technology'. The main language of instruction for these courses is Chinese. However, the main language of international shipping operation and management and any shipping information communication (e.g. information announcement in international maritime organisation) is English. Therefore, there is a need to add English education in Taiwanese shipping management related courses in order to link international shipping transport related industries (including insurance, law, international trade, etc.), international education system and other stakeholders (e.g. research organisation, governmental units, etc.).

Introducing EMI in the university courses has become popular in recent years (Hu et al. 2008; Kedzierski, 2016). However, the introduction of EMI teaching in the university courses has resulted in a number of issues. These can be summarised as: (1) students often lack sufficient vocabulary and cannot fluently express their feelings or thinking (2) inappropriate course material (e.g. students have difficulty in learning all English material due to their limited English ability), (3) mixed Chinese and English in texts and language used, (4) Students' level of English differ and teachers are presented with difficulties when adopting a uniform standard in any course assessments (e.g. IELTS (Pilcher and Richards, 2017). Therefore, such results would affect their learning motivation and teachers' teaching performances (Poon, 2013).

There are in addition a number of other key issues in EMI topics. Issues such as how the subject operates when delivered in English, and what exactly 'English' is key areas here (Richards and Pilcher, 2014; Pilcher and Richards, 2016). Further, some countries, such as Malaysia, attempted to introduce EMI but then returned to using Bahasa after the project did not meet expectations (Gooch, 2009). In terms of the continually shifting nature of the industry and how academia responds, some research notes the onus to be on the Higher Education institutions to keep abreast of the latest developments in the industry and to ensure their courses are up to date (Ng et al., 2009). Another issue to explore would be where shipping education training is situated in terms of whether it is situated in a business school or an engineering school or whether it is standalone (Ng and Yip, 2009). Also, what such a position means for the accreditations it needs (Ng and Yip, 2009). Such issues help give a greater context to current understanding of EMI and are explored in this paper. Although it has been rightly noted in the literature that "a global labour market cannot be regulated by a national policy" (Gekara, 2009, pp.229) it is useful to research and reflect on national policies toward shipping education, especially as it is expected that international guidelines are adhered to and taught in shipping education training (Ng and Yip, 2009).

Previous studies in the EMI field have used a range of methods. Many of these studies have been based on reviews of the literature (Hu et al., 2008; Ng and Yip, 2009; Horck, 2010; Mok and Yu, 2011) or on surveys (Pallis and Ng, 2011) or questionnaires (Dinwoodie, 2000; Ng et al., 2009; Fei and Lu, 2015). However, analysis methods of these surveys in the past studies mainly adopt qualitative or basic descriptive statistics. In order to improve the analysis method of EMI research and obtain more insights into implications in the curriculum design and teaching strategies in the university, Fuzzy Analytic Hierarchy Process (AHP) is used in this paper. This analysis method could help university teacher and related policy-makers to identify the most relevant indicators to develop their teaching strategies and allocate teaching resources allocations in the university.

The remainder of this paper is organised as follows. Section 2 briefly reviews the literature regarding the background and implementation of EMI. Section 3 presents the methodology, and the results are presented and analysed in Section 4. Finally, Section 5 provides discussions and conclusions, and considers limitations and areas for future research.

2. Literature Review

2.1 EMI Related Studies

Much Research has noted the changing face of education in the shipping industry (Demirel and Ziarati, 2013). Many countries are moving toward EMI and asking lecturers to teach in English, for example, Italy (Costa and Coleman, 2013), Finland (Hahl et al., 2016), Korea (Kim et al., 2009; Kim et al., 2014; Lee, 2017), and China (Hu and Lei, 2014). In Taiwan, Huang (2015) used 157 participants to explore the perceived effectiveness of EMI courses for Taiwanese students. Results found most participants were motivated to take EMI courses to strengthen their English ability and professional knowledge. In Spain, Dafouz and Camacho-Miñano (2016), using 383 participants, used accounting as a case to explore the impact of EMI on university student academic achievement. Results found no statistical differences across groups and that the use of EMI did not lower student final academic outcomes. Further, Hellekjær (2009) used 578 Norwegian university students to academic English reading proficiency. Results found that about 30% of the respondents had serious difficulties reading in English, while an additional 44% found it more difficult reading in English than reading in their first language. Kim et al. (2014), using 249 Koreans and 61 international students from non-English-speaking countries, indicated the English proficiency is important for EMI courses. Thus, EMI is a much researched area, something which is entirely understandable given its increased use and prominence worldwide. These studies highlight a number of challenges and key indicators for any consideration of EMI, which we now focus on and expand on here as ones we used in our fuzzy AHP analysis.

2.2 Key Indicators Influencing EMI in the Shipping Courses

Drawing on personal interviews with senior shipping practitioners[iii] and previous studies, fours indicators are described as follows.

i. Syllabus Design

Syllabus design relates to teaching strategies (e.g. material, textbook, assignments, examination, assessment process) used in the course content, which can guide students in understanding how to learn the teaching subjects and provide effective learning guidelines and improve English level. The content of syllabus design includes learning material, learning strategies and learning assessment (Costa and Coleman, 2013; Poon, 2013; Clegg and Simpson, 2016). In a shipping context, syllabus will relate to introduction to shipping market (including liner and bulk shipping), port operation and management, maritime logistics and networks, and so on. Teaching points would differ depending on teachers' area of expertise and interests. Generally, in Taiwan, students have spent much time on reading about shipping, although listening, speaking, and writing may need to be further focused on. In terms of assessments, a term-project is also conducted in the shipping related courses. Students are asked to make a presentation in the end of semester.

ii. Students' Characteristics

Students' characteristics encompass students' learning background, including English level, shipping knowledge (e.g. understanding main components of shipping), and learning habit (e.g. course material preparation and review, and note taking skills) (Byun et al., 2011; Dalton-Puffer, 2007; Kim et al., 2014; Başıbek et al., 2014; Evan and Morrison, 2011a; 2011b). In terms of their English knowledge and level there are a range of items that could be key here. Firstly, students' vocabulary will be essential. Importantly, rather than have a generic vocabulary here that may be useful for something such as an admissions test of English such as the International English Language Testing System, or IELTS (Pilcher and Richards, 2017), what students will need will be a vocabulary that is specific to shipping courses. Moreover, such a vocabulary will arguably be underpinned and be intertwined with key subject based elements specific to the shipping subject (cf. Pilcher and Richards, 2016). In terms of their grammar, clearly this will be essential, but the level of grammar needed might be different to that of an admissions test if the subject takes primacy. Ultimately, students will need to have speaking and lexical ability, but to be able to demonstrate these within the subject. Analogously, if students are studying in the subject area of physics, they would need to be proficient in English in the field of physics (cf. Pilcher and Richards, 2016). Further, if students are studying a general admissions test on English such as IELTS they will need to be proficient in the English for this test, and not for shipping studies (Pilcher and Richards, 2017).

iii. Teachers' Characteristics

Teachers' characteristics relates to teachers' background in terms of English level (including listening, speaking, reading, writing, etc.), shipping professional knowledge (including related teaching subjects), and teachers' past experience of EMI teaching (Pan, 2007; Costa and Coleman, 2013; Goodman, 2014; Huang and Singh, 2014; Dafouz and Camacho-Miñano, 2016). AS with the students' knowledge of English, in this case, the teachers' knowledge of English will need to be operational within the subject of shipping studies. Similarly, this may be a different range of vocabulary and knowledge to physics (cf. Pilcher and Richards, 2016), and different to the English required for a more general test (Pilcher and Richards, 2017) or conversation and small talk. In other words, teachers' English is very much intertwined with their subject knowledge, and provided they are proficient in their subject, this will take primacy over elements such as grammatical accuracy (Richards and Pilcher, 2017). What this means in practice is that teachers level of English may be more than sufficient to deliver their subject in a lecture, and they will be able to answer questions at the end and during the lecture. However, to have sufficient English to hold a fluent conversation about the weather at the end of the lecture may not be needed.

iv. University Resources

University resources includes useful learning and teaching resources provided by the university. These resources include potential incentives used for students and teachers with the aim of improving learning and teaching effectiveness. Based on past studies (Costa and Coleman, 2013; Hellekjær 2009; Kirkgöz, 2009; Agai-Lochi, 2015; Hu, 2007; Tong and Shi, 2012), university resources include classroom facilities, availability of resources, incentives for teachers, incentives for students. Resources could relate to aspects such as translation tools, microphones, recorders and much standard teaching related technology, and support staff such as academic advisors. Incentives for teachers could relate to aspects such as overseas courses, salary increases and favourable workload calculations. For students, incentives could relate to, for example, employability, and the fact that they can add their experience to a CV.

3. Methodology

AHP is a multi-criteria decision making method and used to solve complex problem (Saaty, 1980). However, classical AHP may not accurately represent the decision makers' ideas. Zadeh (1965) defined a fuzzy set is a class of objects with a continuum of grades of membership ranging between zero and one. Based on Zadeh (1965), fuzzy linguistic variables and corresponding fuzzy triangular numbers can be used for comparison among the elements included, and help solve vague and uncertain problems in decision making. Therefore, fuzzy logic, using fuzzy pairwise comparison matrices, is introduced to relieve the uncertainness of AHP method (Chang, 1996). In this paper, an integration of fuzzy set theory and AHP is used to identify the key indicators and sub-indicators that have a bearing on successful shipping EMI courses. The main processes of Fuzzy AHP are followed as: constructing the hierarchic model, constructing the pair-wise comparison matrix, calculating fuzzy number, building the fuzzy positive reciprocal matrix, calculating the fuzzy weights, defuzzification, and normalisation and synthetic analysis.

Questionnaire participants of this paper were collected from three groups: university English teachers, university shipping teachers, and shipping practitioners. All participants in the questionnaires were recruited by the method of convenience and snowball sampling. Before sending the questionnaire, potential participants were confirmed by email or telephone to ensure they could participate the survey. In the questionnaire survey, questionnaire participants were individually asked to respond to a series of pairwise comparisons in order to establish the relative importance of the different elements. A nine-point rating scale was designed to measure the respondents' perceptions of what was relatively "important" and "unimportant".

Based on Saaty (1980), a consistency index (CI) was used to capture any inconsistencies within judgments in each aggregate pair-comparison matrix as well as in the overall decisions structures. Then, a consistency ratio (CR) was used to measure how a given matrix compares to a purely random matrix in terms of the CI. The CI and CR are formulated as follows:

$$\text{CI} = \frac{\theta_{\max} - n}{n - 1} \tag{1}$$

$$\text{CR} = \frac{CI}{RI} \tag{2}$$

Where CI is the consistency index; θ_{max} is the maximum eigenvalue; n is the number of elements in the judgement matrix; RI is the consistency index of a randomly generated reciprocal matrix from the nine-point scale, with forced reciprocals. For matrixes larger than 3×3, a value of the CR≤0.1 is considered acceptable while larger values of the CR require the decision-maker to revise their judgements. The analysis software is Expert Choice. Based on section 2.2, four indicators (including syllabus design, students' characteristics, teachers' characteristics, and university resources) and thirteen sub-criteria are developed (see Table 1).

Table 1: Key indicators and sub-indicators influencing EMI Courses

Indicator	Sub-criteria	Description	Sources
Syllabus Design (A)	Course material (A1)	Textbook, shipping practice news, scene conversation simulation.	Costa and Coleman (2013)
	Learning strategies (A2)	Suitable subjects and implementation processes to attract student's interest and motivation.	Poon (2013)
	Learning assessment (A3)	Providing effective assessment tools and inspectors/examination authorities to maintain equitable assessment method.	Clegg and Simpson (2016)
Students' characteristics (B)	Students 'English' level (B1)	Vocabulary, speaking (oral), grammar, lexical abilities.	Byun et al.(2011); Dalton-Puffer (2007); Kim et al. (2014); Başıbek et al. (2014)
	Student's shipping knowledge (B2)	Ship, port, cargo, charter contract, shipping company, agency, freight forwarder, etc.	Byun et al.(2011)
	Learning habits (B3)	Student's learning motivation, learning preparation and review, taking notes skill, etc.	Byun et al.(2011); Evan and Morrison (2011a; 2011b)
Teachers' Characteristics (C)	Teachers 'English' level (C1)	Vocabulary, speaking (oral), grammar, lexical abilities.	Pan (2007); Costa and Coleman (2013); Goodman (2014)
	Teacher's shipping knowledge (C2)	Teacher is familiar with teaching subjects regarding shipping related fields.	Huang and Singh (2014)
	Teacher's past experience with EMI teaching (C3)	The experience of teaching EMI courses, teaching skill, classroom management	Dafouz and Camacho-Miñano (2016)
University Resources (D)	Classroom facilities (D1)	Learning environment (e.g. location, space, computer (web) facilities, etc.).	Costa and Coleman (2013)
	Availability of assistance (D2)	Administration staff, Language center (tutor hour), library resources (e.g. video, newspaper).	Hellekjær (2009); Kirkgöz (2009); Agai-Lochi (2015)
	Incentives for teachers (D3)	Overseas training, course subsidies, salary increases, and favorable workload calculation.	Hu (2007); Tong and Shi (2012)
	Incentives for students (D4)	Employability knowledge of international shipping language, improving English abilities.	Costa and Coleman (2013)

4. Results

4.1 Data Collection

Questionnaires were sent to 36 participants (including university English teachers (12), university shipping teachers (12), and shipping practitioner[iv] (12)) in Taiwan on 22 February 2017. By 27 February, 2017, 28 questionnaires had been received. For each questionnaire, the consistency index (CI) was tested to confirm the consistency of its pairwise comparison matrix. Results found three questionnaires were highly inconsistent (CI>0.1) (Satty, 1980) and were consequently discarded. Therefore, the overall response rate was 69.4% (=25/36). The profiles of the 25 respondents' characteristics (including eight university English teachers, eight university shipping teachers and 9 shipping practitioners) are shown in Table 2. Results reveal that most of the respondents are senior experts with at least 10 years working experience in university or shipping industries, thus illustrating the reliability of the survey findings.

Table 2: Profiles of the respondents

Characteristics	Range	Frequency	Percentage (%)
University English teachers	Professor	2	25%
	Associate professor	5	62.5%
	Assistant professor	1	12.5%
	Sub-total	8	100%
University shipping teachers	Professor	3	33.3%
	Associate professor	4	44.4%
	Assistant professor	2	22.2%
	Sub-total	9	100%
Shipping practitioners	President/Director	1	12.5%
	Senior deputy director	3	37.5%
	Division director	3	37.5%
	Supervisor	1	12.5%
	Sub-total	8	100%
Age (years)	Under 40	2	8%
	41~50	10	40%
	51~60	10	40%
	Above 60	3	12%
Educational Level	Ph.D.	18	72%
	Master	4	16%
	Bachelor	3	12%
Seniority	10~15	5	20%
	16~20	7	28%
	21~25	8	32%
	Above 26	5	20%

4.2 Fuzzy AHP Analysis

In this paper, as shown in Table 3, all consistency ratio (CR) values are less than 0.1, and thus fit the consistency test. The local weights of each indicator and sub-indicator are shown in Table 3. The results indicate that Teachers' Characteristics (0.262) is the most important indicator influencing the implementation of EMI, followed by Syllabus Design (0.256), University Resources (0.244), and Students' Characteristics (0.239). With regard to sub-indicators, Learning Strategies (0.350), Students 'English' level (0.386), Teachers 'English' level (0.374), and Availability of Assistance (0.347) were perceived to be the most important sub-indicators with respect to each factor in relation to Syllabus Design, Students' Characteristics, Teachers' Characteristics, and University Resources, respectively.

Further, the global weights were synthesized from the second level drawn by multiplying the local weights and the corresponding indicator in the level above, and adding them to each element in a level according to the indicator affected. The results reveal that the top three important criteria influencing the implementation of EMI are Teachers 'English' level (0.0979), Students 'English' level (0.0923) and Learning strategies (0.0894), respectively.

Table 3: Fuzzy AHP results

Indicator	Local weights	Consistency ratio (CR)	Sub-indicators	Local weights	Global weights	Rank
Syllabus Design	0.256	0.0172	Course material	0.346	0.0886	4
			Learning strategies	0.350	0.0894	3
			Learning assessment	0.304	0.0778	8
Students' characteristics	0.239	0.0345	Students 'English' level	0.386	0.0923	2
			Student's shipping knowledge	0.282	0.0675	9
			Learning habits	0.331	0.0792	7

Teachers' Characteristics	0.262	0.0005	Teachers 'English' level	0.374	0.0979	1
			Teacher's shipping knowledge	0.305	0.0799	6
			Teacher's past experience with EMI teaching	0.320	0.0838	5
University Resources	0.244	0.0080	Classroom facilities	0.266	0.0647	11
			Availability of assistance	0.347	0.0576	12
			Incentives for teachers	0.270	0.0657	10
			Incentives for students	0.228	0.0555	13

*Notes: *Local weight is derived from judgment with respect to a single criterion; **Global weight is derived from multiplication by the weight of the criteria.*

5. Discussions and Conclusions

The above results show the relative importance of factors in the implementation of EMI in a Taiwanese context. Using 25 effective sample, teachers' characteristics are the most important indicator, but these were closely followed by Syllabus Design, University Resources and Students Characteristics. Arguably, all these factors are key and must all be in place, but the lead factor needs to be the teachers' characteristics. This being the case, it is arguable that the other factors can play a supporting role. Thus, institutions in Taiwan arguably need to help support teachers in their approaches and roles, possibly through providing incentives, but also through assistance and resources. This approach is confirmed by the second level results. These show that Teachers 'English' Level is the key factor but this is closely followed by Students 'English' level and Learning Strategies. Arguably, this would suggest that participants felt that students needed to have both a good level of English, but also a good range of learning strategies to be able to help them understand the content perhaps when their level of English did not enable to do so.

Arguably, these results would suggest that EMI instruction needs to be given more space and time than first language instruction, and that this in turn needs more support from the teachers and students. This has a number of implications in terms of resources and time. Firstly, from a timetabling perspective, it is arguable that EMI instruction needs to be given more time in the timetable. This could either be done on a weekly basis by according more time to each lesson, or it be done over a lengthier time by extending the number of weeks of the course. These results suggest that, given the importance of learning strategies, a key help for the students and the teachers in explaining the concepts may be to allow more time for questions and answers at the end of the session to allow for dialogue.

Interestingly, the results do not show that shipping knowledge was a key factor. This could be because such knowledge is taken for granted, or it could be because the focus of the study was on EMI instruction. If the latter is the case, it could be assumed that participants felt that when they were responding in relation to the participants 'English' level, they were doing so in response to the perception that this 'English' related to their ability to express themselves in the subject area in 'English', i.e. their ability to deliver subject knowledge in 'English'.

Further research would be useful to study aspects such as how participants felt about assessments being conducted in English, specific research about the exact type of support that would help students and teachers deliver EMI, and about how the effectiveness of such programmes in delivering knowledge can be judged. It is possible, we would argue, that such questions would be key for any policy makers, particularly if the policy of introducing EMI has the implications in terms of resources and timetabling that these results suggest. We note, however, that in order to be successful, such a change to EMI will indeed require support and assistance as these results would suggest, but that, given this, it will help develop Taiwan's graduates for employability, and help Taiwan recruit more international students to study there. Indeed, it is arguable that the costs of implementing EMI could be offset by these benefits.

References

Agai-Lochi, E. (2015). English as medium of instruction in university education, Procedia - Social and Behavioral Sciences 199: 340-347.

Başıbek, N., Dolmacı, M., Cengiz, B.C., Bür, B., Dilek, Y. and Kara, B. (2014). Lecturers' Perceptions of

English Medium Instruction at Engineering Departments of Higher Education: A Study on Partial English Medium Instruction at Some State Universities in Turkey, Procedia - Social and Behavioral Sciences 116: 1819-1825.
Byun, K., Chu, H., Kim, M., Park, I., Kim, S. and Jung, J. (2011). English-medium teaching in Korean higher education: Policy debates and reality, Higher Education 62: 431-449.
Chang, D. Y. (1996). Application of the extent analysis method on fuzzy AHP, European Journal of Operational Research, 95(3): 649-655.
Clegg, J. and Simpson, J. (2016). Improving the effectiveness of English as a medium of instruction in sub-Saharan Africa, Comparative Education 52(3): 359-374.
Costa, F. and Coleman, J. A. (2013). A survey of English-medium instruction in Italian higher education, International Journal of Bilingual Education and Bilingualism 16(1): 3-19.
Dafouz, E. M. and Camacho-Miñano, M. M. (2016). Exploring the impact of English-medium instruction on university student academic achievement: The case of accounting, English for Specific Purposes 44: 57-67.
Dalton-Puffer, C. (2007). Discourse in content and language integrated learning (CLIL) classrooms. Amsterdam, The Netherlands: John Benjamins.
Demirel, E. and Ziarati, R. Establishment of a common platform for the maritime education and training, IMLA21 Conference, St. John's, Newfoundland and Labrador, Canada, October 9th -12th 2013.
Dinwoodie, J. (2000). The perceived importance of employment considerations in the decisions of students to enrol on undergraduate courses in maritime business in Britain, Maritime Policy & Management 27(1): 17-30. DOI: 10.1080/030888300286653.
Evans, S. and Morrison, B. (2011a). The student experience of English-medium higher education in Hong Kong, Language and Education 25: 147-162.
Evans, S. and Morrison, B. (2011b). Meeting the challenges of English-medium higher education: The first-year experience in Hong Kong, English for Specific Purposes 30: 198-208.
Fei, J. and Lu, J. (2015). Analysis of students' perceptions of seafaring career in China based on artificial neural network and genetic programming, Maritime Policy & Management 42(2): 111-126.
Gekara, V. (2009). Understanding attrition in UK maritime education and training. Globalisation, Societies and Education 7(2): 217-232.
Gooch, L. (2009). Malaysia Ends Use of English in Science and Math Teaching. IN New York Times, July 8 2009. Available at: http://www.nytimes.com/2009/07/09/world/asia/09iht-malay.html last accessed February 23rd 2017.
Goodman, B.A. (2014). Implementing English as a medium of instruction in a Ukrainian University: Challenges, adjustments, and opportunities, International Journal of Pedagogies and Learning 9(2): 130-141.
Hahl, K., Järvinen, H. M. and Juuti, K. (2016). Accommodating to English-medium instruction in teacher education in Finland, International Journal of Applied Linguistics 26(3): 291-310.
Hellekjær, G. O. (2009). Academic English reading proficiency at the university level: A Norwegian case study, Reading in a Foreign Language 21: 198-222.
Hu, J. S., Chang, S. W. and Chen, T. S. (2008). Social impacts on the maritime education–a case study of National Kaohsiung Marine University in Taiwan, TransNav: International Journal on Marine Navigation and Safety of Sea Transportation 2(2): 197-203.
Hu, G. W. (2007). The juggernaut of Chinese-English bilingual education. In A.W. Feng (ed.), Bilingual education in China: Practices, policies and concepts (pp. 94-126). Clevedon, UK: Multilingual Matters.
Hu, G. and Lei, J. (2014). English-medium instruction in Chinese higher education: a case study, Higher Education 67: 551-567.
Horck, J. (2010). The gender perspective in maritime education and training, WMU Journal of Maritime Affairs 9(1): 93-119.
Huang, D. F. and Singh, M. (2014). Critical perspectives on testing teaching: reframing teacher education for English medium instruction, Asia-Pacific Journal of Teacher Education 42(4): 363-378.
Huang, D. F. (2015). Exploring and assessing effectiveness of English medium instruction courses: The students' perspectives, Procedia - Social and Behavioral Sciences 173: 71-78.
Kedzierski, M. (2016). English as a medium of instruction in East Asia's higher education sector: a critical realist Cultural Political Economy analysis of underlying logics, Comparative Education 52(3): 375-391.
Kim, A., Son, Y. D. and Sohn, S. Y. (2009). Conjoint analysis of enhanced English Medium Instruction for college, Expert Systems with Applications 36: 10197-10203.
Kim, J., Tatar, B. and Choi, J. (2014). Emerging culture of English-medium instruction in Korea: experiences

of Korean and international students, Language and Intercultural Communication 14(4): 441-459.
Kirkgöz, Y. (2009). Students' and lecturers' perceptions of the effectiveness of foreign language instruction in an English-medium university in Turkey. Teaching in Higher Education 14: 81-93.
Lee, G. J. (2017). (Ed) Challenges in English in University in English in University Education. Hakjisa, Seoul.
Mok, K. H., Yu, K. M. (2011). The quest for regional education hub status and transnational higher education: Challenges for managing human capital in Asia, Asia Pacific Journal of Education 31(3): 229-248.
Ng, A. K., Koo, A. C. and Ho, W. J. (2009). The motivations and added values of embarking on postgraduate professional education: Evidences from the maritime industry, Transport Policy 16(5): 251-258.
Ng, J. M. and Yip, T. L. (2009). Maritime education in a transdisciplinary world: The case of Hong Kong, The Asian Journal of Shipping and Logistics 25(1): 69-82.
Pilcher, N. and Richards, K. (2016). The paradigmatic hearts of subjects which their 'English' flows through, Journal of Higher Education. Research and Development 35(5): 997-1010.
Pallis, A. A. and Ng, A. K. (2011). Pursuing maritime education: an empirical study of students' profiles, motivations and expectations. Maritime Policy & Management, 38(4): 369-393.
Pan, J. Z. (2007). Facts and considerations about bilingual education in Chinese universities. In A.W. Feng (ed.), Bilingual education in China: Practices, policies and concepts (pp. 200–215). Clevedon, UK: Multilingual Matters.
Pilcher, N. and Richards, K. (2016). The paradigmatic hearts of subjects which their 'English' flows through, Higher Education Research and Development 35(5): 997-1010.
Pilcher, N. and Richards, K. (2017). Challenging the power invested in the International English Language Testing System (IELTS): Why determining 'English' preparedness needs to be undertaken within the subject context. Power and Education, 1757743817691995.
Poon, A. Y. K. (2013). Will the new fine-tuning medium-of-instruction policy alleviate the threats of dominance of English-medium instruction in Hong Kong? Current Issues in Language Planning 14(1): 34-51.
Richards, K. and Pilcher, N. (2014). Contextualising higher education assessment task words with an 'anti-glossary' approach. International Journal of Qualitative Studies in Education, 27(5): 604-625.
Richards, K. and Pilcher, N. (2017). Don't panic! You know your subject. You're not Teaching English, You're teaching your subject in English. In Lee, G.J (2017) (Ed) Challenges in English in University in English in University Education. Hakjisa, Seoul. Chapter 10.
Saaty, T.L. (1980). The Analytic Hierarchy Process. McGraw-Hill, New York.
Sepideh, B. and Nasser, G. (2015). Emotional intelligence and teachers' discipline strategies in EFL classes. Modern Journal of Language Teaching Methods 5(3): 446-452.
Tong, F. H. and Shi, Q. (2012). Chinese-English bilingul education in China: A case study of college science majors. International Journal of Bilingual Education and Bilingualism, 15: 165-182.
Zadeh, L. A. (1965). Fuzzy Sets. Inform Control 8 338-353.

---

[i] Ministry of Transportation and Communication, Taiwan. http://www.motc.gov.tw/en/home.jsp?id=154&parentpath=0

[ii] For example, when a student graduates from senior high school (about 18 years old) in Taiwan, he (she) has learnt English for 6 years assuming their junior high school has been conducted English education. In recent years, most public elementary schools in Taiwan have started English language education classes when students are ten-years old. Also, some private elementary schools have started to introduce English education or bilingual Education (Chinese and English).

[iii] These practitioners work in Evergreen Marine Corp. and Yang Mine Marine Transport in Taiwan. Experts interviews were conducted in December 2016.

[iv] These companies include Evergreen Marine Crop. Ltd., Yang Ming Line, Wan Hai Lines, T.S. Line, Chinese Maritime Transport Ltd., COSCO Shipping, NYK Line, Cheng Lie Navigation (CNC) Line, Orient Overseas Container Line, and Taiwan Navigation Corp. Ltd.

The Balancing Number of Container Throughput both of Bangkok Port and Laem Chabang Port

Veerachai Gosasang, Nuttapon Boonchokchuay and Wisetsak Wisetsanyakorn

Bangkok Port, Port Authority of Thailand, Bangkok, Thailand
Email: veerag1968@hotmail.com

Abstract

Maritime transportation is a vitally important part of international business, especially in a country such as Thailand. Thai seaborne trade has increased steadily over the years, and over 80% of its trade volumes are now shipped by sea. Forecasting the volume of containers, both inbound and outbound containers, is central for the planning and operation of the government office and private sector. Therefore, the best fit of forecasting methods and the accuracy of forecasting the future throughput are extremely important to consider when making a decision for planning and managing in Bangkok Port and Laem Chabang Port.

This paper aims to forecast both inbound and outbound container throughput of Bangkok Port and Laem Chabang Port by utilizing cause-and-effect forecasting. This paper applies the Vector Error Correction Model (VECM). VECM is a popular tool for economic analysis and forecasting for multivariate co-integrated time series.

The benefits of forecasting the future container throughput in Bangkok Port and Laem Chabang Port including with; firstly, this paper develops a best-fit forecasting method for Bangkok Port; secondly, not only the methods of forecasting, but economic factors are also important for this paper, the results found that various economic factors affected both inbound and outbound containers of Bangkok Port. The variables are, among others, economic growth rate, exchange rate, population, inflation rate, fuel price, interest rate, manufacturing production index (MPI), trade value of imports and trade value of exports, consumer price index (CPI) and industrial production index (IPI). These factors were entered into the VECM forecasting models, which generated projections of container throughput. The forecasting accuracies from MAE, RMSE and MAPE are satisfactory of VECM forecasting.

Keywords: *Forecasting, Vector Error Correction Model* (*VECM*), *Container Throughput, Inbound, Outbound*

1. Introduction

Bangkok Port is one of the most important determinants for the large investment in the container terminal. Bangkok Port is the most significant river port of Thailand which can service both import and export container throughput about 1.5 million TEUs per year.

While Laem Chabang Port is a deep sea port in the eastern region that has carring on the developments and managements of the infrastructures and facilities for linking with transportation networks and national logistics system.

Forecasting is a method or a technique for estimating many future aspects of a business or other operation. There are two types of quantitative forecasting models, time series and cause-and-effect (Armstrong, 2001).

In the past, researchers applied the traditional regression methods for forecasting the volumes of containers. However, those researchers did not consider this non-stationary relationship between the volumes of inbound and outbound containers, and the economic variables. Because the independent variable is non-stationary then the cause-and-effect forecasting methods are chosen in this paper include with Vector Error Correction Model (VECM).

The advantage of VECM is used for testing the presence of the co-integration relationship among several non-stationary variables (Moniruzzaman et al., 2011).

This paper has made a significant contribution to the knowledge of the forecasting techniques that provide the most accurate predictions for inbound and outbound container at Bangkok Port, as well as economic factors which affect the container throughput volume in Bangkok Port. This paper applies cause-and-effect forecasting for predicting future container volumes of Bangkok Port and Laem Chabang Port. Because economic factors are applied in this paper as independent variables (cause), this causes an effect on the number of containers or dependent variables (effect). This paper also determines the relationship between independent (cause) and dependent variables (effect) and whether both variables have a strong relationship.

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 and gives a discussion of the results; and Section 5 provides some conclusions.

2. Literature Review

This section is devoted to the various quantitative techniques of forecasting (Part 1) and maritime forecasting (Part 2).

2.1 Cause-and-effect forecasting technique classification review

Cause-And-Effect Model: This model assumes that the variable to be forecasted is exhibited by the explanatory relationship with one or more independent variables. In cause-and-effect models, there is a cause (called a driver or independent variable) and there is an effect (called a dependent variable). These models are used where there is a strong relationship between the cause and effect variables, and the relationship between them does not change significantly over time (or at least during the forecast period) (Montgomery, 1982).

There are three methods of cause-and-effect model such as Linear Regression, Neural Network and Vector Error Correction Model (VECM). Linear regression analysis is a technique for modeling the linear relationship between two or more variables. This model is applied in order to investigate variables of interest and employs regression to estimate the quantitative effect of the causal variables upon the variable that they influence.

Econometrics is a mixture of economics, mathematics and statistics. This involves selecting causal variables, identifying the expected directions of the relationships, imposing constraints on the relationships to ensure that they are sensible and selecting functional forms. Vector Error Correction Model (VECM) is applied for time series variables; if a set of variables are found to have one or more co-integrating vectors, then a suitable estimation technique is VECM, which adjusts to both short run changes in variables and deviations from the equilibrium.

2.2 Maritime forecasting reviews

The previous papers of maritime forecasting applied various methods of forecasting. The details are as follows:

The research explored by Babcock and Lu (2002), they predicted inland waterway grain traffic by time series forecasting. While Fung (2002) applied the Error-correction Model to forecast the demand for Hong Kong container handling services and to forecast the nature of interaction between major ports in East and Southeast Asia.

Table 1: Examples of papers of Maritime Forecasting and Economics Factors

Authors	Year	Economic Factors	Methodology	Contributions to research
JICA	1994	GDP, population	Regression Analysis	Forecasting container throughput in Bangkok Port
Fung	2002	Trade values	Error Correction Model	Hong Kong's Container Throughput
Seabooke et al.	2003	Macroeconomics	Regression Analysis	Predict cargo growth of the Port of Hong Kong
Hui et al.	2004	Trade values	Error Correction Model	Forecasting Cargo for the Port of Hong Kong
Syafi et al.	2006	GDP, population, volume of exports and imports	VECM	Container throughput in Indonesia
Chou et al.	2008	GDP, GNP, population and industrial production index	Modified Regression	Forecasting container in Keelung Port, Taichung Port and Kaohsiung Port
Lattila	2009	GDP, exchange rate and inflation	Combination of both ARIMA and Regression	Forecasting of the Seaports of Finland
Gosasang	2011	GDP, world GDP, exchange rate, population, inflation rate, interest rate and fuel price	Neural Network, Linear Regression	Forecasting containers of Bangkok Port
Liu and Park	2011	Hinterland's GDP and Hinterland's import-export volume	Regression Analysis	Analysis of Container Throughput in South Korea and China Ports
Yip	2012	GDP, GDPPC and population	Traditional Gravity Model and Gravity Model	Cereal trade between developing countries

3. Research Methodology

This section focuses on process for qualification of economic factors, data collection the forecasting methodology and evaluates the accuracy of measurements. This research applied VECM methods for forecasting inbound and outbound container in Bangkok Port and Laem Chabang Port.

3.1 Process for qualification of economic factors

The questionnaire survey needs to be conducted in the research in order to show which factors are likely to have influence on inbound and outbound containers for Bangkok Port.

Step 1 (first round): The questions come from literature reviews and include open-ended questions, such as - 1) what factors affect inbound containers?; and 2) what factors affect outbound containers? – which are asked to get answers from each expert to collect opinions and analysis of data, and then synthesise a variety of issues, in order to develop a new questionnaire in the second round of the Delphi technique.

Step 2 (second round): The Delphi questionnaire is bound by five levels. The researcher synthesises the results of the responses from the experts in the first round in order to develop a new questionnaire using a five level scale based on Likert's rating scale. A Likert scale is a psychometric scale commonly involved in research employing questionnaires. Likert's rating scale includes prospective answer choices like 'strongly agree', 'agree', 'undecided', 'disagree' and 'strongly disagree'. Then experts are presented to verify the accuracy of the content, language and index of items and objective congruence (IOC).

From the analysis of data from the second round of Delphi questionnaires, it can be seen that the questionnaire scales derive from the original group of experts; to comment on the nature of ranking the importance of each question. For this result, the method to use that is the median and interquartile (IQR) range.

Step 3 (third round): The researcher analysed questionnaire responses from the Delphi second round. The questionnaire for the Delphi third round appears similar to the questionnaire for the Delphi second round, except it has an additional report for the experts to make the opinion of the group clearly known. It shows the position of median and the range between quartiles for each question; it also recognises the positions of the experts who responded in the second round.

From the previous papers and the Delphi method, this thesis applies economic factors for inbound and outbound containers, as follows: The factors for inbound containers are economic growth rate, interest rate, inflation rate, exchange rate population, MPI and the trade value of imports; while the factors for outbound containers are CPI, population, exchange rate, fuel price, MPI, the trade value of exports, trade value of imports, economic growth rate and IPI.

3.2 Collection data

This paper collects both dependent factors and independent factors from process of Delphi as mentioned in previous section. Dependent factors are the volume of inbound and outbound containers, while independent factors are the economic factors of Thailand and other countries/jurisdictions such as USA, Euro Zone, Japan, China, Malaysia and Indonesia. Six countries/jurisdictions are the dominant trade partners of Thailand.

The economic factors which affect the volume of inbound containers include the economic growth rate, interest rate, inflation rate, exchange rate, population, manufacturing production index (MPI) and trade value of imports; while, on the other hand, economic growth rate, exchange rate, population, fuel rice, MPI, the trade value of imports, trade value of exports, CPI and IPI are the factors that affect the volume of outbound containers.

The data has been collected over a 16 years (192 months), from 2001-2016. The sources of data are from the Bank of Thailand, Office of the National Economic and Social Development Board, World Bank, Ministry of Interior, and Energy Policy and Planning Office. Independent variables are tested and selected by an econometric method such as Unit Root Test, Lag Selection, Johansen Cointegration Test and/or Vector Error Correction Model.

3.3 Select the appropriate method for forecasting the container volume

This part will explore cause-and-effect forecasting. VECM is selected for forecasting inbound and outbound containers of Bangkok Port.

- *Time Series Analysis and VECM*

The econometric approach to forecasting involves the application of a theoretical framework based on the knowledge of economic theory and of the underlying relationships that hold the commodity under consideration. Representations of these relationships are usually called econometric models or structural models.

This research applies Time series analysis, such as unit root test, lag selection and co-integration. These techniques are chosen because they provide a framework to investigate long-run and short-run relationships among variables, and also non-stationary variables. Finally, VECM is chosen for forecasting inbound and outbound container of Bangkok Port and Laem Chabang Port. The procedures are following as:

Step 1: Unit Root Test

The purpose of the unit root test is to help to identify some features of time series data. A series is said to be stationary if the mean and variances of the series do not depend on time (Nelson and Plosser, 1982). If the series is non-stationary and the first difference of the series is stationary, the series contains a unit root.

Step 2: VAR and Lag Selection

The vector autoregression (VAR) model is used for analysis of multivariate time series. It has proved to be useful for describing the behavior of economic and financial time series and forecasting.

Estimating the lag length of the autoregressive process for a time series is a crucial econometric exercise in most economic studies. A number of such lag-order selection criteria are used for the accuracy of the implied impulse response estimates.

Step 3: Johansen Cointegration test

The fundamental idea of co-integration is that, if two or more series are themselves non-stationary or integrated, but a linear combination of them is stationary, then the series are said to be co-integrated. The concept of co-integration was introduced by Engle and Granger (Engle and Granger, 1987), who provided the issue of integrating short-run dynamics with long-run equilibrium. The other methods, such as the maximum likelihood model, were proposed Johansen (Johansen, 1988 and 1991).

Step 4: Vector Error Correction Model (VECM)

This paper applied unit root test for checking a stationary of time series data. The stationary of data is important for forecasting in order to make accurate prediction.

If a set of variables are found to have one or more cointegrating vector then a suitable estimation technique is a VECM (Vector Error Correction Model) which adjusts to both short run changes in variables and deviations from equilibrium.

4. Results and Discussion

This section presents the results of time series analysis such as unit root test, VAR and lag selection and Johansen co-integration. The result of the forecasting both of inbound and outbound containers are presented by VECM and MLPs and finally, gives the discussion of the results.

- *Time Series Analysis*

Time series analysis includes unit root test, lag selection, co-integration and vector error correction model (VECM). The reasons are for checking the stationarity of data, for the estimation the autoregressive lag length and model building.

i. Unit Root Test

The results of unit root tests by augmented Dickey-Fuller (ADF) were performed on the full sample for the period 2001-2016; both on levels as well as differenced forms in order to find the order of integration. All the variables are found to be non-stationary at their levels. A non-stationary series can be made stationary by differencing. The variables become stationary at first difference, or integrated order 1 or I (1) since the null of the unit root is rejected at first difference.

ii. Lag Selection

At Bangkok Port, the lag length of the VAR in levels that minimize the information criteria at AIC = 106.1779 and FPE = 1.80e+36 and Lag selection of inbound series is 2, and the lag length of the VAR in levels that minimize the information criteria at AIC = 167.7637 and FPE = 3.76e+60 and Lag selection of outbound series is 4 (Liew, V.Khin-Sen, 2004).

While at Laem Chabang Port, the lag length of the VAR in levels that minimize the information criteria at AIC = 108.3473 and FPE = 1.57e+37 and Lag selection of inbound series is 2, and the lag length of the VAR in levels that minimize the information criteria at AIC = 175.1384 and FPE = 5.99e+63 and Lag selection of outbound series is 4 (Liew, V.Khin-Sen, 2004).

iii. Co-integration Test

To find the existence and the number of co-integration relationships, as well as calculate the maximum eigenvalues and the trace statistics by applying the Johansen procedure. The number of co-integration relationships is established by a sequential likelihood ratio test on the rank of an estimated parameter matrix from the VEC model. Results of these tests with 95% critical values are reported in Tables 2-5.

Table 2: Cointegration Test by Johansen Procedure at Bangkok Port (Inbound)

H_0 Null	H_1 (Alternative)	Trace test		Max-eigenvalue	
		Test Statistic	95% Critical value	Test Statistic	95% Critical value
r=0	r = 1	181.9033	159.5297	56.26920	52.36261

From table 2, Trace test indicates 1 cointegrating eqn(s) at the 0.05 level and Max-eigenvalue test indicates 1 cointegrating eqn(s) at the 0.05 level, because the value of test statistic (181.9033) more than critical value (159.5297) at Trace test. While the value of test statistic (52.26920) more than critical value (52.36261) at Max-eigenvalue.

Table 3: Cointegration Test by Johansen Procedure at Bangkok Port (Outbound)

H_0 Null	H_1 (Alternative)	Trace test		Max-eigenvalue	
		Test Statistic	95% Critical value	Test Statistic	95% Critical value
r=0	r = 1	331.6744	239.2354	91.56671	64.50472

From table 3, Trace test indicates 1 cointegrating eqn(s) at the 0.05 level and Max-eigenvalue test indicates 1 cointegrating eqn(s) at the 0.05 level, because the value of test statistic (331.6744) more than critical value (239.2354) at Trace test. While the value of test statistic (91.56671) more than critical value (64.50472) at Max-eigenvalue.

Table 4: Cointegration Test by Johansen Procedure at Laem Chabang Port (Inbound)

H_0 Null	H_1 (Alternative)	Trace test		Max-eigenvalue	
		Test Statistic	95% Critical value	Test Statistic	95% Critical value
r=0	r = 1	174.6632	159.5297	67.02661	52.36261

From table 4, Trace test indicates 1 cointegrating eqn(s) at the 0.05 level and Max-eigenvalue test indicates 1 cointegrating eqn(s) at the 0.05 level, because the value of test statistic (174.6632) more than critical value (159.5297) at Trace test. While the value of test statistic (52.26920) more than critical value (52.36261) at Max-eigenvalue.

Table 5: Cointegration Test by Johansen Procedure at Laem Chabang Port (Outbound)

H_0 Null	H_1 (Alternative)	Trace test		Max-eigenvalue	
		Test Statistic	95% Critical value	Test Statistic	95% Critical value
r=0	r = 1	263.8312	239.2354	65.16717	64.50472

From table 5, Trace test indicates 1 cointegrating eqn(s) at the 0.05 level and Max-eigenvalue test indicates 1 cointegrating eqn(s) at the 0.05 level, because the value of test statistic (263.8312) more than critical value (239.2354) at Trace test. While the value of test statistic (65.16717) more than critical value (64.50472) at Max-eigenvalue.

iv. Vector Error Correction Model

In this section, present the regression result of the VECM based on the Johansen procedure. Coefficient matrix of VECM is given in Tables 6-9. To evaluate the accuracy of the model, we generate a series over a sample period and observe how well this estimation series match with the actual data. The process is straightforward; the first and second data in the sample are entered into the model as starting values for the calculation of ΔY_t as given in equations 1-4. Adding the latter to the starting value provides the model estimation Y_t for the third year in the sample. The process is repeated for each year in the sample period. The estimation series is transformed again to the original value (level).

At Bangkok Port, a system VECM equations for inbound is developed with a function of economic growth rate, exchange rate, inflation rate, interest rate, manufacturing production index, population and value of import. The main equation (1) expresses the long run as well as short run association between inbound and other seven concerned factors.

D(INBOUND) = C(1)*(INBOUND(-1) - 24881.00465*ECORATE(-1) - 122188.5365*EXTRATE(-1) + 69824.44286*INF(-1) - 119726.9532*INT(-1) - 16510.4599*MPI(-1) + 0.1068552156 *POPULATION(-1) - 2.095936582E-005*VALIMP(-1) + 1238664.178) + C(2)*D(INBOUND(-1))
+ C(3)*D(INBOUND(-2)) + C(4)*D(ECORATE(-1)) + C(5)*D(ECORATE(-2)) + C(6) *D(EXTRATE(-1)) + C(7)*D(EXTRATE(-2)) + C(8)*D(INF(-1)) + C(9)*D(INF(-2)) + C(10)*D(INT
(-1)) + C(11)*D(INT(-2)) + C(12) *D(MPI(-1)) + C(13)*D(MPI(-2)) + C(14)*D(POPULATION(-1))
+ C(15)*D(POPULATION(-2)) + C(16)*D(VALIMP(-1)) + C(17) *D(VALIMP(-2)) + C(18) (eq. 1)

Where C(1) is long run adjustment coefficient. C(2) to C(17) are short run casuality coeeficient of respective variables and C(18) is a constant term. The values of all coefficients and their probabilities are present in table 6.

Table 6: Coefficient and Probability values for inbound at Bangkok Port

	Coefficient	Std. Error	t-Statistic	Prob.
C(1)	0.001626	0.001976	0.822579	0.412
C(2)	-0.634028	0.075565	-8.390528	0.003
C(3)	-0.386306	0.07368	-5.243024	0.0016
C(4)	333.7307	286.5359	1.164708	0.2459
C(5)	164.5892	278.2613	0.591492	0.555
C(6)	-860.2896	829.2001	-1.037493	0.3011
C(7)	58.01382	835.7867	0.069412	0.9447
C(8)	1177.696	669.9202	1.757964	0.0807
C(9)	-858.0195	677.4744	-1.266497	0.2072
C(10)	108.4658	829.0034	0.130839	0.8961
C(11)	-159.7072	821.9045	-0.194314	0.8462
C(12)	221.7883	55.79561	3.975014	0.0001
C(13)	-58.11632	59.89096	-0.970369	0.3333
C(14)	-0.010086	0.00318	-3.171943	0.0018
C(15)	0.007691	0.003345	2.298944	0.0228
C(16)	-2.35E-07	4.21E-07	-0.55805	0.5776
C(17)	5.49E-07	4.20E-07	1.307758	0.1928
C(18)	261.6428	403.2456	0.648842	0.5174

At Bangkok Port, a system VECM equation for outbound is developed with a function consumer price index, economic growth rate, exchange rate, fuel price, industrial production index, manufacturing production index, population, value of export and value of import. The main equation (2) expresses the long run as well as short run association between inbound and other nine concerned factors.

D(OUTBOUND) = C(1)*(OUTBOUND(-1) - 67.14718716*CPI(-1) + 725.0698322*ECORATE(-1)
- 516.1888013*EXTRATE(-1) - 75.59450551*FUELPRICE(-1) - 1247.540941*IPI(-1)
- 124.6841373*MPI(-1) - 0.0006951788313*POPULATION(-1) + 6.272013314E-007*VALEXPTH

(-1) + 3.917673369E-007 *VALIMP(-1) + 347741.8832) + C(2)*D(OUTBOUND(-1)) + C(3)*D(OUTBOUND(-2)) + C(4)*D(OUTBOUND(-3)) + C(5)*D(OUTBOUND(-4)) + C(6)*D(CPI(-1)) + C(7)*D(CPI(-2)) + C(8)*D(CPI(-3)) + C(9)*D(CPI(-4)) + C(10)*D(ECORATE(-1)) + C(11)*D(ECORATE(-2)) + C(12)*D(ECORATE(-3)) + C(13)*D(ECORATE(-4)) + C(14)*D(EXTRATE(-1)) + C(15)*D(EXTRATE(-2)) + C(16)*D(EXTRATE(-3)) + C(17)*D(EXTRATE(-4)) + C(18)*D(FUELPRICE(-1)) + C(19)*D(FUELPRICE(-2)) + C(20)*D(FUELPRICE(-3)) + C(21)*D(FUELPRICE(-4)) + C(22)*D(IPI(-1)) + C(23)*D(IPI(-2)) + C(24)*D(IPI(-3)) + C(25)*D(IPI(-4)) + C(26)*D(MPI(-1)) + C(27)*D(MPI(-2)) + C(28)*D(MPI(-3)) + C(29)*D(MPI(-4)) + C(30)*D(POPULATION(-1)) + C(31)*D(POPULATION(-2)) + C(32)*D(POPULATION(-3)) + C(33)*D(POPULATION(-4)) + C(34)*D(VALEXPTH(-1)) + C(35)*D(VALEXPTH(-2)) + C(36)*D(VALEXPTH(-3)) + C(37)*D(VALEXPTH(-4)) + C(38)*D(VALIMP(-1)) + C(39)*D(VALIMP(-2)) + C(40)*D(VALIMP(-3)) + C(41)*D(VALIMP(-4)) + C(42) (eq. 2)

Where C(1) is long run adjustment coefficient. C(2) to C(41) are short run casuality coeeficient of respective variables and C(42) is a constant term. The values of all coefficients and their probabilities are present in table 7.

Table 7: Coefficient and Probability values for outbound at Bangkok Port

	Coefficient	Std. Error	t-Statistic	Prob.
C(1)	-0.353232	0.100379	-3.518971	0.0006
C(2)	-0.147662	0.125735	-1.174397	0.2423
C(3)	-0.185621	0.122411	-1.516377	0.1318
C(4)	-0.011197	0.107402	-0.104254	0.9171
C(5)	0.046872	0.083344	0.562391	0.5748
C(6)	-1.495699	21.70439	-0.068912	0.9452
C(7)	-36.52795	27.81438	-1.313275	0.1914
C(8)	-21.34429	27.71039	-0.770263	0.4425
C(9)	-11.56872	21.86915	-0.528997	0.5977
C(10)	-7.229944	262.3961	-0.027554	0.9781
C(11)	217.869	261.8762	0.831954	0.4069
C(12)	-331.3804	264.93	-1.250822	0.2132
C(13)	457.2166	260.3139	1.756405	0.0813
C(14)	-1075.975	729.7927	-1.474358	0.1427
C(15)	676.7373	747.9191	0.904827	0.3672
C(16)	-148.1037	739.9318	-0.200159	0.8417
C(17)	-165.7118	699.7588	-0.236813	0.8132
C(18)	802.7884	348.938	2.300662	0.023
C(19)	-1001.094	440.7342	-2.271424	0.0247
C(20)	-519.7441	428.1883	-1.213821	0.227
C(21)	126.8115	423.3659	0.299532	0.765
C(22)	-437.4351	177.8301	-2.459848	0.0152
C(23)	-287.1769	200.0665	-1.435407	0.1535
C(24)	-350.0928	185.0958	-1.891414	0.0607
C(25)	-443.2117	149.4186	-2.966241	0.0036
C(26)	75.36827	50.88345	1.481194	0.1409
C(27)	46.49252	52.61322	0.883666	0.3785
C(28)	18.59085	55.1554	0.337063	0.7366
C(29)	45.48107	53.10979	0.85636	0.3933
C(30)	-0.000212	0.000538	-0.394731	0.6937
C(31)	0.002442	0.000601	4.063368	0.0001
C(32)	-0.004096	0.000703	-5.825159	0.0438
C(33)	0.000458	0.000725	0.632148	0.5284
C(34)	3.14E-07	4.95E-07	0.634086	0.5271
C(35)	1.71E-08	5.12E-07	0.033304	0.9735

C(36)	-1.69E-07	5.48E-07	-0.307483	0.759
C(37)	1.94E-07	4.84E-07	0.400348	0.6895
C(38)	5.19E-07	1.49E-07	3.485399	0.0007
C(39)	2.66E-07	1.58E-07	1.676753	0.0959
C(40)	-4.50E-08	1.27E-07	-0.355108	0.7231
C(41)	4.56E-08	1.04E-07	0.437674	0.6623
C(42)	116.3285	407.0471	0.285786	0.7755

At Laem Chabang Port, a system VECM equations for inbound is developed with a function of economic growth rate, exchange rate, inflation rate, interest rate, manufacturing production index, population and value of import. The main equation (3) expresses the long run as well as short run association between inbound and other seven concerned factors.

D(INBOUND) = C(1)*(INBOUND(-1) - 3057.523066*ECORATE(-1) - 17108.42175*EXTRATE(-1) + 11020.24645*INF(-1) - 22531.1349*INT(-1) - 3088.525906*MPI(-1) - 0.003781782046*POPULATION(-1) - 4.495986103e-006*VALIMP(-1) + 1351321.908) + C(2)*D(INBOUND(-1)) + C(3)*D(INBOUND(-2)) + C(4)*D(ECORATE(-1)) + C(5)*D(ECORATE(-2)) + C(6)*D(EXTRATE(-1)) + C(7)*D(EXTRATE(-2)) + C(8)*D(INF(-1)) + C(9)*D(INF(-2)) + C(10)*D(INT(-1)) + C(11)*D(INT(-2)) + C(12)*D(MPI(-1)) + C(13)*D(MPI(-2)) + C(14)*D(POPULATION(-1)) + C(15)*D(POPULATION(-2)) + C(16)*D(VALIMP(-1)) + C(17)*D(VALIMP(-2)) + C(18) (eq. 3)

Table 8: Coefficient and Probability values for inbound at Laem Chabang Port

	Coefficient	Std. Error	t-Statistic	Prob.
C(1)	-0.072105	0.036645	-1.967671	0.0493
C(2)	-0.542406	0.078440	-6.914911	0.0000
C(3)	-0.161172	0.075238	-2.142160	0.0324
C(4)	811.0564	796.6416	1.018095	0.3088
C(5)	574.3444	774.5885	0.741483	0.4585
C(6)	97.19539	2265.898	0.042895	0.9658
C(7)	1477.188	2289.764	0.645127	0.5190
C(8)	1775.270	1835.783	0.967037	0.3337
C(9)	615.1660	1860.020	0.330731	0.7409
C(10)	-2013.929	2299.537	-0.875797	0.3813
C(11)	18.23160	2272.283	0.008023	0.9936
C(12)	-169.6089	154.0822	-1.100768	0.2712
C(13)	-32.39457	170.4630	-0.190039	0.8493
C(14)	-0.004214	0.008798	-0.478946	0.6321
C(15)	0.025658	0.008978	2.857819	0.0043
C(16)	-7.92E-07	1.12E-06	-0.705341	0.4807
C(17)	1.07E-06	1.12E-06	0.961156	0.3367
C(18)	1558.749	1122.938	1.388098	0.1654

At Laem Chabang Port, a system VECM equation for outbound is developed with a function consumer price index, economic growth rate, exchange rate, fuel price, industrial production index, manufacturing production index, population, value of export and value of import. The main equation (4) expresses the long run as well as short run association between inbound and other nine concerned factors.

D(OUTBOUND) = C(1)*(OUTBOUND(-1) - 2925.495393*CPI(-1) + 16144.26495*ECORATE(-1) - 12255.49679*EXTRATE(-1) - 4312.632183*FUELPRICE(-1) - 1741.104311*IPI(-1) - 441.3597695*MPI(-1) - 0.02242270724*POPULATION(-1) - 8.80019996e-007*VALEXPTH(-1) + 6.31516264e-006*VALIMP(-1) + 9038422.43) + C(2)*D(OUTBOUND(-1)) + C(3)*D(OUTBOUND(-2)) + C(4)*D(CPI(-1)) + C(5)*D(CPI(-2)) + C(6)*D(ECORATE(-1)) + C(7)*D(ECORATE(-2)) + C(8)*D(EXTRATE(-1)) + C(9)*D(EXTRATE(-2)) + C(10)*D(FUELPRICE(-1)) + C(11)*D(FUELPRICE(-2)) + C(12)*D(IPI(-1)) + C(13)*D(IPI(-2)) + C(14)*D(MPI(-1)) + C(15)*D(MPI(-2)) + C(16)*D(POPULATION(-1)) + C(17)*D(POPULATION(-2)) + C(18)*D(VALEXPTH(-1)) + C(19)*D(VALEXPTH(-2)) + C(20)*D(VALIMP(-1)) + C(21)*D(VALIMP(-2)) + C(22) (eq. 4)

Table 9: Coefficient and Probability values for outbound at Laem Chabang Port

	Coefficient	Std. Error	t-Statistic	Prob.
C(1)	-1.005715	0.158901	-6.329183	0.0000
C(2)	0.006830	0.132345	0.051610	0.9588
C(3)	0.059818	0.115469	0.518046	0.6045
C(4)	-2097.148	1251.186	-1.676127	0.0939
C(5)	-919.1915	1204.760	-0.762966	0.4456
C(6)	10849.80	14145.85	0.766995	0.4432
C(7)	-5565.141	13863.39	-0.401427	0.6882
C(8)	6636.507	38278.09	0.173376	0.8624
C(9)	-8025.964	38059.50	-0.210879	0.8330
C(10)	-2916.191	19232.11	-0.151631	0.8795
C(11)	-3256.716	21403.03	-0.152161	0.8791
C(12)	545.1804	10478.33	0.052029	0.9585
C(13)	-6572.890	7709.150	-0.852609	0.3940
C(14)	1111.407	2516.153	0.441709	0.6588
C(15)	3252.394	2508.007	1.296804	0.1949
C(16)	-0.015807	0.027724	-0.570145	0.5687
C(17)	-0.019291	0.029923	-0.644680	0.5192
C(18)	-7.36E-05	2.54E-05	-2.902680	0.0038
C(19)	-4.43E-05	2.53E-05	-1.751993	0.0800
C(20)	5.01E-06	5.70E-06	0.879559	0.3792
C(21)	1.52E-07	5.39E-06	0.028186	0.9775
C(22)	12536.08	20284.30	0.618019	0.5367

Table 10: Forecasting of Inbound and Outbound Containers at Bangkok Port from 2017-2041
(**unit**: **TEU**)

Year	Inbound	Outbound
2017	935,726	726,207
2018	958,195	735,049
2019	980,663	743,891
2020	1,003,132	752,732
2021	1,025,600	761,574
2022	1,034,151	770,415
2023	1,047,865	779,257
2024	1,061,519	788,099
2025	1,070,539	796,940
2026	1,093,005	805,782
2027	1,105,399	814,623
2028	1,115,436	823,465
2029	1,130,451	832,306
2030	1,137,943	841,148
2031	1,148,193	849,990
2032	1,160,413	858,831
2033	1,182,880	867,673
2034	1,188,343	876,514
2035	1,205,349	885,356
2036	1,217,491	894,198
2037	1,227,817	903,039
2038	1,237,489	911,881
2039	1,248,237	920,722
2040	1,256,586	938,648
2041	1,264,358	949,988

Table 11: Forecasting of Inbound and Outbound Containers at Laem Chabang Port from 2017-2041
(**unit**: **TEU**)

Year	Inbound	Outbound
2017	3,365,246	3,986,102
2018	3,477,041	4,134,693
2019	3,668,836	4,308,989
2020	3,760,035	4,483,285
2021	3,912,426	4,657,580
2022	4,124,221	4,831,876
2023	4,236,016	5,106,172
2024	4,387,811	5,280,467
2025	4,559,606	5,414,763
2026	4,671,401	5,525,099
2027	4,883,196	5,703,354
2028	4,991,991	5,877,650
2029	5,106,786	6,151,946
2030	5,218,581	6,300,537
2031	5,330,376	6,514,833
2032	5,422,171	6,729,128
2033	5,603,966	6,883,424
2034	5,792,964	7,097,720
2035	5,977,556	7,270,215
2036	6,099,531	7,400,537
2037	6,181,146	7,620,607
2038	6,302,941	7,794,902
2039	6,424,736	7,969,198
2040	6,586,531	8,220,607
2041	6,718,326	8,594,902

5. Conclusion

It is extremely important for both the Thailand government offices and private sectors to be able to accurately predict the future throughput volumes of inbound and outbound containers of Bangkok Port and Laem Chabang Port. The forecast numbers will enable Port Authority of Thailand to manage and develop the main infrastructures and equipment necessary for supporting the competitiveness of the Kingdom of Thailand.

The results of this study greatly contribute to the knowledge of which forecasting technique is the most appropriate technique for predicting the future volume of inbound and outbound containers, as well as what factors are important and affect the volume of inbound and outbound containers of Bangkok Port and Laem Chabang Port.

The factors affecting the volume of inbound containers are economic growth rate, interest rate, inflation rate, exchange rate, population, manufacturing production index (MPI) and the trade value of imports; while the factors affecting the volume of outbound containers are consumer price index (CPI), population, exchange rate, fuel price, manufacturing production index (MPI), trade value of exports, trade value of imports, economic growth rate and industrial production index (IPI).

This paper has made a significant contribution to the knowledge bank for choosing the VECM forecasting technique, which is suitable for the prediction of the volume of both inbound and outbound containers of Bangkok Port and Laem Chabang Port.

The findings of this research will assist officers at Bangkok Port and Laem Chabang Port (Phase3) in dealing with the future volumes of inbound and outbound containers, coping with yard planning, management, future revenues that make a valuable contribution to the economy, as well as facilitating both direct and indirect employment.

It would be interesting and very useful to extend the present study to investigate the expansion of the container terminal of Bangkok Port or sharing some number of container to Laem Chabang Port. Because Laem Chabang Port has more terminal capacity of container from Bangkok Port.

6. Acknowledgment

I would like to honestly thank my office, Port Autohrity of Thailand for all supporting.

References

J.Scott Armsrong (2001), A Handbook for Researchers and Practioners: Kluwer Academic Publishers.

Babock, M. W., Lu, X. (2002), "Forecasting inland waterway grain traffic," Transportation Research Part E, Vol.38, No.1, pp.65-74.

C.C Chou, C.W Chub, G.S Liang (2008), "A modified regression model for forecasting the volumes of Taiwan's import containers", Mathematical and Computer Modelling No.47, pp. 797–807.

Engle, R.F. and Granger, C.W.J. (1987), "Co-Integration and Error Correction: Representation, Estimation, and Testing," Econometrica, Vol. 55, No. 2., pp. 251-276.

Fung, M.K. (2002), "Forecasting Hong Kong's container throughput: an error-correction model," Journal of Forecasting, Vol.21, pp.69-80.

Gosasang, V., Chandraprakaikul, W., Kiattisin, S. (2011), "A Comparison of Traditional and Neural Networks Forecasting Techniques for Container Throughput at Bangkok Port", The Asian Journal of Shipping and Logistics, Vol.27, pp. 463–482.

Hui, E., Seabrooke, W., and Wong, G. (2004). "Forecasting Cargo Throughput for the Port of Hong Kong: Error Correction Model Approach." Journal of Urban Planning and Development, Vol.30 (4), pp.195-203.

Johansen, S. (1988), "Statistical Analysis of Cointegration Vectors," Journal of Economic Dynamics and Control, Vol. 12, pp. 231–254.

Johansen, S. (1991), "Estimation and Hypothesis Testing of Cointegration Vectors in Gaussian Vector Autoregressive Models", Econometrica, Vol. 59, pp. 1551–1580.

Lattila (2009), "Combining Advanced Forecasting Methods with System Dynamics: the Case of Finish Seaports", Lappeenranta University of Technology, Department of Industrial Management, Kouvola Research Unit, Research Report 209.

Liew, V. Khim-Sen (2004), "Which Lag Length Selection Criteria Should We Employ?." Economics Bulletin, Vol. 3, No. 33 pp. 1−9.

Liu L. and Park G. (2011). "Empirical analysis of influence factors to container throughput in Korea and China ports." The Asian Journal of Shipping and Logistics, Vol. 27, Issue 2, pp. 279–304.

Moniuzzaman, MD, Toy, M.M. and Hassen, A.B.M. R. (2011) "The export supply model of Bangladesh: An Application of Cointegration and Vector Error Correction Approaches", International Journal of Economics and Financial Issues, Vol.1, No.4, pp. 163-171.

D.C. Montgomery, E.A. Peak and G.G. Vining (1982), Introduction to Linear Regression Analysis: John Wiley & Sons, Inc.

W. Seabrooke, E.C. Hui, W.H. Lam and G.K. Wong (2003), "Forecasting Cargo Growth and the Regional Role of the Port of Hong Kong. " Cities Vol. 20, pp.51-64.

Syafi'i (2006), "Multivariate Autoregressive Model for Forecasting The Demand of Container Throughput in Indonesia," MEDIA TEKNIK SIPIL, pp. 129-134.

Yip, TL. (2012). "Seaborne trade between developed and developing countries", The Asian Journal of Shipping and Logistics, Vol. 28, pp.369-389.

www.bot.or.th, Bank of Thailand.

www.nesdb.go.th, Office of the National Economic and Social Development Board.

www.worldbank.org, World Bank.

www.eppo.go.th, Ministry of Interior, and Energy Policy and Planning Office.

An Effective Partnership of Professional Education in Marine and Offshore Technology

Ivan CK Tam

School of Marine Science and Technology, Newcastle University, NE1 7RU, UK
Email: ivan.tam@newcastle.ac.uk

Abstract

A professional education with international standing plays an important role in a successful engineering career. The availability of world-renowned marine technology programmes at university level was limited in South East Asia. To bridge this gap, an offshore campus established by the School of Marine Science and Technology, Newcastle University in partnership with a local institute of higher learning (IHL) in 2009. Currently, three distinct marine technology programmes, namely, Bachelor of Engineering with Honours in Marine Engineering, Naval Architecture and Offshore Engineering offered. They are identical to the programmes at the home campus and fully accredited by the IMarEST and RINA in the UK. Graduates from the local polytechnics with a marine technology related diploma allowed partial exemption towards these programmes. Around 80 students admitted to these programmes annually. The performance of students tracked with their counterparts in the UK shows that such partnership brings quality maritime education to local students. The local IHL under the partnership gains an insight of the operation, curriculum and international outlook of a reputable university. Newcastle University benefits from a ready pool of selected polytechnic graduates of high calibre to its academic courses. The marine and offshore industry enjoys a competent workforce benchmarked with international players. Furthermore, the economic rewards generated at national level will be obvious in the years to come.

Keywords: Education, Marine, Technology, Partnership, University, Polytechnic

1. Introduction

The Port of Singapore is a premier global hub port, with connections to 600 ports in over 120 countries. Vessel arrival in terms of shipping tonnage reached 2.37 billion gross tonnes in 2014 (Tan, 2015). Singapore achieved a record high of 33.9 million TEUs in terms of container throughput the same year. There was a good growth in the Registry and maintained the fifth largest ownership position by flag. Vessel arrival tonnage increased by 6.3% in 2016 and Singapore maintained its position as the top bunkering ports (Sohmen-Pao, 2017). Despite these sterling figures, currently there is no dedicated engineering programme in the area of marine technology at undergraduate level offered by the local institutes of higher learning (IHL) in Singapore.

Singapore Institute of Technology (SIT) established in 2009 by the Ministry of Education, Singapore (MoE) offering undergraduate degree programmes in partnership with various reputable oversea universities. SIT has brought some of the world’s top industry-focused degree programmes targeted at growth sectors of the economy to Singapore. With this backdrop, SIT invited School of Marine Science and Technology (MaST) to develop its first oversea campus in Singapore. Newcastle University (NU) is the most broad-based marine school in the United Kingdom (UK), with a substantial international reputation built up over more than a century. The School covers the fields of marine engineering, marine environmental engineering, marine science, naval architecture, offshore engineering, coastal management and small craft technology. The worldwide reputation and international spread of influential alumni enables Newcastle University to lead in the globalisation of higher education with a local institution in the region. According to Knight (2004), internationalization is changing the world of higher education, and globalization is changing the world of internationalization. Currently, SIT (2017) has an annual intake of 4,000 students primarily from the polytechnics in 2016 and several oversea universities have jointly provided this enrolment.

2. Successful Partnership

The local institute of higher learning plays an important role in a successful partnership. SIT provides classrooms, lecture theatres, libraries, sports, practical and computing facilities in supporting these programmes. The support of SIT to much-needed facilities has enhanced learning experience of students tremendously. On the other hand, there is an opportunity for teaching staff of SIT, a young and dynamic university, serving as adjunct members for an oversea university with much longer history and tradition. The local IHL under the partnership gains an insight of the operation, curriculum and international outlook of a reputable university in return.

Moreover, the local partner has a strong connection with the industry. There are ample training in job searching and opportunities for an interview prior to graduation. Professional guidance and support boost employment rate among graduates. Table 1 shows starting salary of SIT graduates which is comparable to other two well-established universities i.e. NUS and NTU. It clearly shows that the marine technology graduates are sought-after by the industry and there was almost a full employment among 2015 marine technology graduates. The marine and offshore industry benefits from a competent workforce benchmarked with international players. It also shows that the starting salary is comparable to engineering degree holders of other local IHL.

Table 1: Graduate Employment Survey of NUS/NTU/SIT in 2016

NUS: 2016 GES Employment Rates and Salaries of Graduates by Bachelor Degree (surveyed in November 2016)

Degree	Overall Employment Rate[2]	Full-Time Permanent Employment Rate[3]	Basic Monthly Salary[4]		Gross Monthly Salary[5]			
			Mean	Median	Mean	Median	25th Percentile	75th Percentile
Bachelor of Engineering (Mechanical Engineering)	86.6%	81.0%	$3,470	$3,300	$3,560	$3,400	$3,150	$3,800

NTU: 2016 GES Employment Rates and Salaries of Graduates by Bachelor Degree (surveyed in November 2016)

Degree	Overall Employment Rate[2]	Full-Time Permanent Employment Rate[3]	Basic Monthly Salary[4]		Gross Monthly Salary[5]			
			Mean	Median	Mean	Median	25th Percentile	75th Percentile
Mechanical Engineering	86.0%	79.9%	$3,417	$3,300	$3,505	$3,350	$3,050	$3,959

SIT: 2015 GES Employment Rates and Salaries of Graduates by Bachelor Degree (surveyed in Mar 2016, around six months after their final Examinations)

Degree	Overall Employment Rate[2] (%)	Full-Time Permanent Employment Rate[3] (%)	Basic Monthly Salary[4] ($)		Gross Monthly Salary[5] ($)			
			Mean	Median	Mean	Median	25th Percentile	75th Percentile
Bachelor of Engineering with Honours in Marine Engineering	91.7	91.7	3,180	3,025	3,354	3,225	3,050	3,500
Bachelor of Engineering with Honours in Mechanical Design & Manufacturing Engineering	90.5	83.3	3,069	3,050	3,266	3,200	3,000	3,500
Bachelor of Engineering with Honours in Naval Architecture	100.0	100.0	3,211	3,050	3,266	3,141	2,900	3,500
Bachelor of Engineering with Honours in Offshore Engineering	100.0	94.7	3,166	3,125	3,469	3,350	3,238	3,575

Source: Ministry of Education, Singapore (2016)

Graduates of marine technology programmes typically gain employment in ship design or offshore structures fabrication industry. Shipping and offshore companies also have high demand of graduate engineers as engineering specialists or managers in their workforce. On top of that, they have found jobs in classification societies, oil and gas companies, ship brokering and chartering companies, port authority as well as the Republic of Singapore Navy. In general, 25% of the engineering students in a cohort is company sponsored or holder of a scholarship. They are required to serve a bond of two to five years upon graduation. Table 2 shows the starting salary of a typical engineering diploma holder from local polytechnics. It clearly indicates that professional engineering degree command a higher starting remuneration.

Table 2: Graduate Employment of Five Polytechnics in Singapore

Course Category[4]	Gross Monthly Salary (SGD)					
	Fresh Graduates		Post-NS Graduates		Fresh and Post-NS Graduates	
	Mean	Median	Mean	Median	Mean	Median
Built Environment, Engineering & Maritime	$2,320	$2,200	$2,681	$2,550	$2,493	$2,300

Source: Survey Jointly Conducted by: Nanyang Polytechnic, Ngee Ann Polytechnic, Republic Polytechnic, Singapore Polytechnic & Republic Polytechnic (2016)

The partnership between an oversea and a local higher learning institution provides benefits to students in many facet. Members of faculty are leaders in marine technology and specialists in their own field. Newcastle University, in this case, provides permanent staff as well as flying faculty in delivering the curriculum. Members of academic staff have developed new pedagogy to match the learning styles of two different culture (Murphy & Tam, 2012 and Tam et al 2013). As engineering software is widely used in the design and development in the local marine industry, the same approach is required in terms of information technology supported training in the Singapore campus (Chin & Tam, 2012). Computing software and hardware of industry-standard fully deployed in training such as ship design, structural analysis and hydrodynamics analysis.

The local partnering institution also connects local industrial experts with students through regular seminars. This provide students with an insight of state-of-the-art technology trend through the module known as “Future Marine Projects”. Hence, students have opportunities to learn practical application from industry leaders after they grasp theoretical knowledge in the subject area from academic staff. It helps them in gathering information from various sources in supporting their group design project and independent research project.

3. Student Learning Experience

The Marine Technology Programmes offered by Newcastle University in Singapore is a seamless progression to a bachelor’s degree for qualified polytechnic graduates. Students with a relevant diploma gained an advanced standing for entry to the second year. These degree programmes are two years in duration with an option in Marine Engineering, Offshore Engineering and Naval Architecture. Students who successfully complete the programme in Singapore are awarded Bachelor of Engineering with Honours qualification of exactly same standard and quality as their counterparts in the UK. The degrees are accredited for professional recognition under the standards of the Engineer Council, UK through the Royal Institution of Naval Architects (RINA) and the Institute of Marine Engineering, Science and Technology (IMarEST).

Students are provided with identical curriculum, teaching materials as well as assessment as their UK counterparts though some modules are modified to adapt to local industry and practice. Students graduating with excellent results are eligible for postgraduate study at either Singapore or the UK campus. The total intake of students into the degree programmes is around 80 students per annum. The students at the Singapore campus are predominantly Singaporean citizens and permanent residents. The performance of students tracked and compared with their counterparts in the UK shows sterling results as indicated in Table 3. Newcastle University benefits from a ready pool of selected polytechnic graduates of high calibre to its academic courses.

Table 3: Performance of UK and Singapore Students in AY2015-2016

	Home Campus (Cohort of 37 number)	Oversea Campus (Cohort of 67 number)
First Class (>=70%)	37%	42%
Upper Second (>=60% and <70%)	27%	40%
Lower Second (>=50% and <60%)	35%	13%
Third Class and below (<50%)	5%	4%

Source: Internal Report, School of Marine Science & Technology, Newcastle University (2016)

All students are required to attend an overseas immersion programme (OIP) of four weeks in the month of July during their term break. The programme aims to provide them with greater learning experience at their alma mater. It includes lectures, hands-on project work, workshops and industry visits. Students will interact with members of staff and mentors while they gain an experience of life abroad. Students have to develop competence working with a team and an ability working independently as well. Time management is vital in their skill set in order to successfully cope with the given course assignment and heavy workload.

Teaching curriculum and design projects usually involve elements of research project outcome. The "research-led teaching" style learning offers stimulus to their interest in the subject area and further in-depth independent study. Newcastle University is a member of the Russell Group of 24 leading UK research universities. Research feeds into the degree programmes at all levels, for example, individual degree specialism, specific modules at Stage 3 as well as individual and/or group research projects. The School is currently responding in three recognised areas of sustainability, hence, a) environmental – monitoring, modelling, prediction; b) economic – financially viable engineering and bio-system solutions; c) societal – policy, planning and governance. These research areas will be of interest to the host country in this partnership as well. The interaction with research students and their presentation during the OIP will provide them with first-hand experience of various R&D projects. The project exhibits in the School also provide them with new ideas and an impetus in preparing their final year project upon their return to Singapore.

4. Challenges and Opportunities

One of the main challenges at the local campus is the lack of diversity among students. They have a very homogeneous background from local polytechnics. This is very different from the UK campus where students share the experience of a cohort usually composed of multi-national and multi-cultural background. Contrasting experience and perspective allows creative ideas and solution to problems flourish through discussion and disagreement. The outcome is that local students perform well in modules with facts and mathematical evaluation while UK students excel in design and project work.

Another challenge facing members of staff is the lack of research facility in the local campus. This poses constraint and an over reliance in the use of computing software and simulation. Nevertheless, this creates an opportunity for collaborative research work and joint postgraduate supervision among the staff members between the two campuses. The university has recently established a "Newcastle-Singapore Studentship" to motivate research scholars connect together during their course of study. The successful collaboration will provide a model of multidisciplinary investigation and integration of research projects between the two campuses.

Singapore being a maritime hub, offers plenty opportunities in tie-up, consultancy projects and government funding. However, Newcastle University, a non-local IHL is unable to tap into the public research funding agencies such as Economic Development Board, Maritime Port Authority or the Singapore Maritime Institute directly. The partnership with local IHL provides an opportunity to showcase their technical expertise and verify their research findings once a team with the IHL or industry is formed.

5. Conclusions

The world-wide reputation and international spread of influential alumni enables Newcastle University to lead in the globalisation of higher education with a local institution in the region. It shows that partnership between an oversea and a local IHL brings quality maritime education to local students. The degree programmes in this partnership equip students with all the necessary skills to become a professional marine and offshore engineer or else naval architect.

The local IHL under the partnership gains an insight of the operation, curriculum and international outlook of a reputable university while oversea university benefits from a ready pool of selected polytechnic graduates of high caliber to its academic courses.

Students experience an interactive learning environment that is similar to the UK-based campus. Academic members of staff provide students with timely feedback on projects, coursework, laboratory reports, communication skills and examinations. Teaching is kept up-to-date by the research discoveries of staff and the work of research centres within the School with internationally recognised expertise. This direct link between teaching and research translates into enthusiastic teaching by people who are passionate about their subject and leaders in their field.

Marine students graduate with an accredited degree recognised as meeting standards set by the profession. These degree programmes, accredited by the Institute of Marine Engineering, Science and Technology (IMarEST), and the Royal Institution of Naval Architects (RINA), allow them the fastest route to becoming a professional engineer.

The international partnership between NU and SIT is uniquely placed to contribute to education in marine and offshore technology in the 21st century. The strong international-local collaborative network has enabled this partnership to accelerate the regional resurgence in the marine education sector.

The maritime industry is provided with a competent workforce benchmarked with international players. Furthermore, the economic rewards generated at national level will be obvious in the years to come.

References

Chin, C and Tam, I (2012), Online rubric assessment tool for marine engineering course, International Conference on Learning and Community Enrichment (ICOLACE2012).

Knight, Jane (2004), Internationalization remodelled: rationalization, approaches and rationales, Journal of Studies in International Education 8:5.

Murphy, A.J. and Tam, I.C.K. (2012), Staff exchange teaching model for an offshore campus, IEEE International Conference on Teaching, Assessment and Learning for Engineering (TALE).

Sohmen-Pao, A (2017), Reception Speech, Singapore Maritime Foundation.

Tam, I.C.K., Tin, A.W. and Wong, P.P. (2013), A new paradigm of collaboration in maritime teaching and learning, Education and Professional Development of Engineers in the Maritime Industry, The Royal Institution of Naval Architects.

Tan, A. (2015), Singapore Maritime Services Guide, Singapore Maritime Foundation.

Singapore Institute Technology website: https://www.singaporetech.edu.sg/who-we-are, last accessed in March 2017app.

MOE website: https://www.moe.gov.sg/docs/default-source/document/education/post-secondary/files/ntu.pdf.

MOE website: https://www.moe.gov.sg/docs/default-source/document/education/post-secondary/files/nus.pdf.

MOE website: https://www.moe.gov.sg/docs/default-source/document/education/post-secondary/files/sit.pdf.

MOE website: http://www.polyges.sg/downloads/GES2016PR.pdf.

The Dynamic Berth Allocation Problem with Ship Emissions Consideration

Jue Hou[1] and Dong Yang[2]

[1]China Waterborne Transport Research Institute, Ministry of Transport of the People's Republic of China, Haidian District, Beijing, China. Email: houjue@wti.ac.cn
[2]Faculty of Business, Department of Logistics and Maritime Studies, The Hong Kong Polytechnic University, Hung Hom, Kowloon, Hong Kong. Email: dong.yang@polyu.edu.hk

Abstract

The establishment of the Emission Control Areas (ECAs) in China proposes a higher request for the development of equivalent measures to reduce ship emissions including exhaust gas scrubbing, marine gas oil and shore power. Among the measures of solving ship emissions in berthing, the shore power is very important, but port equipped shore power is still in a low proportion. How to supply power to ships with the shore power more efficiency, while to minimize not only the total service time, but also the emissions during ship mooring period, which is become an urgent need to study under the ECAs in China. In view of the practice, this paper firstly presents an optimal dynamic berth allocation problem with ship emissions consideration (EDBAP) based on an application of shore power, preferred emissions and service level considerations. A mixed integer non-linear programming (MINLP) model is developed for the problem, and considers two strategies: the DBAP with discrete (DBAPD) and continuous (DBAPC) berthing space, a mixed integer non-linear programming (MINLP) model is developed for the problem. Heuristic algorithm method is developed and the numerical results show that the DBAP model with emission consideration in discrete and continuous berthing space, which can reduce the ship air pollution emissions in berthing, and maintain service levels, which allows the terminal operator to be more flexible in their decision to meet the ECAs regulation.

Keywords: Ports, Berth allocation problem, Shore power, Emission control area, Heuristic algorithm

1. Introduction

Ship exhaust emissions are attracting growing attention in China, the port throughput continues to expand increase over the last decades, ship as the major emission sources that also will continue to increase. China has established the three Emission Control Areas in 2015, as shown in Figure 1, they have been created to reduce the levels of ship-generated air pollution and mainly focus on the sulphur content of fuels.

Figure 1: Emission Control Areas in China

The regulations of ECAs in China as shown in Table 1. Below these will find a summary of the ECAs, ports, and the dates upon which the various requirements become mandatory:

Table 1: Ports of Emission Control Areas in China

Emission Control Area	Ports	In Force	Sulphur Limit	Application
Yangtze River Delta	Shanghai	01/04/16	<0.5%	All ships, changeover to low sulphur fuel 1 hour after berthing to 1 hour before departure or shore power.
	Ningbo-Zhoushan			
	Nantong			
	Suzhou			
	Nantong			
Pearl River Delta	Shenzhen	01/10/16	<0.5%	All ships, changeover to low sulphur fuel 1 hour after berthing to 1 hour before departure or shore power.
	Yantian			
	Shekou			
	Chiwan			
	Mawan			
	Dachan Bay			
Key ports in Pearl River Delta, Yangtze River Delta and Bohai Sea	Guangzhou	01/01/17	<0.5%	All ships, changeover to low sulphur fuel 1 hour after berthing to 1hour before departure or shore power.
	Shenzhen			
	Zhuhai			
	Tianjin			
	Qinhuangdao			
	Huanghua			
	Tangshan			
	Shanghai			
	Ningbo-Zhoushan			
	Nantong			
	Suzhou			
All ports in Pearl River Delta, Yangtze River Delta and Bohai Sea	All ports	01/01/18	<0.5%	All ships, changeover to low sulphur prior or shore power to the ship berthing
All ports in Pearl River Delta, Yangtze River Delta and Bohai Sea	All ports	01/01/19	<0.5%	All ships, changeover to low sulphur prior to enter any ECA or shore power in berthing

Source: http://www.nepia.com/insights/industry-news/china-emission-control-areas-starupdatestar/ (2016)

At a date which has yet to be advised after 31 December 2019 there will be an assessment made by the Chinese government to decide whether to adopt one or more of the following: sulphur limit to 0.1% of ships enter to the emission control areas, expand the geographical size of the emission control areas and so on.

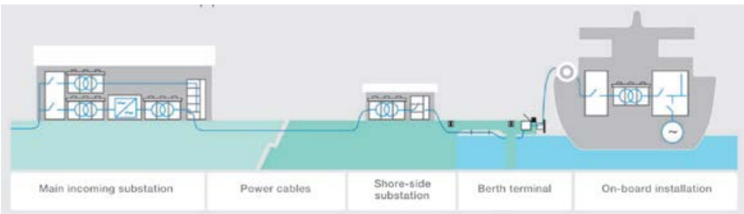


Figure 2: Overview of a shore power connection for ship
Source: ABB Corporation

Operation of ship auxiliary engines, make up a major portion of port air-pollutants. The shore power is an effective solution to substantially reduces air-pollutant emissions in port area. Due to the electric system does not match between port and ship in China (50Hz power system in port and 60Hz power system in ships), the shore power need different components, as shown in Figure 2, including main incoming substation, power cables, shore-side substation (include frequency converter, which could transfer power from 50Hz to 60Hz), berth terminal and ship on-board installation. The system allows ships to plug into the shore power supply and shut down their auxiliary engines while in mooring period. The ship´s power load is seamlessly transferred to the shore power without disruption to on-board services.

Port operators and ship owners face massive environmental protection challenges resulting from a ECAs in China ports. Port need to construct more shore power to meet the growing power demand of ship in mooring period. The shore power construction is a big investment project (0.5-3 million USD), on account of which, port equipped shore power is still in a low proportion. How to supply power to ships with the shore power more efficiency, considering the berth allocation problem (BAP) strategy, to minimize not only the total service time that includes handling time and waiting time, but also the emissions in ship mooring period, which is become an urgent need to study and solve problems under the ECAs in China.

With this coordination between the port service level and emissions in mind, this study adopts a new dynamic berth allocation (DBAP) model with emission consideration, with discrete and continuous berthing space, and focus on the ship of mooring period, formulates the new DBAP as a mixed integer nonlinear programming (MINLP) model. Based on the analysis of fuel consumption, we conduct the ship emission analysis on SO_X, NO_X and PM of ship in mooring periods, with the help of fuel emission factors. Additionally, ship emissions in terminal with shore power, when ships are anchored in the port, are also evaluated. For the new DBAP, this study firstly conducts a direct quantitative analysis on ship emissions with the application of the shore power. The remainder of this paper is organized as follows: first, we introduce the regulations of Emission Control Areas of China, then we review the literature closely related to this study, and take into account the emissions consideration with the DBAP model, with discrete and continuous berth allocation problem. Finally, the numerical results show that the DBAP model with emission consideration in discrete and continuous berthing space, which can reduce the ship air pollution emissions in berthing, and maintain service levels.

2. Literature Review

Berth allocation problem mainly divided into two categories: (a) static and dynamic ship arrivals, and (b) the discrete and continuous ship berthing space of quay shoreline. The static BAP (Li et al., 1998), all the ships to be serviced have already been in anchorage. The dynamic BAP (Imai et al., 2001), ships arrive berth and be serviced in succession dynamically.

The discrete BAP (BAPD) (Brown et al., 1994; Imai et al., 2001, 2003, 2005, 2007) divides the quay into a several berths, while the continuous BAP (BAPC) (Kim and Moon, 2003; Li et al., 1998; Lim, 1998) considers ship can be berthed at any position in the quay shoreline. For a detailed review of recent research on the BAP, we refer the readers to Bierwirth and Meisel (2010). The studies mentioned above always aim to improve the efficiency of seaside operations, by optimizing some of the desired objectives, such as ship departure delays, ship waiting time and the makes pan of the berth plan. However, little literature on BAP, with fuel consumption and emission considerations, can be found. From the business background described in the first section, we can see a considerable gap between academic studies and the practice of maritime transportation. Golias et al. (2009) regard the arrival times of ships as decision variables instead of previously-known parameters when formulating the BAP. They try to reduce fuel consumption and ship emissions by minimizing the total waiting time of ships, based on the assumption that the shorter the waiting time is, the less the fuel consumption and ship emissions. This analysis method, however, is indirectly biased towards fuel consumption and ship emissions. And they aim only to reduce the emissions produced when the ships moor in the port. As a matter of fact, the emissions for sailing are more prominent than those for mooring periods (Schrooten et al., 2008), and, therefore, should be given much more concern.

Lang and Veenstra (2010) also consider the arrival times of ships as decision variables and minimize the fuel consumption for sailing with a customized simulation tool. Their study provides a direct quantitative analysis on fuel consumption, for the first time, and elucidates that introducing the arrival times as decision variables into the model of the BAP could provide a potential coordination opportunity between terminal operators and shipping lines, which will result in fuel consumption savings in sailing periods. This basic idea is also adopted in our study. However, their study cannot handle the nonlinear function between the fuel consumption rate and the sailing speed. They just simplify the nonlinearity by linear regression. This has been noticed by the authors, and the correction has been regarded as an issue for further research. Additionally, emission analysis is absent in their study.

Alvarez et al. (2010) study the hybrid optimization problem on berth allocation and speed control, and develop a discrete event simulation tool primarily consisting of two components: (a) a discrete-event scheduler, which simulates the interaction between the ship operators and the terminal planner; and (b) a mixed-integer optimization routine, which simulates the logic of the terminal planner that finds feasible seaside operation plans. The case study shows the competence of the new berth allocation policy in both fuel savings and terminal productivity. They bypass the nonlinearity originating from the consideration of fuel consumption, by discretizing the feasible domain of the sailing speed. This discretization method may lose the calculation accuracy. Moreover, emission analysis is also absent in their study.

3. Problem Description

Terminal planner gives the order to assign a berth for each ship, which to make the ship handle and depart as sooner as possible, in order to decrease the cost and time for both of terminal and ship owner. As the literature review mentioned, the BAP includes two versions in ship arrival characteristic, the static berth allocation problem (SBAP) Imai et al., (2001), assume all ships are waiting in anchorage, then port operator make berth allocation strategy, and the dynamic berth allocation problem (DBAP) Imai et al., (2003), which considers arrival time of ships is known or in line schedule.

In the literatures, the DBAP is categorized into discrete and continuous problems, referred to as the discrete BAP (BAPD) and the continuous BAP (BAPC). In the dynamic BAPD (DBAPD), the quay length is partitioned into several berths, and the allocation of ships to the quayside is based on discrete berths. However, in the dynamic BAPC (DBAPC), ships can use all points along the quay to berth (in some major container ports, ship berthing is actually performed in a continuous location space)

3.1. Discrete Berth allocation problem model

Figure 3 is the berth allocation in the wharf-time space Du et al., (2011), to explain the BAP. The horizontal axis represents the berth number, while the vertical axis represents the handling time of ships. Each rectangle represents ship arrived in port, the height of a rectangle is handling time of the corresponding ship, the length of a rectangle is the ship length, each rectangle represents a ship to be serviced in one berth.

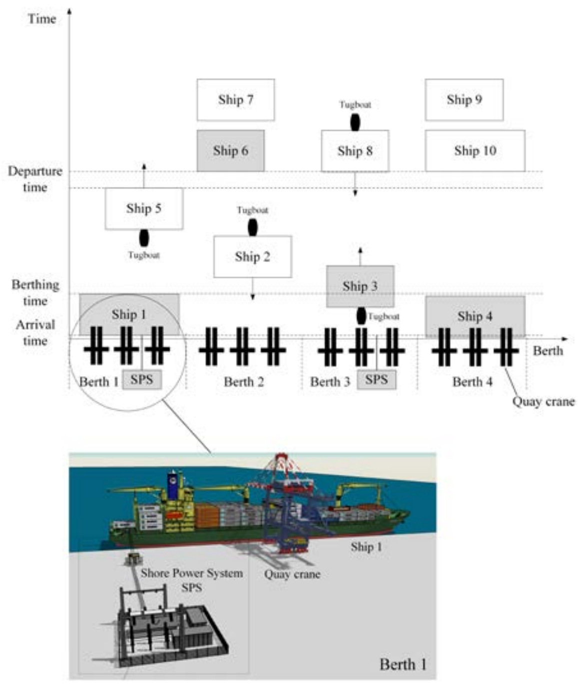


Figure 3: An example of discrete berth allocation with emission consideration (Time-space diagram)

Under the ECAs regulation, port planner seeks to reduce ship emissions for mooring period, without lowering the service level, by reducing ship waiting time and depart time as much as possible in the berth plan. This study develops a model for the DBAP with emission consideration. Considering the berth which equipped shore power, as shown in circle of Figure 3, grey rectangle represents the ship with on-board shore power installation. The SPS represents the shore power system, each SPS could supply power to one berth/ship.

For simplicity in the solution procedure, we make the following assumptions in our EDBAP model with discrete berthing space. All these assumptions are from observing the real-life practice. First, assume no water depth and ships size restrictions. Furthermore, the ship capacity decides its handling time in berth. The third assumption is shore power can supply each ship equipped on-board installing shore power, and ignore manipulation time of the shore power access to ship. According to the ECA regulation, when the ship without on-board shore power installing in berthing period, they need to take the 0.5% sulphur MGO fuel.

The goal of this paper is to propose an algorithm for solving the EDBAPD as follows:

$$\min\ f_1 = \sum_{i\in B}\sum_{j\in V}\sum_{k\in U}\left\{(T-k+1)C_{ij} + S_i - A_i\right\} x_{ijk}\alpha_j w_1 + \sum_{i\in B}\sum_{j\in V}\sum_{k\in U}(T-k+1)y_{ijk}\alpha_j w_1 + \sum_{i\in B}\sum_{j\in V}\sum_{k\in U}\left\{(T-k+1)C_{ij} - A_i\right\} e_{ijk} w_2 \qquad (1)$$

subject to:

$$\alpha_j = \frac{W_j - W_{\min}}{W_{\max} - W_{\min}} \qquad (2)$$

$$\sum_{i\in B}\sum_{k\in U} x_{ijk} = 1,\ \forall j \in V \qquad (3)$$

$$\sum_{j\in V} x_{ijk}^{k} \le 1,\ \forall i \in B,\ k \in U \qquad (4)$$

$$\sum_{i\in V}\sum_{m\in P_k}\left(C_{il}x_{ilm} + y_{ilm}\right) + y_{ijk} - \left(A_j - S_i\right)x_{ijk} \ge 0 \qquad \forall i \in B, j \in W, k \in U \qquad (5)$$

$$x_{ijk} \in \{0,1\} \qquad \forall i \in B, j \in V, k \in U \qquad (6)$$

$$y_{ijk} \ge 0 \qquad \forall i \in B, j \in V, k \in U \qquad (7)$$

The objective function (1) minimize the total service time (waiting and delayed departure time) and emissions for all vessels in discrete quay shoreline. Where T the arrival time of ships, $T \in$ ¥ ; k the set of service orders; C_{ij} the handling time spent by ship at berth i; S_i the time when berth location i becomes idle for the planning horizon, $S \in$ ¥ ; A_i the arrival time of ship j; x_{ijk} ship j is serviced as the kth ship at berth i; y_{ijk} the idle time of berth i between the departure of the (k-1)th ship and the arrival of the kth ship when ship j is serviced as the kth ship; i is set of berth; V, the set of ships, $V \in$ ¥ ; B the set of berths; e_{ijk} the emission of berth location i with each ship j, k the set of service orders, w_1 the weight of total service time, w_2 the weight of total emission, $w_1 + w_2 = 1$.

3.2. Continuous Berth allocation problem model

Considering the continuous quay shoreline which equipped shore power, as shown in Figure 4, grey rectangle represents the ship with on-board shore power installation. The quay as a continuous line that multiple ships can share with each other at the same time. Thus, when the quay is considered as a continuous line, more ships can be served simultaneously at a quay instead of individual berth. Each SPS could supply power to one ship, which berths in short than 300m or longer than 900m in quay shoreline.

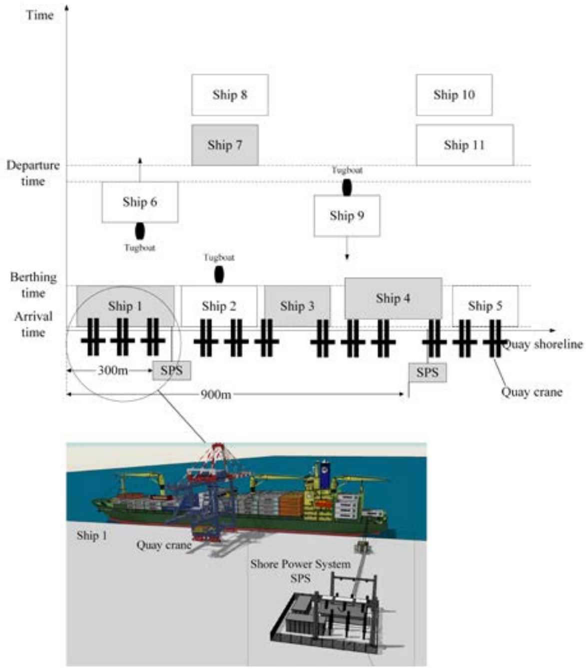


Figure 4: An example of continuous berth allocation with emission consideration (Time-space diagram)

The following assumptions are made for the continuous berthing space in EDBAP (EDBAPC) with dynamic arrivals dealt with in this paper. First, assume quay shoreline is continuous, and no water depth restrictions. Furthermore, in the berth operation, the ship and the ship cannot be directly contacted, there must be a safe distance between the distance and the length of the ship. The third assumption is shore power installed in quay shoreline can supply each ship equipped on-board installing shore power, and ignore manipulation time of the shore power access to ship. According to the ECA regulation, when the ship without on-board shore power installing in berthing period, they need to take the 0.5% sulphur MGO fuel.

The goal of this paper is to propose an algorithm for solving the EDBAPC as follows:

$$\min\ f_2 = \sum_{i\in B}\sum_{j\in V}\sum_{k\in U}\left\{(T-k+1)C_{ij}+S_i-A_i\right\} x_{ijk}\alpha_j w_1 + \sum_{i\in B}\sum_{j\in V}\sum_{k\in U}(T-k+1)y_{ijk}\alpha_j w_1 + \sum_{i\in B}\sum_{j\in V}\sum_{k\in U}\left\{(T-k+1)C_{ij}-A_i\right\}e_{ijk}w_2 \qquad (8)$$

subject to:

$$\alpha_j = \frac{W_j - W_{\min}}{W_{\max} - W_{\min}} \qquad (9)$$

$$\sum_{i\in B}\sum_{k\in U} x_{ijk} = 1,\ \forall j\in V \qquad (10)$$

$$\sum_{j\in V} x_{ijk}^{k} \le 1,\ \forall i\in B,\ k\in U \qquad (11)$$

$$\sum_{i\in V}\sum_{m\in P_k}\left(C_{il}x_{ilm}+y_{ilm}\right)+y_{ijk}-\left(A_j-S_i\right)x_{ijk}\ge 0 \qquad \forall i\in B, j\in W, k\in U \qquad (12)$$

$$b_j + b_i + l_i - \left(m_{ij}-1\right)\cdot L \ge 1 \qquad \forall i,j\in ¥, i\ne j \qquad (13)$$

$$m_{ij}+m_{ji}+n_{ij}+n_{ji}\ge 1 \qquad \forall i,j\in ¥, i\ne j \qquad (14)$$

$$m_{ij}+m_{ji}\le 1 \qquad \forall i,j\in ¥, i\ne j \qquad (15)$$

$$n_{ij} + n_{ji} \le 1 \qquad \forall i, j \in ¥, i \ne j \tag{16}$$

$$x_{ijk} \in \{0,1\} \qquad \forall i \in B, j \in V, k \in U \tag{17}$$

$$y_{ijk} \ge 0 \qquad \forall i \in B, j \in V, k \in U \tag{18}$$

$$P_{ij} \in \{0,1\} \qquad \forall i \in B, j \in V, k \in U \tag{19}$$

$$B_{ij} \in \{0,1\} \qquad \forall i \in B, j \in V, k \in U \tag{20}$$

The objective function (8) minimize the total service time (waiting and delayed departure time) and emissions for all vessels in continuous quay shoreline. Eq.13 to Eq.16 ensure no overlap between the ships. *b* the ship berth position, *l* the length of ship, *L* the length of quay shoreline, m_{ij}=1 the berthing ship *i* left the pre-ship *j* in time-space diagram, otherwise, m_{ij}=0. n_{ij}=1 the berthing ship *i* below the pre-ship *j* in time-space diagram, otherwise, n_{ij}=0.

4. Emission Model

In the last decade years, with China's domestic and foreign trade continues to expand, the throughput of Chinese ports substantial increase, meanwhile, air-pollution increases fast in port area and which is increasingly valued, especially the auxiliary engine produces large quantities of air-pollutions in ship mooring period. Now we first discuss the relationship between the fuel consumption and the auxiliary machine power.

$$\text{ship emissions} = \text{fuel consumption} \times \text{emission factor} \tag{21}$$

This study calculates the NO_X, SO_X and PM emissions by individual container ships at berth. The fuel consumption of a container ship by considering the amount of fuel required for the auxiliary engines. We use a modified version equation of Corbett et al., (2009) to calculate emissions of ships:

$$F_{ijx} = \left[MF_x \cdot \left(\frac{s_{1x}}{s_{0x}} \right)^3 \cdot \left(\frac{d_{ij}}{24 s_{1x}} \right) + AF_x \cdot \left(\frac{t}{24 s_{1x}} \right) \right] \tag{22}$$

F_{ijx} the fuel consumption of ship *x* from point *i* to *j*; MF_x the main engine fuel consumption of ship *x*, g/kWh; s_{1x} the speed of ship *x*, nm/h; s_{0k} the design speed of ship *x*, nm/h; AF_x the auxiliary engine fuel consumption of ship *x*, g/kWh; d_{ij} the ship movement distance from point *i* to *j*; *t* the time duration in mooring, min. During the mooring period of ships, which shut down main engine, and auxiliary engine is still working to supply power, then MF_x=0, d_{ij}=0 and s_{1x}=0, Eq.22 be written as Eq.23:

$$F_x = AF_x \cdot t \tag{23}$$

Where F_x is the amount of fuel consumed by ship *x* in mooring period, AF_x is determined by the power of the ship, fuel consumption rates (g/kWh), and engine load factors. Using assumptions from Wang et al. (2007), we assume the 4-stroke auxiliary engine (AF_x) of container ship fuel consumption rate to be 221g/kWh, and average auxiliary engine load factor of 0.5 in mooring period. F_x multiply emission factors to calculate the ship *x* emissions as:

$$E_{x,m} = \sum_m \left(F_x \times EF_m \right) \tag{24}$$

Where $E_{x,m}$ the emissions *m*(kg) of ship *x*, *EF* the emission factor; *m*, the pollutant (*m*=1,NO_X; *m*=2, SO_2 and *m*=3, PM). In this study, due to the absence of measurement equipment of emission factors installed in container ships, we adopt the emissions factors in Table 2, which are widely used in reference studies.

Table 2: Emission factors for "in port" operation regarding container ship adopted by this paper

Sulphur	Emission	Emission factor (g/kg-fuel)
1.5%	CO_2	3179
	NO_X	62
	SO_X	30
	PM	4.2
0.5%	CO_2	3179
	NO_X	64.8
	SO_X	15.9
	PM	4.5
0.1%	CO_2	3179
	NO_X	64
	SO_X	2.0
	PM	2.6

Following the regulation of ECA of China, this study adapts the mission factor of 0.5% sulphur MGO fuel in the next empirical experiment.

5. Solution Procedure

The EDBAP with model described in this study, in which emission is considered, is known to be NP-hard problem Imai et al. (2013), and cannot be solved to optimality with analytical methods, even for small instances. One way to solve the problem is to construct heuristic algorithm to get the feasible solution as close as possible to the optimal solution. A basic genetic algorithms (GA)-based heuristic is developed, furthermore, in order to compare the performance of the GA, niching genetic algorithm (NGA) is developed in our study.

5.1. Genetic Algorithm

One solution procedures for the EDBAP, is implemented using the Genetic Algorithm (GA). Therefore, the three procedures are basically the same (selection, crossover and mutation), before describing how to allocate ships at a berth, we outline the GA framework, is based on the following steps, depicted in Figure 5:

a) Initialize the population by randomly selecting a set of *m* individuals (i.e. a set of ships arrival time, volume, whether has on-board shore power installation).
b) By applying the GA operators, generate a new population.
c) Compute the objective function to evaluate the fitness of each individual, select the best individuals of the population.
d) Return to step (b) or stop, if reach the fixed number of iterations.

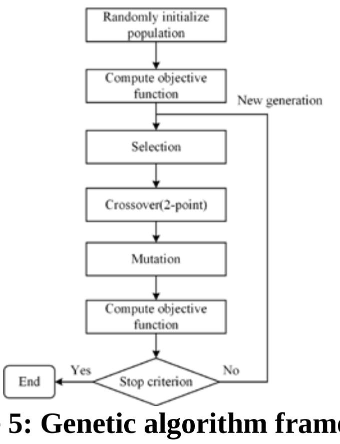


Figure 5: Genetic algorithm framework

Based on the paper of Imai et al. (2013) that developed the GA, we employ a string represent the numbers of ship and berth. For a typical BAP problem, Figure 6 shows a ship 8, 7, 3 and 5 be serviced in berth 1, ships 9, 2, and 4 be serviced in berth 2, ships 10, 1 and 8 be serviced in berth 3, each berth separated by 0. The GA's application for EDBAP only needs a small computational memory space to be used without any significant loss in solution quality.

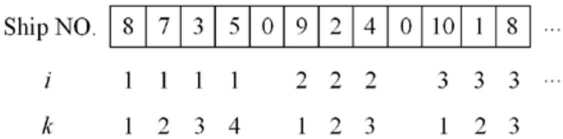


Figure 6: Randomly generated solutions

Goldberg and Lingle (1985) introduce the crossover operator which called partial-mapped crossover (2-point crossover), to order to reproduced chromosomes constitute a new population.

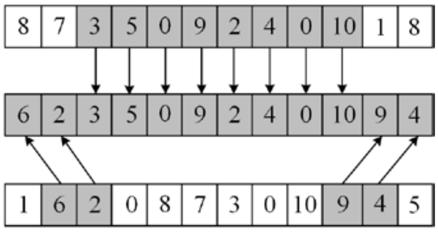


Figure 7: An illustration of the crossover

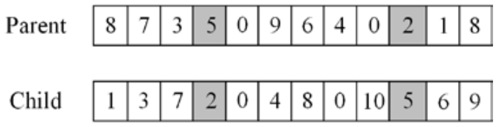


Figure 8: An illustration of the mutation

The sigmoid function as defined in Eq.25, which was found to be better where *y(x)* denotes the objective function value, *f(x)* has a value ranging from 0 to 0.5. The *f(x)* could be defined as the reciprocal of the objective function.

$$f(x) = 1/\left(1+\exp\left(y(x)/100{,}000\right)\right) \tag{25}$$

5.2. Niching Genetic Algorithm

Niching Genetic Algorithm (NGA) minimize the effect of genetic drift, which is resulting from the selection operator in GA S.W.Mahfoud (1995). For each niche, the physical resources are finite and must be shared among the population of that niche, species in a niche, are defined as a collection with similar features. A niche is defined to as an optimum of the domain, the resources of niche *i* are represented by the fitness f_i. The shared fitness $f_i^{'}$ of an individual f_i with fitness is simply:

$$f_i^{'} = f_i / \sum_{j=1}^{N} sh\left(d_{ij}\right) \tag{26}$$

$$sh\left(d_{ij}\right) = \begin{cases} 1-\left(d_{ij}/\sigma_s\right)^{\alpha} & \text{if } d_{ij} < \sigma_s \\ 0 & \text{otherwise} \end{cases} \tag{27}$$

where *N* the population size, d_{ij} the distance between the individual *i* and *j*, *sh* the sharing function, which to measure the similarity level between two populations, σ_s the a threshold which is distance cut off or the niche radius, α□ a constant parameter to regulate the shape of *sh*, α=1 in this study.

6. Numerical Results

In this section, we perform a computational study on a number of ships arrival data in ten days, from an international container terminal in the Yangtze River Delta ECA, in order to evaluate possible impacts on environmental, and service level, from the ECA regulations. The quay length L=1200m, set 4 container berths (in discrete berth strategy), each berth has 4 quay crane which's average operating efficiency is 1 TEU/min, two berths with shore power (berth 1 and berth 3 in DBAPD strategy, as shown in Figure 3), and two suits of shore power located short than 300m or longer than 900m in quay shoreline in DBAPC strategy, as shown in Figure 4) equip shore power system. The container terminal to the information data of 10 days in 2015, 28 calling ships are serviced with various handling volumes as an example, the specific data see Table 3.

Table 3: Calling ship data in a container terminal

Ship Numbs	Length (m)	Volume (TEU)	Arrival Time (day/h:m)	Auxiliary engine (kW×Numbers)	On-board shore power
Ship 1	293	5623	01/03:20	2320×4	Yes
Ship 2	241	2354	01/09:31	1260×3	No
Ship 3	293	5442	02/17:45	1960×3	No
Ship 4	320	6325	02/20:05	2320×4	Yes
Ship 5	293	4531	02/20:39	1960×3	No
Ship 6	241	2415	03/21:42	1260×3	No
Ship 7	241	2158	03/23:01	1260×3	Yes
Ship 8	320	6545	03/11:50	2320×4	No
Ship 9	293	5642	04/18:07	1960×3	No
Ship 10	293	5785	04/20:02	2320×4	No
Ship 11	293	4573	05/02:45	1960×3	No
Ship 12	183	1354	05/10:19	700×3	No
Ship 13	350	7562	05/12:42	2760×4	Yes
Ship 14	241	3350	05/20:05	1260×3	No
Ship 15	293	4545	06/07:27	1960×3	Yes
Ship 16	241	3453	07/13:11	1260×3	No
Ship 17	350	7650	07/17:42	2760×4	No
Ship 18	375	7838	07/20:05	2760×4	Yes
Ship 19	241	3216	07/20:50	1260×3	No
Ship 20	320	6542	08/03:24	2320×4	No
Ship 21	293	4556	08/11:29	1960×3	Yes
Ship 22	293	4320	09/20:37	1960×3	No
Ship 23	241	2231	10/09:12	1260×3	Yes
Ship 24	293	5423	10/13:42	1960×3	No
Ship 25	241	2374	11/08:07	1260×3	No
Ship 26	293	4523	11/14:26	1960×3	Yes
Ship 27	293	5652	11/17:30	2320×4	No
Ship 28	293	5681	11/20:05	2320×4	Yes

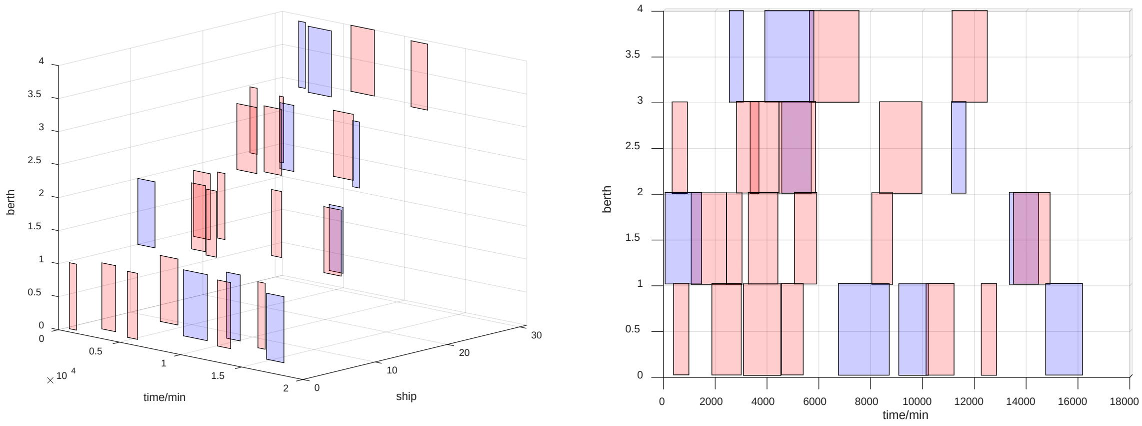
Numerical experiments are conducted to evaluate the performance of the proposed discrete and continuous EDBAP model. The optimization model concerned is formulated by MATLAB 2015a, and run on a personal computer with Intel Core i7 4.00 GHz CPU and 16 GB RAM with a Microsoft Windows 10 operating system.

The number of GA generations is 300, mutation rate is 0.10, population size is 50. The solution times for all test problems were minimal (<20 s). We take 20 times loop calculation to find the best solution in the sets of the experiment. In order to assess the performance of the EDBAP, we use three scenarios adopted: scenario 1, ships take the minimizing the waiting time during the mooring period, scenario 2, ships take the minimizing the emission during the mooring period, scenario 3, ships take the minimizing the waiting time and emissions during the mooring period.

6.1. DBAPD Strategy

6.1.1. Scenario 1

Figure 9 shows using the Eq.1, the result by terminal operator takes the DBAP strategy of berth allocation taking by genetic algorithm. The length of a rectangle is handling time of the corresponding ship, left of rectangle is arrival time, right of rectangle is departure time. Each rectangle represents a ship to be serviced in one berth, red rectangle represents the ship without shore power on-board installation, blue rectangle represents the ship with shore power on-board installation, overlapped rectangles represent delay event. Only in berth 1 or berth 3, ship with shore power on-board installation can be supplied power form the shore power.



(a) Three-dimensional perspective of DBAPD (berth-time-ship)

(b) Two-dimensional perspective of DBAPD (berth-time)

Figure 9: Perspectives of DBAPD in Scenario 1

From Table 4, we can see the empirical test result, all the ships total waiting time is 2356.68 min, only five ships delay, the DBAP is competent to guarantee the integrity of shipping schedules and make high service level. Ships emits 8986.03 kg of NOx, 1551 kg of SOx and 624.05 kg of PM in mooring period. Due to the DBAP only minimize the total waiting time of all ships, ship 1 and ship 26 which have on-board shore power installation, are allocated to berth 2. Meanwhile, ship 7 and ship 13 are assigned to the berth 4. The DBAP ignores the emission of these ship which could has no emission in mooring period if there are assign to berth 1 or berth 3. The sum of emissions of above 4 ships reach 22.63% of total emissions.

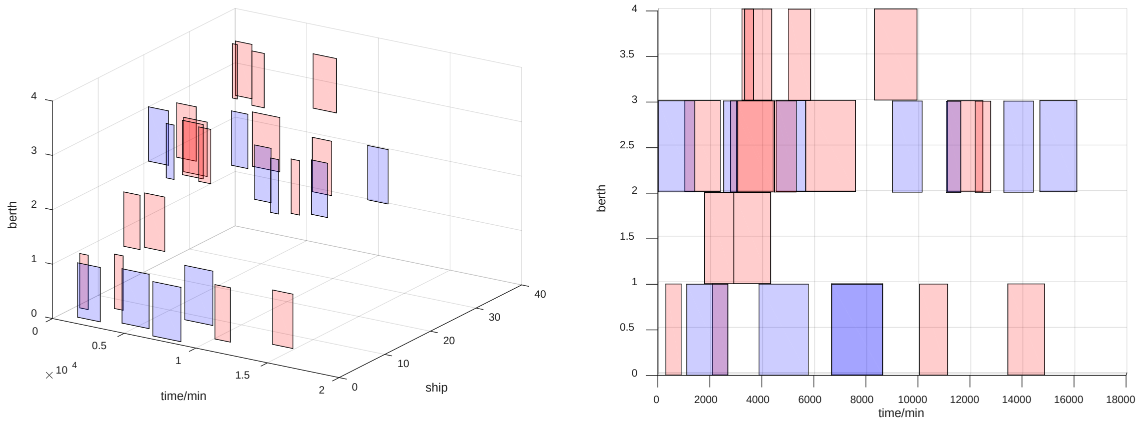
Table 4: Empirical test result of DBAPD in Scenario 1

Berth NO.	Ship NO.	On-board shore power	Waiting time/min	NO_X/kg	SO_X/kg	PM/kg
Berth 1 with shore power	Ship 2	No	0	106.19	26.06	7.37
	Ship 5	No	0	317.95	78.02	22.08
	Ship 10	No	0	640.67	157.20	44.49
	Ship 14	No	0	151.12	37.08	10.49
	Ship 18	Yes	0	0.00	0.00	0.00
	Ship 21	Yes	0	0.00	0.00	0.00
	Ship 22	No	0	303.14	74.38	21.05
	Ship 25	No	0	107.09	26.28	7.44
	Ship 28	Yes	0	0.00	0.00	0.00
Berth 2	Ship 1	Yes	0	622.73	152.80	43.25
	Ship 3	No	291.50	381.88	93.70	26.52
	Ship 6	No	0	108.94	26.73	7.57
	Ship 11	No	0	320.90	78.74	22.28
	Ship 16	No	0	155.77	38.22	10.82
	Ship 19	No	0	145.08	35.60	10.07
	Ship 26	Yes	0	317.39	77.88	22.04
	Ship 27	No	776.32	625.95	153.59	43.47
Berth 3 with shore	Ship 4	No	0	106.19	26.06	7.37
	Ship 8	No	0	724.84	177.85	50.34
	Ship 9	No	229.17	395.91	97.14	27.49

power	Ship 12	No	0	33.93	8.33	2.36
	Ship 15	Yes	953.28	213.76	52.48	14.87
	Ship 20	No	0	724.51	177.77	50.31
	Ship 23	Yes	0	0.00	0.00	0.00
Berth 4	Ship 7	Yes	0	97.35	23.89	6.76
	Ship 13	Yes	106.41	996.30	244.46	69.19
	Ship 17	No	0	1007.90	247.31	69.99
	Ship 24	No	0	380.54	93.37	26.43
		Total	2356.68	8986.03	2204.94	624.05

6.1.2. Scenario 2

Figure 10 shows using the Eq.1, the result by terminal operator takes the DBAP strategy of berth allocation taking by genetic algorithm. Different from the scenario 1, we only consider the minimizing the emission during the mooring period, the fitness function is total emission of all ships.



(a) Three-dimensional perspective of DBAPD (berth-time-ship)

(b) Two-dimensional perspective of DBAPD (berth-time)

Figure 10: Perspectives of DBAPD in Scenario 2

When the Eq.1 only minimize the emission to the all ships during the mooring period, Table 5 shows the empirical test result, Ships emits 6487.23 kg of NOx, 1591.77 kg of SOx and 450.50 kg of PM in the mooring period, 27.81% less than scenario 1, and all the ships which have the on-board shore power installation, are allocated to the berth 1 or berth 3. In the scenario 2, terminal operator could satisfy each berthing ship to use shore power supply, to minimize all the ships emissions. Only consider minimizing the emissions also bringing the problem, the waiting time is 4282.67 min, 42.86%(12/28) ships delayed in the strategy, more than 25 percent over the strategy which scenario 1 is taken (17.86%(5/28) ships delayed), it causes severe congestion in berths, meanwhile the service in inferior level.

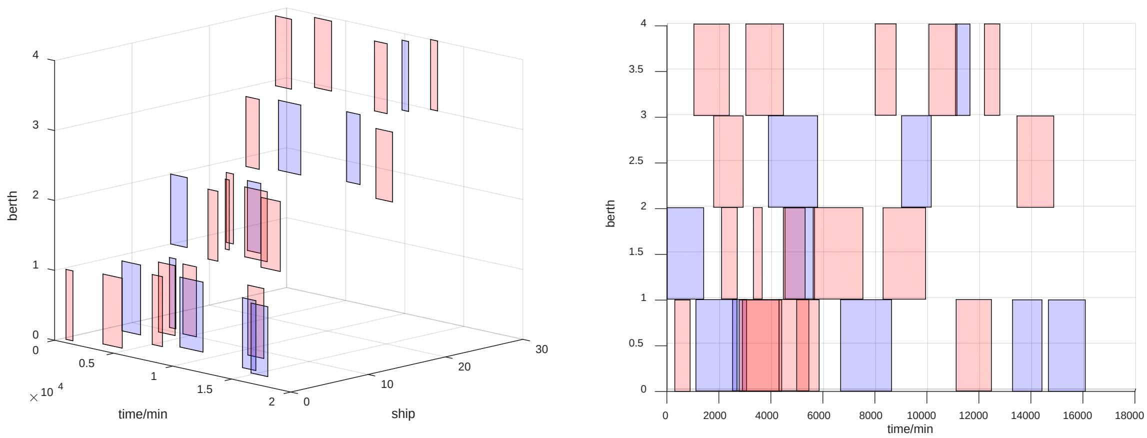
Table 5: Empirical test result of DBAPD in Scenario 2

Berth NO.	Ship NO.	On-board shore power	Waiting time/min	NO_X/kg	SO_X/kg	PM/kg
Berth 1 with shore power	Ship 2	Yes	0	0.00	0.00	0.00
	Ship 4	Yes	0	0.00	0.00	0.00
	Ship 6	Yes	479.12	0.00	0.00	0.00
	Ship 13	No	0	303.14	74.38	21.05
	Ship 5	No	727.67	106.19	26.06	7.37
	Ship 18	No	0	625.94	153.59	43.47
	Ship 22	No	0	108.94	26.73	7.57
	Ship 27	Yes	0	0.00	0.00	0.00
Berth 2	Ship 5	No	0	317.95	78.02	22.08
	Ship 9	No	0	395.91	97.14	27.49
Berth 3	Ship 1	Yes	0	0.00	0.00	0.00
	Ship 3	No	397.78	107.09	26.28	7.44

with shore power	Ship 7	Yes	245.21	0.00	0.00	0.00
	Ship 8	Yes	213.70	0.00	0.00	0.00
	Ship 10	Yes	259.56	0.00	0.00	0.00
	Ship 14	No	177.60	151.12	37.08	10.49
	Ship 15	No	512.47	640.67	157.20	44.49
	Ship 17	No	333.50	724.84	177.85	50.34
	Ship 21	Yes	0	0.00	0.00	0.00
	Ship 23	No	0	380.54	93.37	26.43
	Ship 24	Yes	497.88	0.00	0.00	0.00
	Ship 25	No	178.62	381.88	93.70	26.52
	Ship 26	Yes	0	0.00	0.00	0.00
	Ship 28	No	0	1007.90	247.31	69.99
Berth 4	Ship 11	No	0	155.77	38.22	10.82
	Ship 12	No	259.56	33.93	8.33	2.36
	Ship 16	No	0	320.90	78.74	22.28
	Ship 20	No	0	724.51	177.77	50.31
Total			4282.67	6487.23	1591.77	450.50

6.1.3. Scenario 3

Figure 11 shows using the Eq.1, the result by terminal operator takes the EDBAP strategy of berth allocation taking by genetic algorithm. Different from the scenario 1 and scenario 2, we both consider the minimizing the waiting time and emissions during the mooring period, w_1=0.5 and w_2=0.5 in Eq.1, the fitness function is total waiting time and emissions of all ships.



(a) Three-dimensional perspective of EDBAPD (berth-time-ship)

(b) Two-dimensional perspective of EDBAPD (berth-time)

Figure 11: Perspectives of EDBAPD in Scenario 3

To satisfy the superior service level and low emission, we study the empirical test under scenario 3. Table 6 shows the result, Ships emits 7737.42 kg of NOx, 1898.53 kg of SOx and 537.32 kg of PM in the mooring period, 16.16% less than scenario 1, and 13.90% higher than scenario 2. The waiting time is 3209.76 min, 25%(7/28) ships delayed in the strategy, less than 17.86 percent over the strategy which scenario 2 is taken. Although this will cause some emissions, for reducing waiting time, ship 1 and ship 15 which have on-board shore power installation are assigned to berth 2, ship 23 is allocate to berth 4.

Table 6: Empirical test result of EDBAPD in Scenario 3

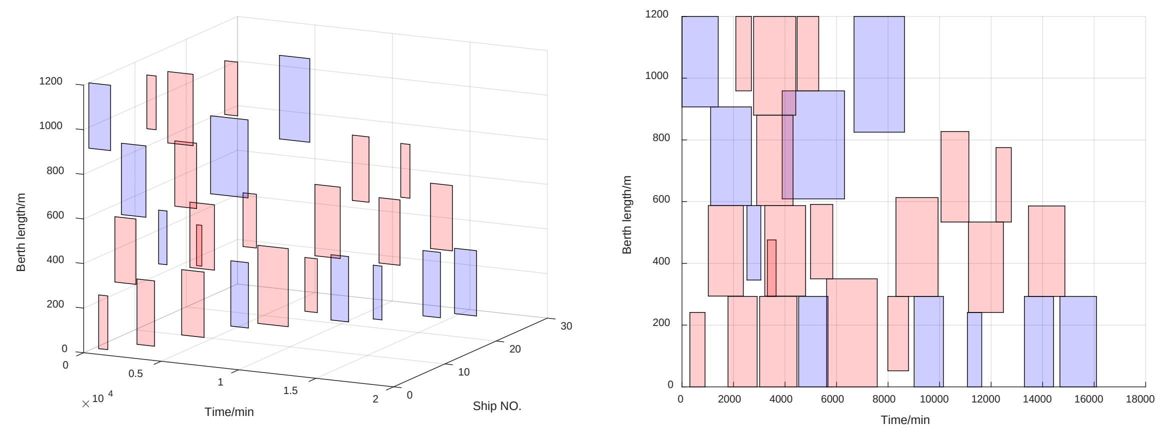
Berth NO.	Ship NO.	On-board shore power	Waiting time/min	NO_X/kg	SO_X/kg	PM/kg
Berth 1 with shore power	Ship 2	No	0	106.19	26.06	7.37
	Ship 4	Yes	0	0.00	0.00	0.00
	Ship 7	Yes	156.54	62.82	15.41	4.36
	Ship 8	No	132.29	724.84	177.85	50.34
	Ship 9	No	111.56	395.91	97.14	27.49

	Ship 11	No	1057.77	320.90	78.74	22.28
	Ship 16	No	398.86	155.77	38.22	10.82
	Ship 18	Yes	0	0.00	0.00	0.00
	Ship 24	No	0	380.54	93.37	26.43
	Ship 26	Yes	0	0.00	0.00	0.00
	Ship 28	Yes	0	0.00	0.00	0.00
Berth 2	Ship 1	Yes	0	622.73	152.80	43.25
	Ship 6	No	0	108.94	26.73	7.57
	Ship 12	No	0	33.93	8.33	2.36
	Ship 14	No	0	151.12	37.08	10.49
	Ship 15	Yes	1276.22	318.93	78.26	22.15
	Ship 17	No	0	1007.90	247.31	69.99
	Ship 20	No	0	724.51	177.77	50.31
Berth 3 with shore power	Ship 5	No	0	317.95	78.02	22.08
	Ship 13	Yes	0	0.00	0.00	0.00
	Ship 21	Yes	0	0.00	0.00	0.00
	Ship 27	No	0	625.94	153.59	43.47
Berth 4	Ship 3	No	0	381.88	93.70	26.52
	Ship 10	No	0	640.67	157.20	44.49
	Ship 19	No	0	145.08	35.60	10.07
	Ship 22	No	0	303.14	74.38	21.05
	Ship 23	Yes	76.52	100.64	24.69	6.99
	Ship 25	No	0	107.09	26.28	7.44
		Total	3209.76	7737.42	1898.53	537.32

6.2. DBAPC Strategy

6.2.1. Scenario 1

Figure 12 shows using the Eq.8, the result by terminal operator takes the DBAPC strategy of berth allocation taking by genetic algorithm. The length of a rectangle is handling time of the corresponding ship, left of rectangle is arrival time, right of rectangle is departure time. Each rectangle represents a ship to be serviced in one berth, red rectangle represents the ship without shore power on-board installation, blue rectangle represents the ship with shore power on-board installation, only in short than 300m or longer than 900m in quay shoreline, which could be supplied power form the shore power.



(a) Three-dimensional perspective of DBAPC (berth-time-ship)

(b) Two-dimensional perspective of DBAPC (berth-time)

Figure 12: Perspectives of DBAPC in Scenario 1

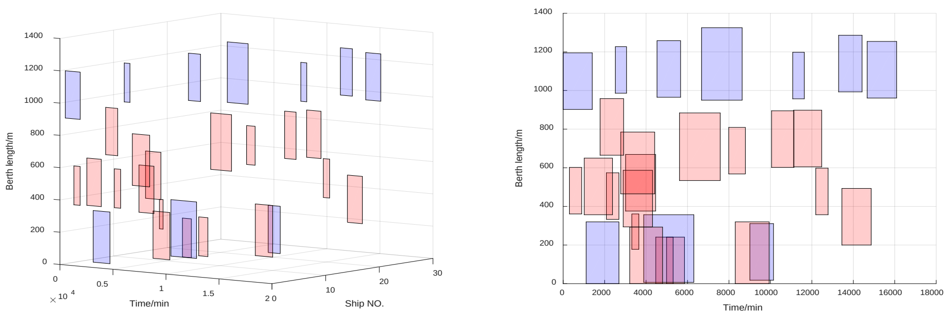
From Table 7, we can see the empirical test result, all the ships total waiting time is only 1021 min, only three ships delay, the DBAPC is competent to guarantee the integrity of shipping schedules and make high service level than DBAPC. Ships emits 2426.36 kg of SOx, 9888.55 kg of NOx and 686.7 kg of PM in mooring period. Due to the DBAPC only minimize the total waiting time of all ships, ship 4, ship 7, ship 13 and ship 18, ship which have on-board shore power installation, are allocated to non-shore power berth. The DBAPC ignores the emission of these ship which could has no emission in mooring period if there are assign to quay shoreline shore power. The sum of emissions of above 4 ships reach 31.40% of total emissions.

Table 7: Empirical test result of CDBAP in Scenario 1

Berth Pos.	Ship NO.	On-board shore power	Waiting time/min	NO_X/kg	SO_X/kg	PM/kg
907	1	Yes	0	0	0	0
0	2	No	0	106.19	26.06	7.37
294	3	No	0	381.88	93.70	26.52
587	4	Yes	0	700.48	171.88	48.64
0	5	No	0	317.95	78.02	22.08
959	6	No	0	108.94	26.73	7.57
346	7	Yes	0	97.35	23.89	6.76
880	8	No	441.16	724.84	177.85	50.34
587	9	No	0	395.91	97.14	27.49
0	10	No	528.20	640.67	157.20	44.49
294	11	No	0	444.68	109.11	30.88
293	12	No	0	33.93	8.33	2.36
609	13	Yes	0	1274.56	312.74	88.51
959	14	No	52.11	151.12	37.08	10.49
0	15	Yes	0	0	0	0
350	16	No	0	155.77	38.22	10.82
0	17	No	0	1035.30	254.03	71.90
825	18	Yes	0	1032.67	253.39	71.71
52	19	No	0	145.08	35.60	10.07
293	20	No	0	724.51	177.77	50.31
0	21	Yes	0	0	0	0
534	22	No	0	303.14	74.38	21.05
0	23	Yes	0	0	0	0
241	24	No	0	380.54	93.37	26.43
534	25	No	0	107.09	26.28	7.44
0	26	Yes	0	0	0	0
293	27	No	0	625.95	153.59	43.47
0	28	Yes	0	0	0	0
		Total	1021	9888.55	2426.36	686.70

6.2.2. Scenario 2

Figure 13 shows using the Eq.8, the result by terminal operator takes the DBAP strategy of berth allocation taking by genetic algorithm. Different from the scenario 1, we only consider the minimizing the emission during the mooring period, the fitness function is total emission of all ships.



(a) Three-dimensional perspective of DBAP (berth-time-ship)

(b) Two-dimensional perspective of DBAP (berth-time)

Figure 13: Perspectives of DBAP in Scenario 1

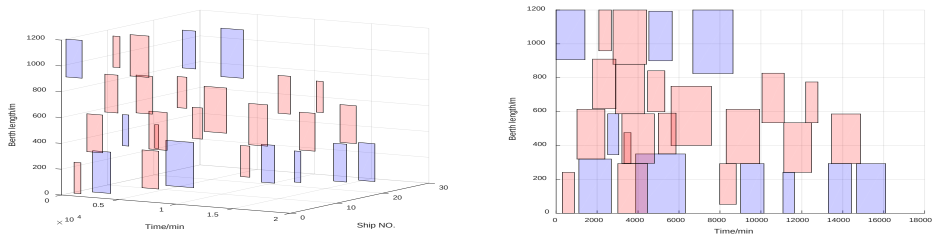
Table 8 shows the empirical test result, Ships emits 7905.46 kg of NOx, 1914.33 kg of SOx and 546.22 kg of PM in the mooring period, 20.05% less than scenario 1, and all the ships which have the on-board shore power installation, are allocated to the quay shoreline which satisfy the need of power supply. In the scenario 2, terminal operator could satisfy each berthing ship to use shore power supply, to minimize all the ships emissions. However, only consider minimizing the emissions also bringing the problem, the waiting time is 8115.52 min, 25%(7/28) ships delayed in the strategy, more than 14.29 percent over the strategy which scenario 1 is taken (10.71%(3/28) ships delayed), it causes severe congestion in berths, meanwhile the service in inferior level. The strategy is not feasible in the real world.

Table 8: Empirical test result of CDBAP in Scenario 2

Berth Pos.	Ship NO.	On-board shore power	Waiting time/min	NO_X/kg	SO_X/kg	PM/kg
902	1	Yes	0	0	0	0
361	2	No	0	106.19	26.06	7.37
357	3	No	0	381.88	93.70	26.52
0	4	Yes	0	0	0	0
665	5	No	0	317.95	78.02	22.08
333	6	No	362	206.99	50.79	14.38
986	7	Yes	0	0	0	0
465	8	No	1636.25	724.84	177.85	50.34
294	9	No	1410.5	871.00	213.71	60.48
376	10	No	1446.25	1345.41	330.12	93.43
0	11	No	0	0	0	0
178	12	No	1192	95.00	23.32	6.61
7	13	Yes	0	0	0	0
0	14	No	867.52	378.82	67.52	23.52
965	15	Yes	0	0	0	0
0	16	No	0	155.77	38.22	10.82
534	17	No	1201	1035.30	254.03	71.90
950	18	Yes	0	0	0	0
568	19	No	0	145.08	35.60	10.07
0	20	No	0	724.51	177.77	50.31
18	21	Yes	0	0	0	0
602	22	No	0	303.14	74.38	21.05
957	23	Yes	0	0	0	0
605	24	No	0	380.54	93.37	26.43
357	25	No	0	107.09	26.28	7.44
993	26	Yes	0	0	0	0
200	27	No	0	625.95	153.59	43.47
961	28	Yes	0	0	0	0
		Total	8115.52	7905.46	1914.33	546.22

6.2.3. Scenario 3

Figure 14 shows using the Eq.8, the result by terminal operator takes the EDBAPC strategy of berth allocation taking by genetic algorithm. Different from the scenario 1 and scenario 2, we both consider the minimizing the waiting time and emissions during the mooring period, w_1=0.5 and w_2=0.5 in Eq.8, the fitness function is total waiting time and emissions of all ships.



(a) Three-dimensional perspective of DBAPC (berth-time-ship)

(b) Two-dimensional perspective of DBAPC (berth-time)

Figure 14: Perspectives of DBAP in Scenario 3

To satisfy the superior service level and low emission, we study the empirical test under scenario 3. Table 9 shows the result, Ships emits 9220.04 kg of NOx, 2262.32 kg of SOx and 640.3 kg of PM in the mooring period, 6.76% less than scenario 1, and 16.63% higher than scenario 2. The waiting time is 2363.84 min, 10.71%(3/28) ships delayed in the strategy, less than 14.29 percent over the strategy which scenario 2 is taken. Although this will cause some emissions, for reducing waiting time, ship 7 which have on-board shore power installation is assigned to 346m in quay shoreline, which cannot supply power to ship 7. Ship 13 is allocated to 0m in quay shoreline, however, due to the allocation strategy, the ship is waiting for 835.87 min until pre ship departure, which still emits NO_X, SO_X and PM.

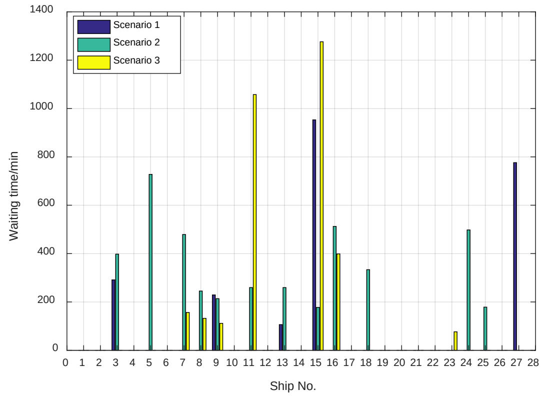
Table 9: Empirical test result of CEDBAP in Scenario 3

Berth Pos.	Ship NO.	On-board shore power	Waiting time/min	NO_X/kg	SO_X/kg	PM/kg
907	1	Yes	0	0	0	0
0	2	No	0	106.19	26.06	7.37
294	3	No	0	381.88	93.70	26.52
0	4	Yes	0	0	0	0
587	5	No	0	317.95	78.02	22.08
959	6	No	0	108.94	26.73	7.57
346	7	Yes	1326.44	204.44	50.17	14.20
880	8	No	0	724.84	177.85	50.34
587	9	No	0	395.91	97.14	27.49
0	10	No	0	640.67	157.20	44.49
294	11	No	0	444.68	109.11	30.88
293	12	No	0	33.93	8.33	2.36
0	13	Yes	835.87	2070.60	508.06	143.80
600	14	No	0	151.12	37.08	10.49
902	15	Yes	0	0	0	0
350	16	No	0	155.77	38.22	10.82
400	17	No	201.53	1196.81	293.66	83.12
825	18	Yes	0	0	0	0
52	19	No	0	145.08	35.60	10.07
293	20	No	0	724.51	177.77	50.31
0	21	Yes	0	0	0	0
534	22	No	0	303.14	74.38	21.05
0	23	Yes	0	0	0	0
241	24	No	0	380.54	93.37	26.43
534	25	No	0	107.09	26.28	7.44
0	26	Yes	0	0	0	0
293	27	No	0	625.95	153.59	43.47
0	28	Yes	0	0	0	0
		Total	2363.84	9220.04	2262.32	640.30

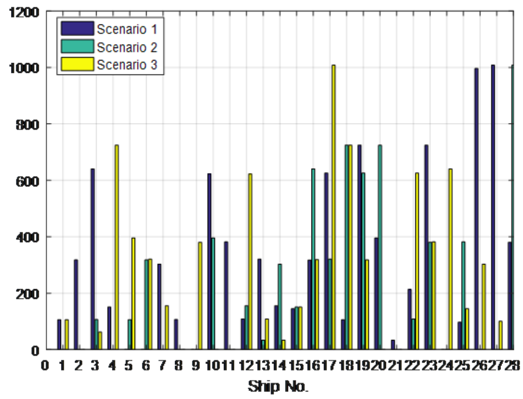
6.3. Results Analysis

6.3.1. Discrete DBAP

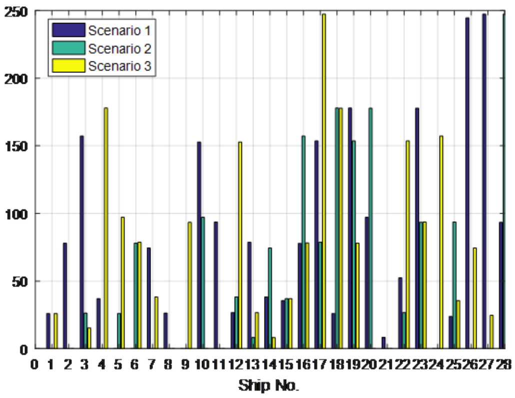
Figure 15 shows all these scenarios empirical test results by using GA, the EDBAP creates a coordination mechanism which can produce win–win economic and environmental benefits for both the port and the ship. Adjusting the weight of Eq.1, which allows the terminal operator to be more flexible in their decision to meet the ECA regulation.



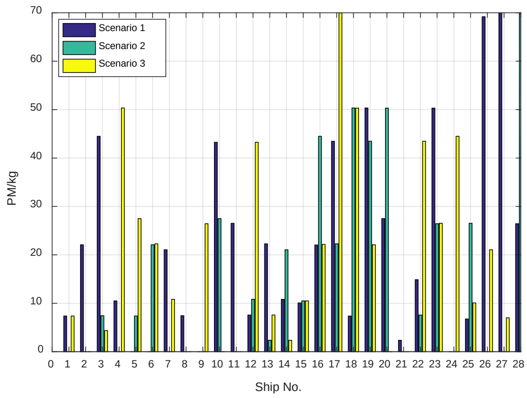
(a) Waiting time



(b) NOx emission



(c) SOx emission



(d) PM emission

Figure 15: Empirical test result of all scenarios in DBAPD

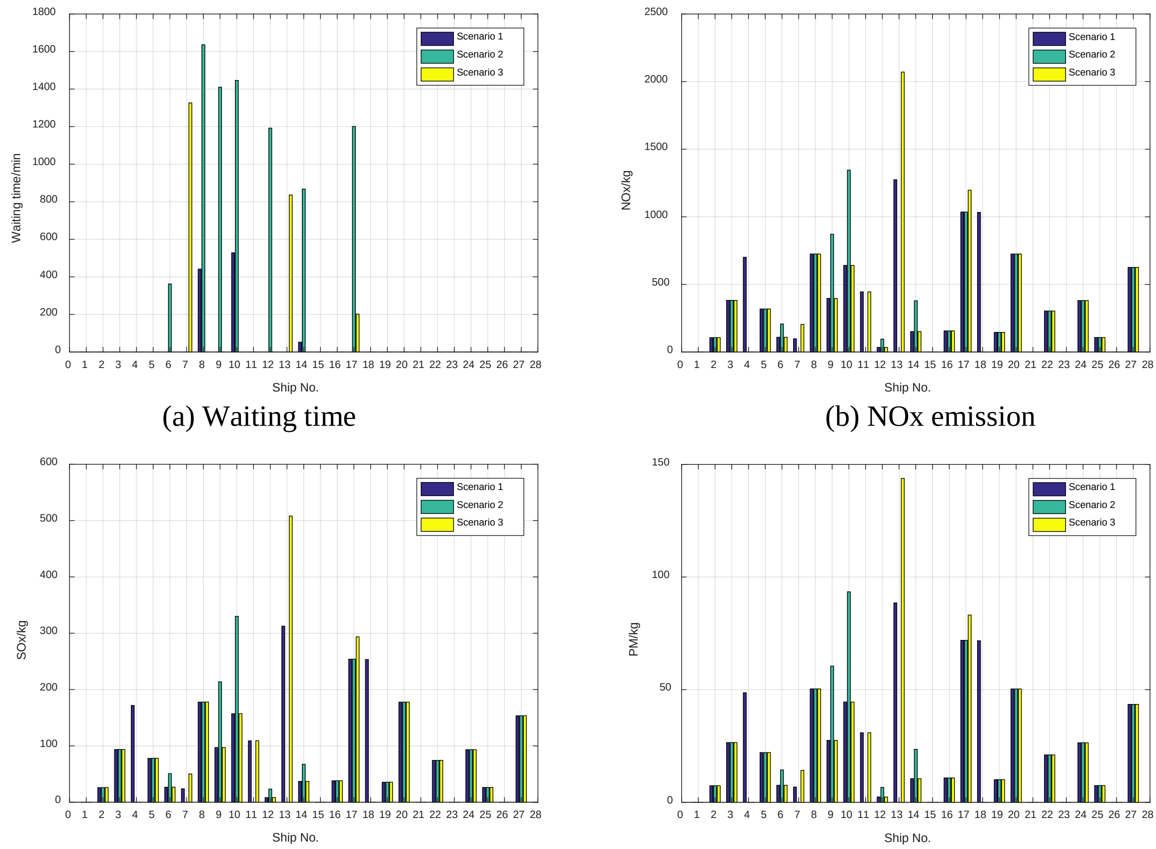
We use the NGA to compare with the GA, the number of NGA generations is 200, mutation rate is 0.12, population size is 50. The solution times for all test problems were minimal (<20 s), take 20 times loop calculation to find the best solution in the sets of the experiment. As shown in Table 10, optimization results demonstrate the NGA is better than the GA of all the scenarios.

Table 10: Empirical test result

Scenario	Strategy	GA				NGA			
		Waiting time/min	SO_X/kg	NO_X/kg	PM/kg	Waiting time/min	SO_X/kg	NO_X/kg	PM/kg
1	DBAPD	2356.68	8986.03	2204.94	624.05	2178.18	8522.80	2071.70	591.21
2	DBAPD	4282.67	6487.23	1591.77	450.50	4028.40	6201.72	1440.07	421.55
3	EDBAPD	3209.76	7737.42	1898.53	537.32	3071.28	7476.27	1651.87	499.02

6.3.2. Continuous DBAP

Figure 16 shows all these scenarios empirical test results by using GA, the EDBAPC creates a coordination mechanism which can produce win–win economic and environmental benefits for both the port and the ship. Adjusting the weight of Eq.8, which allows the terminal operator to be more flexible in their decision to meet the ECA regulation.



(a) Waiting time (b) NOx emission

(c) SOx emission (d) PM emission

Figure 16: Empirical test result of all scenarios in DBAPC

We use the NGA to compare with the GA, the number of NGA generations is 200, mutation rate is 0.12, population size is 50. The solution times for all test problems were minimal (<20 s), take 20 times loop calculation to find the best solution in the sets of the experiment. As shown in Table 11, optimization results demonstrate the NGA is better than the GA of all the scenarios.

Table 11: Empirical test result

Scenario	Strategy	GA				NGA			
		Waiting time/min	SO_X/kg	NO_X/kg	PM/kg	Waiting time/min	SO_X/kg	NO_X/kg	PM/kg
1	DBAPD	1021	9888.55	2426.36	686.70	1001.60	9671.00	2372.98	671.59
2	DBAPD	8115.52	7905.46	1914.33	546.22	7936.98	7802.69	1889.44	539.12
3	EDBAPD	2363.84	9220.04	2262.32	640.30	2323.65	9044.86	2219.34	628.13

7. Conclusions

In order to comply with ECAs regulations, terminal operator need to decrease the ship emissions and keep the service level in a high degree as much as possible in the berth plan. Considering the shore power construction is a big investment project, port equipped shore power is still in a low proportion, therefore, terminal operator cannot satisfy each berthing ship to use shore power supply, to minimize not only the ships total service time that includes handling time and waiting time, but also the emissions in ships mooring period, which is become an urgent need to study and solve problems under the ECAs in China. In this paper, we considered a new optimization berth allocation problem that arise for ships use the shore power in berthing of ECAs, we extend the DBAP formulation with discrete and continuous problems, and take the ship emissions into account in the objective function, which allows the terminal operator to be more flexible in their decision to meet the ECA regulation.

With the ship emissions considering, this paper presents a MINLP model for the DBAP with emissions consideration (EDBAP), and considers two strategies: the DBAP with discrete (DBAPD) and continuous (DBAPC) berthing space, aiming the ship mooring period, based on ship fuel consumption and the widely-used emission factors, consider the application of shore power, we evaluate the emission mitigation effect of the EDBAP model. Furthermore, heuristic algorithm is developed and numerical experiments show that with short computation time, the new berth allocation strategy, can considerably cut down the ship emissions and total time during the mooring period. This study illustrates the potential to support operational and tactical decision-making for port operator, who can keep the ship service level in a high degree, meanwhile, the total ship emissions during the mooring periods can also be reduced. These strategies create a coordination mechanism which can produce win–win economic and environmental benefits for both the port and the ship.

The collaborative scheduling mechanism between the port and the shipping line, based on information technologies, such as Automatic Identification System(AIS), Vessel Traffic System(VTS), etc. The ships convey the basic info (the ship speed, direction and length, fuel type, loading/unloading workload, the requested departure time, etc.) to the port proactively; based on the information related to the ships to be berthed, the port designs a berth plan which takes into account both the concerns of the port (the equipped shore power berth, customer service level, ship emissions for mooring); then, the port transmits the suggested ship arrival time and berth back to the ships. Besides the win–win economic and environmental benefits that drive the strategy, it must be noted that information sharing and collaboration motivation are prerequisites.

There are also some limitations in this study. First, the EDBAP model in this study does not consider quay crane assignment, which has an impact on the handling time of ships. Second, in the practice of the container terminal, the moveable shore power system will be taking more and more attention, which could supply each ship berthing in with shore power on-board installation. Overcoming these limitations and improving the models could be the topics for future research.

8. Acknowledgements

This research was partly supported carried out with financial support from the Conservice Energy and Reduce Emissions Grant (CEREG) 2015-JNJP-010-056 from the Ministry of Transport of the People's Republic of China.

References

Alvarez, J.F., Longva, T., Engebrethsen, E.S., 2010. A methodology to assess vessel berthing and speed optimization policies. Marit. Econom. Logist. 12 (4), 327–346.

A. Petrowski, "A Clearing Procedure as a Niching Method for Genetic Algorithms", IEEE 3rd International Conference on Evolutionary Computation (ICEC'96), Nagoya, 1996.

Bierwirth, C., Meisel, F., 2010. A survey of berth allocation and quay crane scheduling problems in container terminals. Eur. J. Oper. Res. 202 (3), 615–627.

B.L. Miller, M.J. Shaw, "Genetic Algorithms with Dynamic Niche Sharing for Multimodal Function Optimization," IEEE International Conference on Evolutionary Computation, pp. 786-791, 1996.

Brown, G.G., Lawphongpanich, S., Thurman, K.P., 1994. Optimizing ship berthing. Nav. Res. Logist. 41 (1), 1–15.

Chang, Y. T., Roh, Y., & Park, H. (2014). Assessing noxious gases of ship operations in a potential emission control area. Transportation Research Part D Transport & Environment, 27(2), 91-97.

Du, Y., Chen, Q., Quan, X., Long, L., & Fung, R. Y. K. (2011). Berth allocation considering fuel consumption and ship emissions. Transportation Research Part E Logistics & Transportation Review, 47(6), 1021-1037.

G. Harrik, "Finding multimodal solutions using restricted tournament selection," in L.J. Eshelman (Ed.), Proceedings of the 6th International Conference on Genetic Algorithms (ICGA6), San Francisco, CA: Morgan Kaufmann, pp. 24-31, 1995.

Golias, M.M., Saharidis, G.K., Boile, M., Theofanis, S., Ierapetritou, M.G., 2009. The berth allocation problem: optimizing vessel arrival time. Marit. Econom.Logist. 11 (4), 358–377.

Imai, A., Nishimura, E., & Papadimitriou, S. (2001). The dynamic berth allocation problem for a container port. Transportation Research Part B Methodological, 35(4), 401-417.

Imai, A., Nishimura, E., & Papadimitriou, S. (2003). Berth allocation with service priority. Transportation Research Part B Methodological, 37(5), 437-457.

Imai, A., Sun, X., Nishimura, E., & Papadimitriou, S. (2005). Berth allocation in a container port: using a continuous location space approach. Transportation Research Part B Methodological, 39(3), 199-221.

Imai, A., Nishimura, E., Hattori, M., & Papadimitriou, S. (2007). Berth allocation at indented berths for mega-containerships. European Journal of Operational Research, 179(2), 579-593.

Imai, A., Nishimura, E., & Papadimitriou, S. (2013). Marine container terminal configurations for efficient handling of mega-containerships. Transportation Research Part E Logistics & Transportation Review, 49(1), 141–158.

J.S. Chun, M.K. Kim, H.K. Jung, S.K. Hong, "Shape Optimization of Electromagnetic Devices Using Immune Algorithm," IEEE T-Mag. 33n2, pp. 1876-1879, 1997.

Kim, K.H., Moon, K.C., 2003. Berth scheduling by simulated annealing. Transport. Res. B – Methodol. 37 (6), 541–560.

Lang, N., Veenstra, A., 2010. A quantitative analysis of container vessel arrival planning strategies. OR Spectrum 32 (3), 477–499.

Li, C.L., Cai, X.Q., Lee, C.Y., 1998. Scheduling with multiple-job-on-one-processor pattern. IIE Trans. 30(5), 433–445.

Lim, A., 1998. The Berth planning problem. Oper. Res. Lett. 22 (2–3), 105–110.

Nishimura, E., Imai, A., & Papadimitriou, S. (2001). Berth allocation planning in the public berth system by genetic algorithms. European Journal of Operational Research, 131(2), 282-292.

Representative emission factors for use in “Quantification of emissions from ships associated with ship movements between port in the European Community” (ENV.C.1/ETU/2001/0090) FINAL REPORT 2002.

Schrooten, L., De Vlleger, I., Panis, L.I., Styns, K., Torfs, R., 2008. Inventory and forecasting of maritime emissions in the Belgian sea territory, an activity-based emission model. Atmos. Environ. 42 (4), 667–676.

S.W. Mahfoud, Niching Methods for Genetic Algorithms. IlliGAL Report 95001, Univ. of Illinois at Urbana Champaign, I.G.A. Lab.,1995. Available by ftp://gal4.ge.uiuc.edu/pub/papers/.

Technical Code of Shore-to-Ship Power Supply System, JTS 155-2012, Ministry of Transport of China, 2012.

Applying Multilayer QFD to Assess Quality of Short Sea Shipping: An Empirical Study on Maritime Express Service between Taiwan and Mainland China

Sheng-Teng Huang and I-Hsuan Su

Department of Transportation Science, National Taiwan Ocean University, Taiwan
Email: danielhuang@ntou.edu.tw, sd12142003@gmail.com

Abstract

The purpose of this study is to investigate service quality of maritime express. Maritime express is a new way to provide convenient and efficient express service between China and Taiwan. With the development of e-commerce, the express service becomes more and more important. In comparison with air cargo express, maritime express has the advantage of lower cost. Because of the relative lower price, maritime express may attract more customers and facilitate the Cross-Strait e-commerce business to compete with air cargo express. However, the maritime express is still in the early stage of development, it faces some problems. For example, the cargo volume can't meet the expectations, the related supporting measures are not complete, and the service quality such as reliability, on-time delivery needs to be improved. Therefore, this study applies scientific method to help operators to identify important service quality requirement and technical requirement (improvement strategies). We combine Analytic Hierarchy Process (AHP) and Multilayer Quality Function Deployment (QFD) to investigate the service quality of maritime express in Taiwan. The feature of this study is to modify classic QFD framework by using refined multilayer analysis method. The main criticism of classic QFD over-emphasizes the requirement of customer side. Multilayer QFD framework may improve this situation by assessing the requirements from both service provider side (operators of maritime express) and customer side (shippers of maritime express). Therefore, the Multilayer QFD constructs two house of quality (the most important tool in the QFD framework) from service provider and customer to calculate the significant technical requirements (improvement strategies) rather than constructing one house of quality in classic QFD framework. According to the results, we can propose the improvement strategies and suggestions which need to be implemented urgently to be as a reference for future development for express operators.

Keywords: Analytic hierarchy process, maritime express, multilayer quality function deployment, service quality

1. Introduction

According to the White paper published by Ministry of Transportation and Communications in Taiwan in 2013, there is 99% of cargo uses ocean transport as a way to transit abroad in Taiwan. Thus, ocean transport to international trade is very important. After government opened cross-strait shipping, the communications between Taiwan and China are more frequent. In addition to the rising of e-commerce also facilitates demand of express cargo. The express market between Taiwan and China mainly uses air transport now. In comparison with air cargo transport, the freight of maritime shipping is lower. That's why maritime express appears. Maritime express not only has lower cost, but also uses good location with China to provide services. It uses high speed ship like Rera ship and Haixiahao as a transport tool and only takes 3 hours to navigate from Taiwan's Taipei port to China's Pingtan port. Maritime express aims to provide lower costs with high speed to attract shippers between Taiwan and China to use this service.

Maritime express is a service-oriented industry. This kind of service begins with contacting between customers and service providers, so the purpose of service providers is satisfy customer's requirements (Lam, 2015). There are lots of literatures about shipping, air express and other kinds of logistics have published (Ayag, 2014; Durvasula, 2002; Gil et al., 2008; Ho et al., 2012; Park et al., 2009; Huang et al., 2015). However, research about maritime express is few. Therefore, providing service providers a clear guideline to improve service quality is very important. Not only can increase customer's satisfaction, but also can let service provider to build long term sustainability in the competitive market. This study aims to investigate service quality of maritime express and provide effective improvement strategies.

This study applies multilayer Quality Function Deployment as an analytic tool. Using this method can improve traditional QFD weakness that over-emphasizes customer requirements and take service provider's requirement into consideration so that the improvement strategies which we propose can effectively implement and improve service quality.

The step of this study is to review some related literature about maritime express completely first. Then, we can use these studies which are about express, logistics, and maritime shipping industry as a basic to find out service attributes. After examining by experts, we can construct two House of Quality (HoQ) under multilayer QFD framework. Finally, we can find out improvement strategies which need to be implemented urgently.

According to Bureau of Foreign Trade in Taiwan, total trade volume between cross-strait is increasing. The volume fell down from 2008 to 2009 because of financial crisis, but generally, total trade volume between cross-strait is gradually increasing.

In comparison with air express, the freight of maritime express is lower. Both of maritime express and air express have the same weight of limitation which is 70kg. Air express provides the service around the world, but maritime express only provides the service between Taiwan and China.

According to the report of Liberty of Times in Taiwan in 2015, there is about NT. 50 billion that Taiwanese consumers purchased goods on a Chinese e-commerce platform, Taobao. It means that this industry is potential.

2. Literature Review

According to Oxford Economics Forecasting which mentioned in "The impact of the express delivery industry on the global economy", express operators provide the service of guaranteeing, fast speed, reliability and door to door service and it can trace the cargo status when shipping.

Most of the express delivery service mainly uses airplane as a transport tool. Maritime express which started providing service in April, 2015 becomes a new innovative way to deliver express cargoes. It uses the advantage of lower cost and good location with China to provide fast and efficient express service. It only takes 3 hours to ship from Taipei port to Pingtan port.

According to the regulations in Taiwan, the limitation of administrative documents is different than usual. Generally, the export cargo needs to send shipping order in 24 hours after the ships arrive. However, the simple custom clearance which maritime express uses needs to send shipping order in 2 hours before the ships arrive. It makes the custom clearance more efficiency.

Currently, there are few literatures about maritime express. Therefore, this study collects some related studies such as the service quality of home delivery, maritime shipping and air cargo express to find out some service attributes that can be fitted in maritime express. And this study aims to provide service providers some references to improve service quality.

Table 1: Related literatures about shipping industry

Author	Studies	Findings
Ana C. Paixão Casaca, Peter B. Marlow (2005)	The competitiveness of short sea shipping in multimodal logistics supply chains: service attributes	It finds out many service attributes about short sea shipping in multimodal logistics supply chains by reviewing literature
Chin-Shan Lu (2007)	Evaluating Key Resources and Capabilities for Liner Shipping Services	This study finds out that operating capabilities is the most important capabilities. The following is customer service, human resources management,

		information integration, pricing, purchasing and financial management.
Wang (2007)	Improving service quality using quality function deployment: The air cargo sector of China airlines	Applying quality function deployment (QFD) to improve the air cargo sector. The result shows that accuracy and efficiency are the main factors to air freight forwarder.
Gin-Shuh Liang, Tsung-Yu Chou, Shu-Fen Kan (2007)	Applying fuzzy quality function deployment to identify service management requirements for an ocean freight forwarder	Applying fuzzy QFD to identify service management requirements for ocean freight forwarder. The result reveals that safe delivery, on-time delivery, short transit time, emergency handling ability and the ability to keep cargos are important service attributes.
Vinh V. Thai (2007)	Service quality in maritime transport: conceptual model and empirical evidence	This study divides service quality into six dimensions. There are resources, outcomes, process, management, image, and social responsibility.
Yonghwa Park, Jung Kyu Choi, Anming Zhang (2008)	Evaluating competitiveness of air cargo express services	Evaluating competitiveness of air cargo express services by applying AHP finds out that on-time delivery is the most important service factor. However, the users think that price is the most important service factor.
Irene Gil Saura et al. (2008)	Logistics service quality: a new way to loyalty	Applying structural equation modeling (SEM) to investigate differences of 194 companies to discuss about the relationship between customer satisfaction and customer loyalty.
Kee-Kuo Chen, Ching-Ter Chang, Cheng-Sheng Lai (2009)	Service quality gaps of business customers in the shipping industry	This study believes that not only SERVQUAL but also SERVPERF is not an appropriate evaluating dimension to apply in shipping industry in Taiwan.
Pin-Fenn Chou, Chin-Shan Lu (2009)	Assessing service quality, switching costs and customer loyalty in home-delivery services in Taiwan	Using customers' perspective to assess service quality, switching costs and customer loyalty in home-delivery services in Taiwan. It finds out that service quality influences the switching costs and customer loyalty directly. The most satisfied service item is range of delivery.
Birdogan Baki, Cigdem Sahin Basfirinci, Zuhal Cilingir, Ilker Murat AR (2009)	An application of integrating SERVQUAL and Kano's model into QFD for logistics services A case study from Turkey	After analyzing by QFD, it can show that the top three service attributes for logistics services are VIP services, informing customers about delivery time before sending and taking deliveries from customers' addresses.
Ana C. Paixao Casaca, Peter B. Marlow (2009)	Logistics strategies for short sea shipping operating as part of multimodal transport chains	By reviewing literature, this study arranges seven service strategies for short sea shipping. There are carrier's logistics network design and speed, investment policy, company & operator, and carrier-shippers' relationship policies, corporate image, service guarantee, involvement in the forwarding industry, carrier's representatives sales & after-sales behavior, cost of service and reliability.
Kai Chieh Hu, Mei Chieh Huang (2011)	Effects of service quality, innovation and corporate image on customer's satisfaction and loyalty of air cargo terminal	Through the questionnaire which distributed in Taiwan Taoyuan International Airport finds out that service satisfaction of customers has a lot to do with loyalty. Service quality, innovation and corporate image affect customer satisfaction positively.
Mu-Chen Chen, Chia-Lin Hsu,	Applying quality function deployment to develop the	On line shoppers put more emphasis on safety of transaction and personal information. In terms of

Ying-Yi Lee (2012)	home delivery service model for specialty foods in traditional market	home delivery, consumers hope that it can reduce the cargo damage happened and to maintain the products of freshness.
Yoon, Park (2014)	A study of the competiveness of airline cargo services departing from Korea: Focus on the main export routes	This study focus on airline cargo services departing from Korea to identify the competitiveness factors of airlines. The results show that price is the most important factor in every route.
Vinh V. THAI, Wei Jun TAY, Raymond Tan, Alan LAI	Defining service quality in tramp shipping: Conceptual model and empirical evidence	From Total Quality Management (TQM) and International Organization for Standardization (ISO) to find out the service attributes and analyze the performance in tramp shipping.
Mu-Chen Chen (2015)	Exploring logistics service quality in home delivery industry: Do service providers and customers have different viewpoints?	Using SERVQUAL as evaluating dimension to assess the differences of service quality between customers and service providers in home delivery. The result reveals that quality of staffs needs to be improved. Better service quality will increase the costs. If service providers put cost into consideration, they will hesitate to enhance service quality.
Show-Hui S. Huang, Wen-Kai K. Hsu (2015)	Evaluating the service requirements of combination air cargo carriers	Combining fuzzy and AHP to investigate the service requirements of perception differences between airline carriers and air freight forwarders. The results reveal that operators should improve ground handling to reach the goal of delivering goods perfectly and accurately to destination.
Wen-Kai K. Hsu, Hong-Fwu Yu, Show-Hui S. Huang (2015)	Evaluating the service requirements of dedicated container terminals: a revised IPA model with fuzzy AHP	Modifying Importance Performance Analysis (IPA) model and combining fuzzy AHP to provide some items which need to be improved and the priorities of improvement.
Sheng-Teng Huang, Emrah Bulut, Okan Duru (2015)	Service quality assessment in liner shipping industry: An empirical study on Asian shipping case	Applying fuzzy AHP and QFD to improve service quality of liner shipping. It finds out that setting a standard operating process can promote customer satisfaction helpfully.
Ji Feng Ding, Wen Hwa Shyu, Chun-Tsen Yeh, Pi Hui Ting, Chung-Te Ting, Chien Pang Lin, Chien Chang Chou, Su Sin Wu (2016)	Assessing customer value for express service providers: An empirical study from shippers' perspective in Taiwan	Applying fuzzy multiple criteria decision making (MCDM) to investigate service quality of air cargo express in Taiwan from shippers' perspective. The results show that dimension of time is the most important dimension for shippers.

As the table 3 shown, most of the studies modify SERVQUAL as the dimensions of service quality. However, some researchers pointed that SERVQUAL is not an appropriate way to apply in transportation industry because of its changeable feature. This study considers maritime express as a special industry so we do not classify service attributes.

By reviewing some related literature and examining by experts, we can obtain service attributes. It can be divided into three parts. There are customer requirements, service provider requirements, and technical requirements (improvement strategies).

Table 4 is customer requirements. They are selected from the literature of logistics, transportation, and express industry. Through examining by experts, we delete two requirements which are “Employees appear neat” and “Sufficient shipping space”. The former one is deleted because it is too similar with other attribute and the later one is deleted because the description is not clear.

Table 2: Customer requirements

Customer requirement	Description	Source
Shipment tracing ability	The ability of tracing the shipment in any time	Vinh V. Thai (2007)
Speed of service performance	The speed of transit time	Vinh V. Thai (2007)
Reliability of service performance	Timeliness of shipment pick-up and delivery	Vinh V. Thai (2007)
Staff’s attitude and behavior	Staff’s attitude and behavior in meeting customers’ requirements	Vinh V. Thai (2007)
Quick response to customers’ inquiries and requests	The staffs can response customers’ inquiries quickly	Vinh V. Thai (2007)
Company’s reputation	Corporate image	Vinh V. Thai (2007)
Range of delivery	The range of cargos which can be delivered	Pin-Fenn Chou, Chin-Shan Lu (2009)
Accurate delivery	Accurate delivery to address of shipment	Yonghwa Park, Jung Kyu Choi, Anming Zhang (2009)
Compensation	Compensation policy	Yonghwa Park, Jung Kyu Choi, Anming Zhang (2009)
Schedule	Convenient schedule for pick-up and delivery	Yonghwa Park, Jung Kyu Choi, Anming Zhang (2009)
Reasonable price	Reasonable price by volume and/or weight	Yonghwa Park, Jung Kyu Choi, Anming Zhang (2009)
Emergency handling ability	The ability to react when emergency happened	Gin-Shuh Liang, Tsung-Yu Chou, Shu-Fen Kan (2006)
Information system performance	Convenient information system for customers	Gin-Shuh Liang, Tsung-Yu Chou, Shu-Fen Kan (2006)
Accurate documentation	Handling the documents accurately and effectively	Chin-Shan Lu (2007)
Door-to-door service	Providing door-to-door service to customers	Gin-Shuh Liang, Tsung-Yu Chou, Shu-Fen Kan (2007)

Table 5 is service provider requirements. They are selected from the literature of logistics, transportation and express industry. After examining by experts, one attribute is deleted because of its unclear description.

Table 3: Service provider requirements

Service provider requirement	Description	Source
Reasonable operating costs	Rationality of operating maritime express costs	Gin-Shuh Liang, Tsung-Yu Chou, Shu-Fen Kan (2006)
Ability of cargo tracing	Ability of tracing cargo instantly	Gin-Shuh Liang, Tsung-Yu Chou, Shu-Fen Kan (2006)
Staff having emergency handling ability	The ability to deal with unexpected situations	Gin-Shuh Liang, Tsung-Yu Chou, Shu-Fen Kan (2006)
Effectively and accurately handling important documentation	Handling important documentation effectively and accurately	Gin-Shuh Liang, Tsung-Yu Chou, Shu-Fen Kan (2006)
Good company's reputation	Corporate image	Gin-Shuh Liang, Tsung-Yu Chou, Shu-Fen Kan (2006)
Sufficient waypoints	Advising government to open more waypoints to operate maritime express	Show-Hui S. Huang, Wen-Kai K. Hsu (2015)
Stable financial condition	Having a stable financial condition	Vinh V. Thai (2007)

Perfect infrastructure	Having good infrastructure	Vinh V. Thai (2007)
Having the ability of understanding customer requirements	The degree of understanding of customer needs	Vinh V. Thai (2007)
Good management strategies	Having professional knowledge and ability of managing a company effectively	Vinh V. Thai, Wei Jun Tay, Raymond Tan, Alan Lai (2014)
Having good relationships with shippers	Ability of having good relationships with shippers	Vinh V. Thai, Wei Jun Tay, Raymond Tan, Alan Lai (2014)
Ability of handling customer complaint	Handling customer complaint instantly	Chin-Shan Lu (2007)

Table 6 is technical requirements (improvement strategies). They are selected from the literature of logistics, transportation, and express industry as well as related news, annual reports and journals. “Signing trade agreement between cross-strait” and “Focusing on corporate social responsibility” are proposed by this study. After discussing with experts, these attributes are decided to put into the technical requirements

Table 4: Technical requirements

Technical requirement	Description	Source
Modernizing IT platforms	Integrating information to provide a system for tracing cargos	Fedex 2015 annual report
Personnel training	Enhancing the quality of personnel by training	Chia-Lin Hsu, Chin-shen Lin, Mu-Chen Chen (2011)
Strategic alliances	Cooperating with other logistics companies and enhancing operating ability	International cruise and ferry review 2015
Exploring new sailing routes	Advising government to open more shipping routes	International cruise and ferry review 2015
Flexible delivery	Re-shipping unsigned goods	Junjie Xu, Ling Jiang, Yiliang Li (2013)
Setting the standard service processes	To design the standard service processes to shorten service time	Gin-Shuh Liang, Tsung-Yu Chou, Shu-Fen Kan (2007)
More capacity	Increasing the number of fleets to provide more shipping capacity	Sheng Teng Huang, Okan Duru, Emrah Bulut (2015)
Frequent service	Justifying shipping schedule to provide frequent service	Sheng Teng Huang, Okan Duru, Emrah Bulut (2015)
Unbinding more regulations	Advising government to unbind more regulations	Taiwan Shin Sheng Daily News (2016/5/5)
Holding regular seminar for reviewing customer services	Holding regular seminar to understand which services need to be improved	LRQA Business Assurance ISO（2015）
Signing trade agreement between cross-strait	Advising government to sign trade agreement between cross-strait	By interviewing with experts
Focusing on corporate social responsibility	Focusing on corporate social responsibility to improve corporate images	By interviewing with experts

Through the arrangement above, we can apply them into multilayer QFD. By using customer requirements and service provider requirements, we can transform into technical requirements (improvement strategies).

3. Methodology

This study combines analytic hierarchy process and multilayer quality function deployment to investigate service quality of maritime express. First, we review some literature to find out customer requirements, service provider requirements, and technical requirements (improvement strategies). After checking these requirements by experts, we use them to design questionnaires. By using analytic hierarchy process, we can obtain the weights of customer requirements and service provider requirements. Then, the experts estimate the relationship between technical requirements and customer requirements as well as the relationship between technical requirements and service provider requirements. Finally, we can calculate the weights of technical requirements and rank the priorities of improvement strategies.

3.1 AHP (Analytic Hierarchy Process)

Analytic hierarchy process (AHP) is a method of multiple criteria decision making. It was proposed by Saaty (G. Rajesha, P. Malligab, 2013). This method can be applied in various fields and use pairwise comparison to help decision makers to find out the best alternatives.

The following are the four basic steps of this method (Arijit Bhattacharya, Bijan Sarkar, Sanat Kumar Mukherjee, 2005, G. Rajesha, P. Malligab, 2013 and G.S. Liang, 2016):

Step 1: Define the issue.

Step 2: Use pairwise comparisons to evaluate the priority of each item. The following is the framework of the matrix.

$$\begin{matrix} 1 & a_{12} & \cdots & a_{1n} \\ 1/a_{12} & 1 & \cdots & a_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ 1/a_{1n} & 1/a_{2n} & \cdots & 1 \end{matrix}$$

$a_{ij} > 0$, $\forall\ i, j$, $i, j = 1, 2, \ldots, n$, represents the importance of item i relative to item j.

$$w_i = \frac{\sum_{j=1}^{n} a_{ij}}{\sum_{i=1}^{n}\sum_{j=1}^{n} a_{ij}},\ i = 1,2,\ldots,n$$

w_i represents the weight of each item.

Step 3: After integrating the priorities, we can rank the priorities.

Step 4: According to the results of step 2, we need to evaluate the consistency check. If the results are consistent, it means that the results are convincing. When the consistency ratio (C.R.) is < 0.1, the result is consistent. The calculate process of C.R. is as follow:

Consistency index, C.I. = $\frac{\lambda_{max} - n}{n-1}$

C.R. = $\frac{\text{C.I.}}{\text{R.I.}}$

R.I. (Random value) can be found in Table 7.

Table 5: Random value

Level	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
R.I.	0.00	0.00	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49	1.51	1.48	1.56	1.57	1.58

3.2 QFD (Quality Function Deployment)

QFD (Quality function deployment) was proposed by Yoji Akao in 1966. It is mainly used to evaluate the effect of customer requirements to product features. In this method, the most important tool is House of Quality (HoQ). It is a way to transform customer requirements into technical requirements. It was first applied in a shipyard in Kobe, Japan. After that, it applies in various fields (Akao, 2004).

The following are the framework and contents (John R. Hauser, and Don Clausing, 1988):

1. Customer requirement: To listen the voice of customer, and deeply realize the feature of products or services that customers demand.
2. Technical requirement: The method to improve products or service quality.
3. Relation matrix: It shows how technical requirements affect customer requirements.
4. Relative weight: The value that customer evaluates.
5. Targets: Calculate from relative weight and the relation between customer requirement and technical requirement.
6. Rank of improvement strategies: To rank the priorities of technical requirements according to the results.

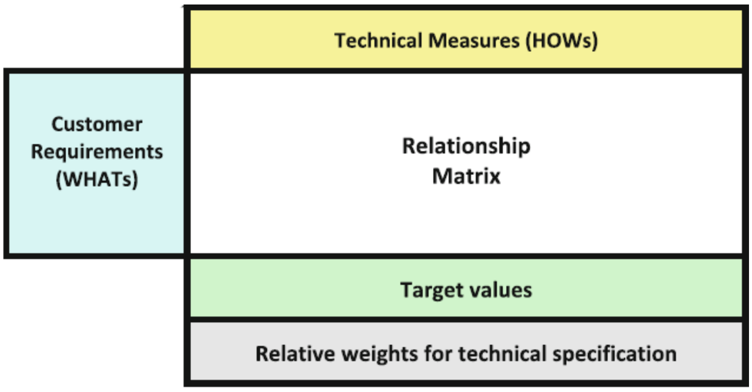


Figure 1: Framework of House of Quality

Source: Okan Duru, Sheng Teng Huang, Emrah Bulut and Shigeru Yoshida (2013)

The basic steps of QFD are as follow (Emrah Bulut, Okan Duru, and Sheng Teng Haung, 2016):

1. Identify customer requirements
2. Evaluate the degree of the importance of customer requirements (shippers and service providers)
3. Assess the priorities of customer requirements.
4. Identify technical requirements after checking by experts
5. Construct the relation matrix to investigate the relation between technical requirements and customer requirements.
6. Present the relationship between customer requirements and technical requirements.
7. Rank the technical requirements.

3.3 Multilayer Quality Function Deployment

Traditional QFD only considers the opinions that customers think about products or services, it doesn't take opinions of service providers into consideration. Multilayer QFD was proposed by Okan Duru, Sheng Teng Huang, and Emrah Bulut in 2011. It considers the demand of service providers to products or services. Therefore, this method can find out the alternatives that can be accepted by customers and service providers at the same time. In another word, applying this method can realize the improvement strategies that customers consider and the service providers also have the ability to reach the goal. This makes the improvement strategies can be implemented effectively and precisely.

Figure 3 is the framework of multilayer QFD. This framework is consisted by three dimensions. It includes the customer requirements house of quality, service provider requirements house of quality and the matrix of cross synthesis. As the figure shows that the front dimension represents house of quality of customer requirement orientation. The side represents house of quality of service provider requirement orientation. The two for the common part of the technical requirements (edge 3). The top side of the cube represents the conflict resolution. It is formulated by customer requirements (edge 1) and service providers (edge 2).

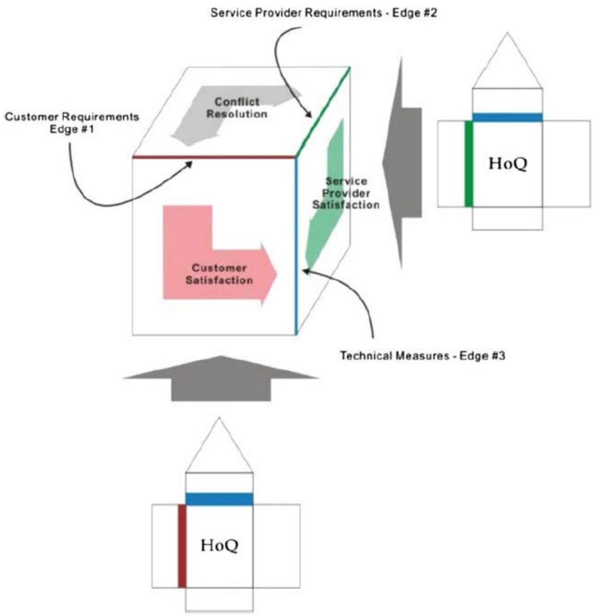


Figure 2: Framework of multilayer QFD

Source: Okan Duru, Sheng Teng Huang, Emrah Bulut and Shigeru Yoshida (2013)

3.3.1 Cross synthesis analysis

Cross synthesis analysis is part of the multilayer QFD. It is used to solve the conflict between customer and service provider. This study uses this analysis to transform from customer (shipper) and service provider (operator of maritime express) into new values. Then, we can obtain the priorities of improvement strategies. The process of calculation is as follow (Okan Duru, Sheng Teng Huang, Emrah Bulut and Shigeru Yoshida, 2011):

Let R_i^s and R_j^c represent the service provider requirement and customer requirement. *i (i=1,2, …,k)* represents the number of service providers, *j (j=1, 2, …, k)* represents the number of customer. The relationship between these two can be represented by A_{ij}.

$$A_{ij} = \begin{bmatrix} r_{11} & r_{12} & \cdots & r_{1l} \\ r_{21} & r_{22} & \cdots & r_{2l} \\ \vdots & \vdots & \vdots & \vdots \\ r_{k1} & r_{k2} & \cdots & r_{kl} \end{bmatrix}$$

The relative importance of service provider requirements and customer requirements can be represented by w_i^s and w_j^c. The calculation process of relative importance is as follow,

$$\sum_{i=1}^{k} w_i^s r_{ij} \qquad (1)$$

$$\sum_{j=1}^{l} w_j^c r_{ij} \qquad (2)$$

The third equation and fourth equation represent relative weight of service provider and shipper after the cross synthesis analysis:

$$\omega_j^c = \frac{\frac{\sum_{i=1}^{k} w_i^s r_{ij}}{\sum_{j=1}^{l}\sum_{i=1}^{k} w_i^s r_{ij}} + w_j^c}{2} \quad (3)$$

$$\omega_i^s = \frac{\frac{\sum_{j=1}^{l} w_j^c r_{ij}}{\sum_{i=1}^{k}\sum_{j=1}^{l} w_j^c r_{ij}} + w_i^s}{2} \quad (4)$$

Finally, put the results of equation 3 and equation 4 into service provider house of quality and customer house of quality. Then, calculate the relative importance of technical requirement separately. After that, calculate the average of these two relative importance and we can obtain the average relative importance. At last, we can rank the priorities of technical requirements (improvement strategies). In order to realize and be familiar with the methodology, this study reviews some literature that applies this method.

Table 6: Literature review of methodology

Author	Methodology	Content
Arijit Bhattacharya, Bijan Sarkar, Sanat Kumar Mukherjee (2005)	AHP and QFD	This study combines AHP and QFD to choose the appropriate robots. It also illustrates how to combine these two methods to apply in this field.
William Ho (2008)	AHP and QFD	This study reviews lots of literature with AHP and arranges which methods can combine with AHP. It also refers how to apply and combine AHP and QFD.
William Ho, Ting He, Carman Ka Man Lee, Ali Emrouznejad (2012)	Fuzzy AHP and QFD	This study describes how to combine Fuzzy AHP and QFD to evaluate the third party logistics.
Okan Duru, Sheng Teng Huang, Emrah Bulut, Shigeru Yoshida (2013)	3D QFD and Fuzzy AHP	This study introduces how to use multilayer QFD.
Sheng Teng Huang, Emrah Bulut, Okan Duru (2015)	Fuzzy AHP and QFD	Using Fuzzy AHP and QFD to evaluate service quality of Asian liner shipping companies.
Emrah Bulut, Okan Duru, Sheng Teng Huang (2016)	3D QFD and Fuzzy AHP	Using multilayer QFD to evaluate service quality of Kansai airport in Japan.
Show-Hui S. Huang, Wen-Kai K. Hsu (2016)	An assessment of service quality for international distribution centers in Taiwan- a QFD approach with fuzzy AHP	Using fuzzy AHP and QFD to investigate international distribution center. It uses SERVQUAL as service quality dimension. The results find out the operators should promote the usage of warehouses, enhance staff's professional ability and establish better information system.

4. Empirical study

Service quality of maritime express industry is explored to evaluate service quality and several technical requirements are applied to express customer requirements and service provider requirements.The design of the questionnaire in this study can be divided into two parts. The first part is shippers of maritime express and the second part is service providers of maritime express. They may have different opinions about service quality, so this study conducts a survey that considers both of their thoughts. By comparing their differences, the improvement strategies can be implemented easily and convincing. This study use maritime express in Taiwan as example. We apply multilayer QFD to investigate service quality of maritime express in Taiwan. There are three types of questionnaires which are customer requirement questionnaire, service provider questionnaire, and expert questionnaire which asked 13 experts to complete. Each of them was delivered 20 copies. The return rates are 70%, 75%, 100% respectively. The rates of valid questionnaires are 65%, 65%, and 87% respectively. By combing AHP and multilayer QFD, the main results are as follow.

According to the previous texts, when consistency ratio is lower than 0.1, the result is convincing. The CR of customer questionnaire is 0.006 and the CR of service provider questionnaire is 0.013. Both of them are lower than 0.1, so the results are persuasive. According to the results of AHP, the most important attributes of customer requirements are “Reliability of service performance”, “Accurate delivery”, and “Speed of service performance”. The most important attributes of service provider requirements are “Having the ability of understanding customer requirements”, “Ability of cargo tracing” and “Staff having emergency handling ability”. The results about “Exploring new sailing routes”, the relative weight of customer is 0.11(Table 10), but the relative weight of service provider is only 0.056 (Table11). This means that there are differences of thoughts between customer and service provider. If we use traditional QFD, the results may have bias and it can’t show that the improvement strategies which need to be implemented urgently and effectively.

This study reviews some literature and arranges the customer requirements and service provider requirements. After checking by experts, we can propose 12 improvement strategies to be the technical requirements. By using HoQ of three dimensions to rank the priorities of improvement strategies, the results consider not only customer demand but also service provider’s viewpoint. Therefore, the results are more persuasive. This study uses AHP to calculate the relative weight of customer requirement and service provider requirement. Then, we can use conflict resolution matrix to calculate both of customer and service provider new relative weight so that we can use these results to bring into the HoQs. By calculating three dimensions HoQ, we can obtain priorities rank of technical requirements. The most important improvement strategies are “Personnel training”, “Setting the standard service processes”, and “Modernizing IT platforms”.

Table 7: Conflict Resolution Matrix

	Column No.	1	2	3	4	5	6	7	8	9	10	11	12			
	Relative weight	0.084	0.11	0.089	0.086	0.073	0.082	0.066	0.068	0.111	0.074	0.074	0.083			
Relative weight		Reasonable operating costs	Ability of cargo tracing	Staff having emergency handling ability	Effectively and accurately handling important documentation	Good company's reputation	Sufficient waypoints	Stable financial condition	Perfect infrastructure	Having the ability of understanding customer requirements	Good management strategies	Having good relationship with shippers	Ability of handling customer complaint	Sum of products	Relative weight	Weight after cross-synthesis
0.08	Shipment tracing capability	3.4	7.7	6.7	6.3	4.7	4.3	2.8	4.7	6.3	5.6	5.9	5.7	5.491	0.074	0.077
0.081	Speed of service performance	5.0	6.0	5.3	5.7	5.0	6.0	3.2	5.3	5.6	5.6	5.7	4.3	5.276	0.071	0.076
0.12	Reliability of service performance	5.7	6.3	6.3	7.0	4.7	5.3	3.6	5.0	5.0	5.0	5.0	3.9	5.309	0.071	0.096
0.054	Staff’s attitude and behavior	2.9	4.7	7.3	5.3	5.6	3.2	3.6	2.9	6.0	5.6	5.7	7.3	5.079	0.068	0.061
0.047	Quick response to customers’ inquiries and requests	2.8	5.3	7.3	4.7	4.6	2.8	3.2	4.3	6.7	4.9	5.3	7.3	5.043	0.068	0.057
0.045	Company’s reputation	4.0	4.7	6.3	4.7	7.7	3.6	6.3	4.9	6.3	6.7	6.0	6.3	5.587	0.075	0.060
0.068	Range of delivery	5.3	6.3	4.6	4.7	3.6	7.0	3.6	5.3	4.6	5.3	4.3	2.9	4.848	0.065	0.067
0.084	Accurate delivery	4.3	7.0	6.0	6.0	4.3	4.3	4.0	4.7	5.3	4.6	6.3	4.0	5.152	0.069	0.077
0.055	Compensation	5.0	4.8	6.6	5.0	6.7	2.3	5.0	3.3	4.0	6.0	5.3	6.7	5.036	0.068	0.061
0.065	Schedule	4.6	5.6	3.8	4.6	4.0	6.7	3.3	3.9	5.0	4.7	4.3	2.8	4.508	0.061	0.063
0.077	Reasonable price	8.0	4.3	4.2	5.0	4.0	3.3	4.3	4.7	4.0	4.3	3.3	3.3	4.403	0.059	0.068
0.053	Emergency handling ability	3.6	5.3	9.0	4.9	4.7	2.9	2.9	4.3	6.3	4.6	4.7	7.0	5.129	0.069	0.061
0.055	Information system performance	3.3	7.3	3.6	4.6	4.0	2.9	3.3	5.3	3.9	3.9	2.9	3.9	4.163	0.056	0.056
0.067	Accurate documentation	4.0	4.0	5.0	7.7	4.9	3.2	3.0	4.0	5.3	4.0	4.6	4.0	4.532	0.061	0.064
0.049	Door-to-door service	4.7	5.7	3.6	4.6	4.5	4.3	3.3	3.9	5.7	4.3	6.7	4.3	4.695	0.063	0.056
	Sum of products	4.611	5.778	5.679	5.561	4.771	4.324	3.638	4.510	5.266	4.975	5.059	4.689			
	Relative weight	0.078	0.098	0.096	0.094	0.081	0.073	0.062	0.077	0.089	0.085	0.086	0.080			
	Weight after Cross-Synthesis	0.081	0.104	0.093	0.090	0.077	0.078	0.064	0.072	0.100	0.079	0.080	0.081			

Table 8: House of quality matrix for customers' requirements

Row No.	Relative weight		Modernizing IT platforms	Personnel training	Strategic alliances	Exploring new sailing routes	Flexible delivery	More capacity	Setting the standard service processes	Frequent service	Unbinding more regulations	Holding regular seminar for reviewing customer services	Signing trade agreement between cross-strait	Focusing on corporate social responsibility
1	0.077	Shipment tracing capability	7.3	6.0	2.9	5.0	4.3	1.8	7.0	1.9	2.8	2.2	2.4	3.6
2	0.076	Speed of service performance	5.9	5.7	4.7	5.0	5.6	4.5	6.3	4.7	2.1	2.2	2.9	4.6
3	0.096	Reliability of service performance	4.7	6.0	4.3	5.0	5.7	3.8	5.9	3.9	2.5	3.3	1.8	3.3
4	0.061	Staff's attitude and behavior	3.1	8.3	2.9	5.0	4.6	1.6	5.9	1.8	1.8	3.8	2.0	2.5
5	0.057	Quick response to customers' inquiries and requests	5.0	7.9	2.3	5.0	2.5	0.9	5.9	1.1	2.8	3.9	1.3	2.9
6	0.060	Company's reputation	5.2	5.7	4.0	5.0	4.3	2.8	4.6	2.9	2.1	3.6	2.8	5.9
7	0.067	Range of delivery	4.3	4.0	3.3	5.0	4.3	5.2	5.3	5.3	2.3	2.2	3.8	2.0
8	0.077	Accurate delivery	5.3	6.7	4.0	5.0	4.8	1.7	4.5	1.8	2.2	3.3	2.8	2.8
9	0.061	Compensation	3.1	4.6	2.3	5.0	3.0	1.6	5.7	1.8	2.0	3.3	2.3	4.3
10	0.063	Schedule	5.6	4.5	3.5	5.0	4.0	5.5	4.6	5.7	2.4	1.8	2.0	2.8
11	0.068	Reasonable price	3.9	4.2	3.0	5.0	3.3	2.5	3.8	2.7	1.6	2.1	1.7	2.0
12	0.061	Emergency handling ability	5.2	9.0	2.5	5.0	3.2	1.7	6.6	1.8	1.3	3.5	1.7	2.7
13	0.056	Information system performance	8.3	5.6	2.2	5.0	3.3	1.3	5.3	1.4	2.1	2.5	2.3	2.3
14	0.064	Accurate documentation	6.3	7.7	2.9	5.0	2.8	1.6	5.7	1.8	2.8	2.1	1.7	2.9
15	0.056	Door-to-door service	4.8	6.3	5.3	5.0	4.6	3.4	5.7	3.6	2.5	2.9	2.0	2.2
		Sum of products	5.198	6.105	3.393	5.000	4.104	2.700	5.525	2.867	2.223	2.823	2.244	3.144
		Relative weight	0.115	0.135	0.075	0.110	0.091	0.060	0.122	0.063	0.049	0.062	0.050	0.069
		Rank of improvement strategies	3	1	6	4	5	10	2	8	12	9	11	7

Table 9: House of quality for service providers' requirements

Row No.	Relative weight		Modernizing IT platforms	Personnel training	Strategic alliances	Exploring new sailing routes	Flexible delivery	More capacity	Setting the standard service processes	Frequent service	Unbinding more regulations	Holding regular seminar for reviewing customer services	Signing trade agreement between cross-strait	Focusing on corporate social responsibility
1	0.081	Reasonable operating costs	4.3	2.8	3.2	1.5	3.9	2.7	5.0	4.3	1.4	1.4	1.4	2.8
2	0.104	Ability of cargo tracing	6.3	5.3	3.6	1.8	4.8	1.8	6.6	4.8	1.4	2.5	1.4	2.8
3	0.093	Staff having emergency handling ability	3.8	7.7	2.5	1.5	3.8	1.4	5.9	3.8	1.1	3.5	1.3	3.1
4	0.09	Effectively and accurately handling important documentation	3.9	6.3	2.8	1.1	3.2	1.6	5.9	4.3	1.8	1.8	1.1	2.6
5	0.077	Good company's reputation	4.3	5.0	3.9	2.1	3.8	2.8	5.3	4.5	1.5	4.3	2.5	6.6
6	0.078	Sufficient waypoints	3.9	2.5	4.3	7.0	4.3	5.6	3.2	5.2	2.9	2.2	3.7	2.5
7	0.064	Stable financial condition	3.3	2.5	2.6	2.9	2.7	3.3	3.7	4.3	1.4	2.3	1.4	3.9
8	0.072	Perfect infrastructure	6.7	2.8	2.9	3.0	3.6	4.0	4.7	4.7	2.3	1.1	1.3	1.8
9	0.1	Having the ability of understanding customer requirements	3.8	6.3	2.5	1.4	5.3	2.1	4.4	3.8	1.1	5.0	1.5	2.8
10	0.079	Good management strategies	4.2	4.0	3.3	1.8	2.8	2.2	5.6	4.3	1.5	3.3	1.8	2.9
11	0.08	Having good relationship with shippers	4.6	5.8	3.0	1.9	5.3	1.8	4.3	5.6	1.5	3.9	1.8	2.2
12	0.081	Ability of handling customer complaint	3.7	6.9	2.1	1.5	3.2	1.3	5.3	3.4	1.1	4.3	1.7	1.8
		Sum of products	4.412	4.979	3.041	2.211	3.950	2.458	5.042	4.378	1.558	2.997	1.706	2.949
		Relative weight	0.111	0.125	0.077	0.056	0.100	0.062	0.127	0.110	0.039	0.076	0.043	0.074
		Rank of improvement strategies	3	2	6	10	5	9	1	4	12	7	11	8

Table 10: Selection objectives

		Modernizing IT platforms	Personnel training	Strategic alliances	Exploring new sailing routes	Flexible delivery	More capacity	Setting the standard service processes	Frequent service	Unbinding more regulations	Holding regular seminar for reviewing customer services	Signing trade agreement between cross-strait	Focusing on corporate social responsibility
Customer	Sum product	5.198	6.105	3.393	5.000	4.104	2.700	5.525	2.867	2.223	2.823	2.244	3.144
	Relative weight	0.115	0.135	0.075	0.110	0.091	0.060	0.122	0.063	0.049	0.062	0.050	0.069
Service provider	Sum product	4.412	4.979	3.041	2.211	3.950	2.458	5.042	4.378	1.558	2.997	1.706	2.949
	Relative weight	0.111	0.125	0.077	0.056	0.100	0.062	0.127	0.110	0.039	0.076	0.043	0.074
Synthesis	Mean relative weight	0.113	0.130	0.076	0.083	0.095	0.061	0.124	0.087	0.044	0.069	0.046	0.072
	Priority rank	3	1	7	6	4	10	2	5	12	9	11	8

5. Conclusion and Suggestions

This study uses multilayer QFD to investigate service quality of maritime express and it uses customer requirements and service provider requirements to transform into technical requirements (improvement strategies). According to the results, the strategy that needs to be implemented urgently is “Personnel training”. Maritime express is an innovative industry that uses the geographical position between Taiwan and China. This study have referred that maritime express is still in early stage of development. It means that the staff of maritime express may not have enough experience. They need to enhance their works so that they can improve the efficiency and service quality. Therefore, service provider should hold more personnel training courses and distribute more budgets to this part to improve the service quality.

The second strategy that needs to be implemented is “Setting the standard service process”. As the study mentioned above, maritime express is still in the early stage of development, so the staffs may not familiar with their works. If service provider can set the standard service process to provide a manual for staff to follow, and in accordance with this process to design a perfect staff training courses, it will not only improve the operating efficiency but also reduce the error rate when the staffs are working so that they can improve service quality of maritime express.

The third strategy that needs to be implemented is “Modernizing IT platform”. In the era of e-commerce gradually rising, when customers make orders online, they will care about the status of the orders definitely. If service provider can modernize IT platform with cargo tracking system, it can let customers realize the status of their orders at any time so that it can improve service quality. Additionally, if service provider can use the IT platform to establish word mouth, it can surely attract more potential customers to increase the cargo volume. By modernizing IT platform can also easily to realize the customers’ preference and consolidate data so that it can provide better service to customers in the future.

Other improvement strategies of rank are as follow, “Flexible delivery”, “Frequent service”, “Exploring new sailing routes”, “Strategic alliances”, “Focusing on corporate social responsibility”, “Holding regular seminar for reviewing customer services”, “More capacity”, “Signing trade agreement between cross-strait”, “Unbinding more regulations”.

Maritime express is a new and innovative industry so the research about this industry is few. Therefore, it is difficult to collect relative information. Additionally, it is a difficult work to find appropriate experts and customers to fill the questionnaire, so this study only investigates the service quality of maritime express in

Taiwan. We do not consider the customers and service providers in China. It suggests that future research investigate the service quality of maritime express both of Taiwan and China and figure out the improvement strategies that can be implemented both in Taiwan and China.

6. Acknowledgement

Authors are thankful for support from Ministry of Science and Technology MOST 105-2410-H-019-014.

References

Akao, Y. (2004). Quality function deployment.

Akao, Y., & Mazur, G. H. (2003). The leading edge in QFD: past, present and future. International Journal of Quality & Reliability Management 20(1): 20-35.

Ayağ, Z. (2014). An intelligent approach to prioritize logistics requirements in food industry. International Journal of Supply Chain Management, 3(4).

Baki, B., Sahin Basfirinci, C., Murat AR, I., & Cilingir, Z. (2009). An application of integrating SERVQUAL and Kano's model into QFD for logistics services: a case study from Turkey. Asia Pacific Journal of Marketing and Logistics 21(1): 106-126.

Bhattacharya, A., Sarkar*, B., & Mukherjee, S. K. (2005). Integrating AHP with QFD for robot selection under requirement perspective. International journal of production research 43(17): 3671-3685.

Bulut, E., Duru, O., & Huang, S.T. (2016). A multidimensional QFD design for the service quality assessment of Kansai International Airport, Japan. Total Quality Management & Business Excellence, 1-23.

Chan, L.K., & Wu, M.L. (2002). Quality function deployment: A literature review. European Journal of operational research 143(3): 463-497.

Chen, K.K., Chang, C.T., & Lai, C.S. (2009). Service quality gaps of business customers in the shipping industry. Transportation Research Part E: Logistics and Transportation Review 45(1): 222-237.

Chen, M.C., Chang, K.C., Hsu, C.L., & Yang, I.C. (2011). Understanding the relationship between service convenience and customer satisfaction in home delivery by Kano model. Asia Pacific Journal of Marketing and Logistics 23(3): 386-410.

Chen, M.C., Hsu, C.L., & Lee, Y.Y. (2012). Applying quality function development to develop the home delivery service model for specialty foods in traditional market. Paper presented at the 2012 IEEE International Conference on Industrial Engineering and Engineering Management.

Chou, P. F., & Lu, C. S. (2009). Assessing service quality, switching costs and customer loyalty in home-delivery services in Taiwan. Transport Reviews 29(6): 741-758.

Ding, J.-F., Chou, M.-T., Yeh, I.-C., Yang, Y.-L., Chou, C.-C., & Shyu, W.-H. (2016). An Evaluation of Key Service Effectiveness of Keelung Port. Journal of Marine Science and Technology 24(2): 174-183.

Ding, J.F., Shyu, W.H., Yeh, C.T., Ting, P.H., Ting, C.T., Lin, C.P., Wu, S.S. (2016). Assessing customer value for express service providers: An empirical study from shippers' perspective in Taiwan. Journal of Air Transport Management 55: 203-212.

Duru, O., Huang, S. T., Bulut, E., & Yoshida, S. (2013). Multi-layer quality function deployment (QFD) approach for improving the compromised quality satisfaction under the agency problem: A 3D QFD design for the asset selection problem in the shipping industry. Quality & Quantity 47(4): 2259-2280.

Durvasula, S., Lysonski, S., & Mehta, S. C. (2002). Understanding the interfaces: How ocean freight

Gil Saura, I., Servera Frances, D., Berenguer Contri, G., & Fuentes Blasco, M. (2008). Logistics service quality: a new way to loyalty. Industrial Management & Data Systems, 108(5): 650-668.

Govers, C. P. (1996). What and how about quality function deployment (QFD). International journal of production economics 46: 575-585.

Hauser, J. R. (1993). How Puritan-Bennett used the house of quality. Sloan Management Review, 34(3), 61.

Ho, W. (2008). Integrated analytic hierarchy process and its applications–A literature review. European Journal of operational research 186(1): 211-228.

Ho, W., He, T., Lee, C. K. M., & Emrouznejad, A. (2012). Strategic logistics outsourcing: An integrated QFD and fuzzy AHP approach. Expert Systems with Applications, 39(12): 10841-10850.

Hsu, C.L., Lin, C.S., & Chen, M.C. (2011). Exploring logistics services quality in home delivery industry: do service providers and customers have different viewpoints? Journal of Quality 18(5): 439-454.

Hsu, W.K. K., Yu, H.F., & Huang, S.H. S. (2015). Evaluating the service requirements of dedicated container terminals: a revised IPA model with fuzzy AHP. Maritime Policy & Management 42(8): 789-805.

Hu, K. C., & Huang, M. C. (2011). Effects of service quality, innovation and corporate image on customer's satisfaction and loyalty of air cargo terminal. International Journal of Operations Research 8(4): 36-47.

Huang, S. T., Bulut, E., & Duru, O. (2015). Service quality assessment in liner shipping industry: an empirical study on Asian shipping case. International Journal of Shipping and Transport Logistics 7(2): 221-242.

Huang, S. T., Bulut, E., Duru, O., & Yoshida, S. (2012). Service quality evaluation of international logistics company: an empirical case using QFD approach. Journal of International Logistics and Trade 10(3): 31.

Huang, S.-H. S., & Hsu, W.-K. K. (2016). Evaluating the service requirements of combination air cargo carriers. Asia Pacific Management Review 21(1): 1-8.

Karsak, E. E. (2004). Fuzzy multiple objective programming framework to prioritize design requirements in quality function deployment. Computers & Industrial Engineering 47(2): 149-163.

Ladhari, R. (2008). Alternative measures of service quality: a review. Managing Service Quality: An International Journal 18(1): 65-86.

Lam, J. S. L., & Bai, X. (2016). A quality function deployment approach to improve maritime supply chain resilience. Transportation Research Part E: Logistics and Transportation Review.

Lam, J. S. L., & Dai, J. (2015). Developing supply chain security design of logistics service providers: an analytical network process-quality function deployment approach. International Journal of Physical Distribution & Logistics Management, 45(7): 674-690.

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. Total Quality Management & Business Excellence 17(5): 539-554.

Liberty Times Net website: http://news.ltn.com.tw/news/world/breakingnews/1199418, last accessed in March 2017.

Liu, Y., Chen, X., & Dong, D. (2015). Study on the Service Quality Evaluation Research on Express Based on the Customer Perceptive LISS 2014 (pp. 933-938): Springer.

Lu, C. S. (2007). Evaluating key resources and capabilities for liner shipping services. Transport Reviews 27(3): 285-310.

Matzler, K., & Hinterhuber, H. H. (1998). How to make product development projects more successful by integrating Kano's model of customer satisfaction into quality function deployment. Technovation 18(1): 25-38.

Paixão Casaca, A. C., & Marlow, P. B. (2005). The competitiveness of short sea shipping in multimodal logistics supply chains: service attributes. Maritime Policy & Management 32(4): 363-382.

Park, Y., Choi, J. K., & Zhang, A. (2009). Evaluating competitiveness of air cargo express services. Transportation Research Part E: Logistics and Transportation Review 45(2): 321-334.

Shahin, A., & Chan, J. (2006). Customer requirements segmentation (CRS): A prerequisite technique for quality function deployment (QFD). Total Quality Management & Business Excellence 17(5): 567-587.

shipping lines can maximize satisfaction. Industrial Marketing Management, 31(6): 491-504.

Thai, V. V. (2008). Service quality in maritime transport: conceptual model and empirical evidence. Asia Pacific Journal of Marketing and Logistics 20(4): 493-518.

Transportation Research Part E: Logistics and Transportation Review, 45(2): 321-334.

Vinh, V., Tay, W. J., Raymond, T., & Alan, L. (2014). Defining Service Quality in Tramp Shipping: Conceptual Model and Empirical Evidence.

Wang, R.T. (2007). Improving service quality using quality function deployment: The air cargo sector of China airlines. Journal of Air Transport Management 13(4): 221-228.

Xu, J., Jiang, L., & Li, Y. (2013). Service requirement for terminal delivery: An empirical study from the perspective of online shoppers. Journal of Industrial Engineering and Management 6(4): 1223-1237.

Yoon, S.-H., & Park, J.-W. (2015). A study of the competitiveness of airline cargo services departing from Korea: Focusing on the main export routes. Journal of Air Transport Management 42: 232-238.

Identification and Analysis of the Evolution of Port Shipping Industry in Hong Kong

Zhongzhen Yang, Dongxu Chen and Qinghui Xiu*

College of Transport Management, Dalian Maritime University, 1 Linghai Road, Liaoning 116026, Dalian, China. Email: yangzz@dlmu.edu.cn

Corresponding author

Abstract

Based on spatial pattern statistics, the paper analyses the spatial pattern trend of the Hong Kong port shipping industry development by selecting 21 Chinese coastal ports as the research object and collecting the container data from 2001 to 2015. The result shows that from 2001 to 2015, the spatial distribution of China's container throughput is showing a tendency of moving from Hong Kong port to the northeast coastal city. By comparing the development trend of Hong Kong port and mainland China port shipping industry and combining Hong Kong container transit from 2001 to 2015, the paper further identifies that the China's port center is moving from Hong Kong to the inland, the pivotal position of Hong Kong port is gradually weakened in the international trunk transportation and the development speed is slowing down. The paper analyses the reasons that the Hong Kong port shipping industry is slow down from the angles of the spatial distribution of goods demand, port infrastructure, location conditions, port handling fees, port opening policy and so on. Combining with the development environment of Hong Kong shipping industry insurance and ship market and the current situation and development trend of world maritime transport under the background of the “ one belt, one road”, the paper puts forward the development opportunity and development strategy of Hong Kong port shipping industry under the maritime Silk Road strategy, and provides the development direction of Hong Kong port shipping industry.

Keywords: Hong Kong port; Spatial pattern statistics; Development trend; Cause analysis

1. Introduction

From 1940s to 1990s, Hong Kong Port has been developing rapidly, and Hong Kong Port became the world's largest container port with 8 million TEU throughput in 1992. However, since 2001, the increment speed of Hong Kong Port container throughput has slowed down, and the title of the largest container port was replaced by Singapore in 2005. The recession of Hong Kong Port is not only because of the change of the economy structure of HK and the whole world, but also the participant of the China mainland into the International economic cycle and rapid development of port logistics industry. Therefore, it is necessary to analyze and identify the evolution process of the port shipping industry in Hong Kong and study the causes of the slow development of Hong Kong port in the 21 Century, putting forward the Countermeasures for the development of Hong Kong port shipping logistics.

In recent years, many scholars have studied the development trend of Hong Kong port shipping industry， Zhu Dashou introduce the development process of Hong Kong port in twentieth Century, who has become a free port and an international shipping center and has a great impact on the economic development of Hong Kong. But after entering the twenty-first Century, the development of Hong Kong port is not satisfactory. Lin Jingwen first affirmed the shipping center status of the Hong Kong port, but in recent years, the loss of cargo of Hong Kong port made the competitiveness of Hong Kong port reduce. K Cullinane, WT Fei, S Cullinane proposed that the rapid development of China's ports reduced the competitiveness of Hong Kong port. At the same time, Wang Yanbin put forward that the lack of talent and lack of government support are also important reasons for the slow development of Hong Kong port. In order to improve the speed of the development of Hong Kong port, Liu Kaizhi, Xu Zhihua, Cao Xiaoshu think that Hong Kong port should comply with the overall development of the Maritime Silk Road, seeking cooperation with the ports along the Maritime Silk Road.

Therefore, based on the standard deviation ellipse in direction distribution of the spatial pattern statistics and combined with the comparative analysis of the development trend of Hong Kong port and mainland China port, the paper identify whether there is a trend of China's port center moving from Hong Kong to inland. And combining with the development trend and challenger of Hong Kong port, the paper studies the cause of slow development of Hong Kong port to present the development strategy of Hong Kong port shipping logistics.

2. Analysis on the Evolution of Hong Kong Port and Mainland China Port

2.1 Analysis of port container throughput trend in Hong Kong

Since the mid 1960s, Hong Kong port had the container cargo, and in 1969, the container throughput is up to 12000TEU. Until 1970s, Hong Kong Kwai Chung container terminal officially put into use, and container ports in Hong Kong have entered the stage of rapid development. The paper selects the container throughput of Hong Kong port from 1978 to 2000 to analyze the development trend of Hong Kong port shipping industry. Trend of container throughput in Hong Kong port from 1978 to 2000 is shown in figure 1.

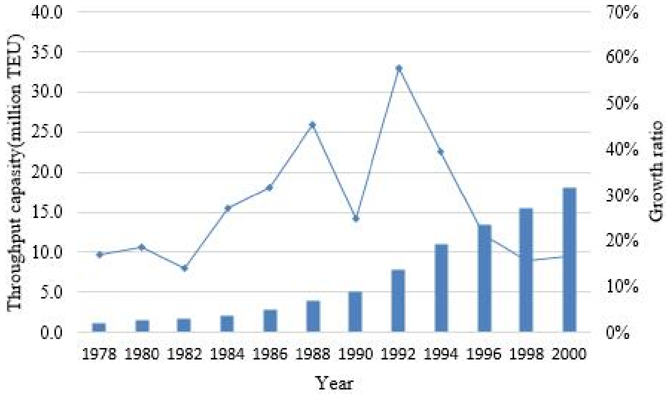


Figure 1: Trend of Hong Kong port container throughput from 1978 to 2000
Source: Hong Kong Shipping Statistics

From 1978 to 2000, Hong Kong port container throughput increased from 1.23million TEU to 18.1 million TEU, and the lowest growth rate was about 10%, the highest reached 50%, and the rest of the year remained at about 20%, much higher than the same period of the development of Singapore port, Rotterdam port, etc. In 1992, Hong Kong port container throughput is up to 7.92million TEU, becoming the world's largest container port.

Trend of container throughput in Hong Kong port from 2001 to 2015 is shown in figure 2.

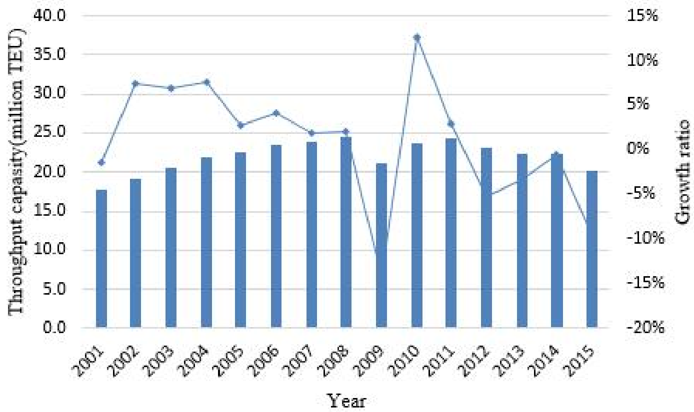


Figure 2: Trend of Hong Kong port container throughput from 2001 to 2015
Source: Hong Kong Shipping Statistics

From 2001 to 2015, container throughput growth rate continued to be lower than 10%, much lower than the growth rate of higher than 20% in 1990s. Since the global financial crisis in 2008, Hong Kong port container throughput began to reverse the trend of growth, and from 2012 to 2015, container throughput in Hong Kong port has been reversed the trend of growth the for four consecutive years. Thus, since twenty-first Century, the development speed of Hong Kong port is slow down.

2.2 The comparative analysis of the development trend of Hong Kong port and ports at home and abroad

In order to further analysis the development trend of Hong Kong port since 2001, this paper analyses the trend of port container throughput in Hong Kong and mainland China and neighboring countries from 2001 to 2015, shown in figure 3.

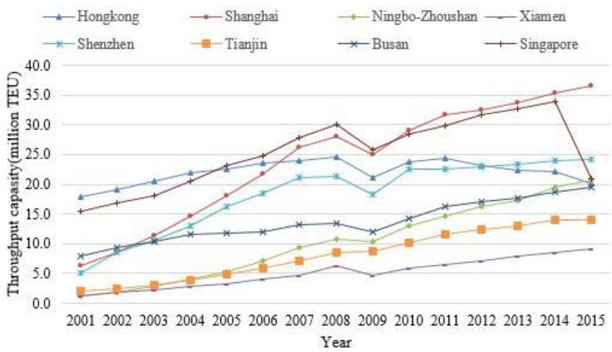


Figure 3: Trends comparison of port container throughput

Source: China Port Yearbook

We can see that the container throughput of Hong Kong port in 2001 is still much higher than that of mainland China port, Busan port and Singapore port and so on, but from 2001 to 2015 the growth rate of container throughput of mainland China port, Busan port and Singapore port is up to 15% and that of Hong Kong port is only up to 2%. Thus, in the context of the same shipping market, the development speed of Hong Kong port (especially container port) is far less than the development speed of major mainland China ports, Busan port and Singapore port. The title of the largest container port in China was replaced by Shanghai port in 2007.

By comparing the development speed of Hong Kong port with that of mainland China port from 2001 to 2015, the paper identifies that the development speed of Hong Kong port is slow down since 2001.

2.3 Analysis of spatial pattern evolution of Hong Kong and domestic ports

Standard deviation ellipse is an important method to analyze the distribution characteristics of container freight throughput, and the barycenter of the standard deviation ellipse indicates the relative position of the spatial distribution of container throughput. The paper select the standard deviation ellipse to describe the spatial pattern of Chinese ports to analyze the change of the position of Hong Kong port in the spatial pattern of Chinese ports to further identify the development trend of Hong Kong port.

Standard deviation ellipse is shown as formula (1) and formula (2).

$$SDE_x = \sqrt{\frac{\sum_{i=1}^{n}\left(x_i - \bar{X}\right)^2}{n}} \tag{1}$$

$$SDE_x = \sqrt{\frac{\sum_{i=1}^{n}\left(y_i - \bar{Y}\right)^2}{n}} \tag{2}$$

The paper Selecting 21 China coastal ports including Hong Kong port, Shanghai port ,Shenzhen port and so on and using standard deviation ellipse, the paper analyses the variety of The spatial pattern of container throughput of China coastal port from 2001 to 2015 and determine whether the barycenter of the container throughput is gradually deviated from Hong Kong port and then determine whether the development speed of Hong Kong port shipping is slow down. Using the ArcGis, the paper gets the spatial pattern of port container throughput from 2001 to 2015, shown as figure 4.

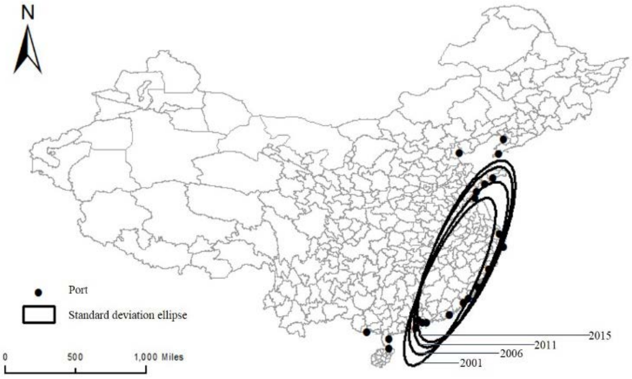


Figure 4: Container throughput pattern change from 2001 to 2015

Figure 4 shows standard deviation ellipse of the mainland China port and Hong Kong port container throughput. It can be seen that the barycentric of the ellipse moves gradually, and the interior space of the ellipse expands. Namely, from2001 to 2015, the spatial distribution of container throughput of Hong Kong port and mainland China port presents the pattern of moving from south (near to Hong Kong, slighting westing) to north (far away Hong Kong ,slightly easting). We can see that the inner region of the standard deviation ellipse is the Yangtze River Delta Port Group in 2015, which explains that the spatial pattern of container throughput in Hong Kong port and mainland China port has obvious evolution characteristics, which can be summarized as moving away from Hong Kong to the northeast and spatial expansion.

In order to further study the evolution characteristics of Chinese ports, based on the barycentric coordinates of standard deviation ellipse of container throughput from 2001 to 2015, the paper gets the moving track of the barycentric of standard deviation ellipse of container throughput, shown in figure 5.

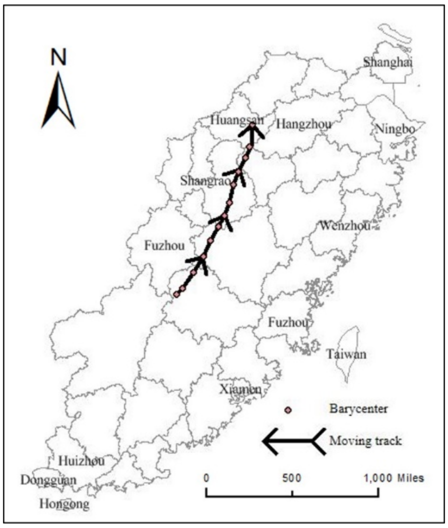


Figure 5: Barycenter moving track of standard deviation ellipse

Accroding to the figure 5, from 2001 to 2015, the barycenter of the container throughput of Hong Kong port and mainland China port moves from Fujian to Jiangxi, and then to Anhui, namely away from Hong Kong to the Yangtze River Delta region. Thus, the growth rate of container throughput of mainland China port is faster than that of Hong Kong port. Compared with the Hong Kong port, the effect of mainland ports on the overall development of China's ports is more obvious.

2.4 Analysis of transit container volume of Hong Kong port

With the rapid rise of Shenzhen Yantian port and Pearl River Delta port, transit cargo volume of Pearl River Delta through Hong Kong decreased from 90% before twenty-first Century to 30% - 40%.

In addition, according to statistics released by Hong Kong Shipping Statistics, Hong Kong transshipment volume accounting for the total inland container volume decreased from 4.9% to 2.2%; at the same time, we found that transshipment volume through Hong Kong port to the Asian countries decreased from 4.74 million TEU to 4.13 million TEU.

Thus, the ability of Hong Kong port to attract transit cargo dropped, and pivotal position of Hong Kong port in international trunk transportation weakened gradually, further identifying the trend of the slow development speed of Hong Kong port.

3. Cause Analysis of the Evolution of Hong Kong Port Shipping Industry

The reason of the slow development speed of Hong Kong port shipping industry is the change of Hong Kong and the global economic structure and the results of China's economic participation in the international economic cycle and the rapid development of port logistics industry. These changes are mainly reflected in the spatial distribution of demand for goods transportation, port infrastructure and charges, location conditions, government policies, etc.

3.1 The spatial distribution of demand for goods transportation

After reform and open, China's cheap land, labor prices and the preferential policies presented by the mainland China government to attract the foreign investment attract Hong Kong's original manufacturing industry to transfer to the mainland China. The decrease of the demand for the transportation of the exports of manufactured goods in the direct hinterland of Hong Kong port – Hong Kong affected the development of Hong Kong port. At this point, the operation of Hong Kong port only relies on the mainland cargo or the transit cargo.

At the same time, with the development of mainland ports, the ability of Hong Kong port attracting the mainland cargo gradually decline. Since 2000, the proportion of the mainland China cargo through Hong Kong continues to decline, shown as figure 6.

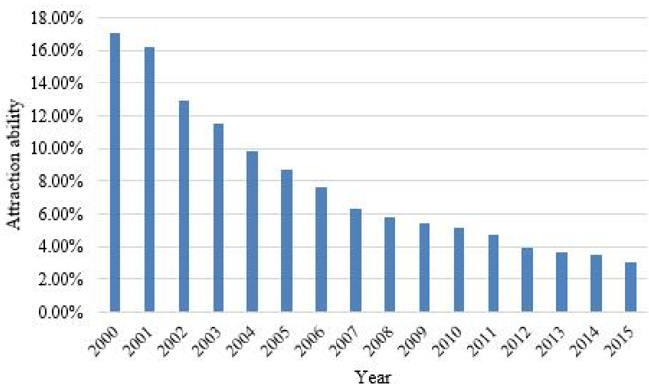


Figure 6: Capacity of Hong Kong port to attract inland cargo from 2000 to 2015

According to figure 6, the proportion of mainland China export cargo through Hong Kong changed from 17.07% to 3.06% from 2000 to 2015. The proportion of mainland China export cargo through Hong Kong has dropped significantly, which is the main reason that affects the development of Hong Kong port.

3.2 The impact of port infrastructure on the development of Hong Kong port

In order to further analyze the reasons for the decline of the proportion of mainland China cargo through Hong Kong, the paper further analyzes the development of Hong Kong port and Chinese port infrastructure.

Before the 1990s, there was no hub port in mainland China, and Hong Kong port is the gateway for Chinese cargo. After the 1990s, the port of mainland China enters a stage of rapid development. For example, in 1993, Yantian Port Group and Hutchison Whampoa jointly built 5 container berths, and in 2001, built 4 container berths of 50 thousand ton. Until 2013, Shanghai port has 45 container berths, and the main container port of Hong Kong port is located in Kwai Chung and Tsing Yi, including 24 berths, accounting for 53% of the muber of container berths in Shanghai port. The capacity of the mainland ports and the ability to anchor the ship is much higher than Hong Kong. For example, the 18 thousand TEU container ship can berth at Shanghai yangshan port. Restricted by geographical conditions, Hong Kong port throughput capacity cannot meet the needs of China export cargo, resulting in part of the export demand shift to the mainland.

3.3 The impact of port location on the development of Hong Kong port

With the development of port facilities and throughput capacity of mainland China ports, the regional advantages are gradually emerging, shown in figure 7.

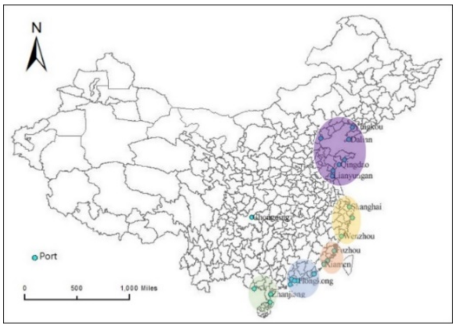


Figure 7: Distribution of Chinese ports

Compared with Hong Kong port, the direct hinterland of mainland China ports is big. For example, Shanghai port currently has China maximum hinterland resources, whose direct hinterland is Shanghai, whose second layer hinterland is Jiangsu, Zhejiang, Anhui and Jiangxi, whose outer hinterland is the Yangtze River, Longhai and The area along the Zhejiang Jiangxi Railway. For the hinterland of China, port to land transportation network of mainland China is more developed, greatly reducing the cost of transportation to land compared with Hong Kong. At the same time, the major ports of mainland China (such as Shanghai port) also has obvious geographical advantages.

3.4 The impact of port charges on the development of Hong Kong port

Taking Hong Kong port, Shanghai port and Shenzhen port as an example, in 2015, Hong Kong port terminal handling charge is significantly higher than mainland China ports, shown as figure 8, which is the important reason that a large number of goods abandon the Hong Kong port as an export port.

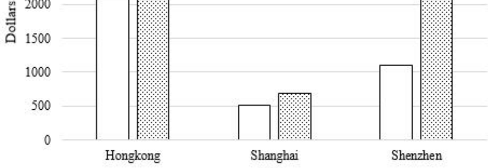


Figure 8: Port handling charges

3.5 The impact of port related policies on the development of Hong Kong port

As a famous transit port in the world, the initial development of the Hong Kong port is mainly due to the implementation of the policy of opening to the outside world, any cargo is free in and out Hong Kong, just declaration for 14 days in advance. However, since China's accession to the World Trade Organization (WTO), foreign businessmen can control the operation of China's mainland ports, to a certain extent, weakening the competitiveness of the Hong Kong port as a hub of transit hub. Since twenty-first Century, the Chinese government has gradually relaxed the port policy, and has set up a number of bonded port and free trade zone. The bonded port area is entitled to be bonded, tax-free and free of license. Foreign goods entering the bonded area need not pay customs duties, and domestic goods entering the bonded port area shall be regarded as export, and the tax refund shall be implemented. With the establishment of bonded port area in China, the policy advantage of Hong Kong port is gradually weakened. China's existing coastal bonded port area and Chongqing bonded port area is shown as Figure 9.

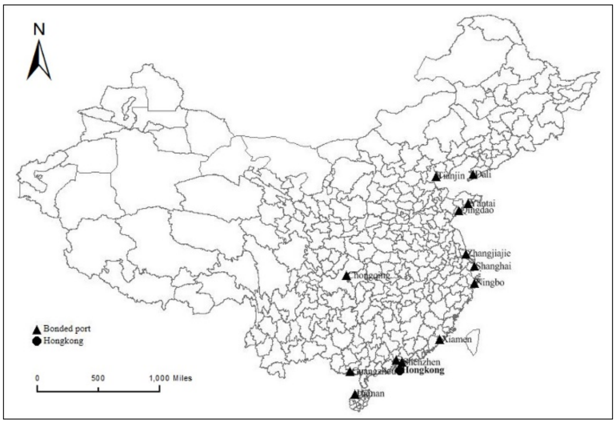


Figure 9: Distribution of bonded port

In addition, the police of entry into the zone before declaration in free trade zone further increases the demand for port hinterland cargo. Shanghai free trade zone was set up in 2013. Within 1 year, 14 thousands businesses were set in the trade zone, 160 overseas investment projects succeeded, China's foreign investment was up to 3.8 billion dollars, import customs clearance speed increased by 41.3%, the level of corporate earnings increased by 20%, 6925 free trade account were set, and deposit was up to 4.89 billion RMB. With the rapid development of free trade zone, Shanghai free trade zone has introduced the ship registration policy, the port of departure tax rebate policy, the negative list management system, coastal incidentally policy, which further enhance the port competitiveness of mainland China ports.

4. Analysis on the Challenge of Port Shipping Development in Hong Kong

Since twenty-first Century, the development of Hong Kong port is facing further challenges, which includes relevant policies of port shipping industry and manufacturing industry transfer effect on world shipping patterns under the background of “One Belt, One Road” (OBOR).

4.1 The challenges to Hong Kong port brought about the innovation policies of port shipping industry

With China's accession to the WTO, China's ports gradually open to the outside world, and the rapid development of the port has gradually threatened the status of Hong Kong port. At present, the Chinese government is committed to develop shanghai shipping center, and based on the free system, location advantage and price police of Shanghai port, Shanghai port will further seize the market share of Hong Kong port.

At the same time, other governments are implementing the relevant innovative policies of the port shipping industry. For example, in order to consolidate the Singapore port as an international shipping hub port, the government of Singapore use tax, financing and other preferential policies to promote the Singapore port to transform the shipping center with the comprehensive, high-end services including ship registration, ship financing and so on. Singapore's innovative policies enhance the competitiveness of the Singapore port as a transit port.

However, unlike most of the ports in the world, Hong Kong port facilities, port supervision has been owned, managed and operated by the private sector, and the government of Hong Kong has not yet implemented measures related to port development. Therefore, the policy support has become an important challenge for the future development of Hong Kong port.

4.2 The challenge to Hong Kong port brought about industry transfer under the background of OBOR

Since 2011, with the development of economic society, land costs, capital costs, labor costs and management costs in mainland China, especially in the developed coastal areas have risen sharply, and China's manufacturing industry has gradually lost its geographical advantages, and China's manufacturing industry is showing the sign of recession. Labor cost and other cost along the Maritime Silk Road are significantly lower than that in China, therefore, the countries along the Maritime Silk Road have gradually become the place that undertakes the industrial transfer. It can be predicted that with the deepening of the maritime Silk Road strategy, in the next 10-20 years, the manufacturing industry will transfer to the countries along the Maritime Silk Road. By then, the share of the product made in China in the global consumer market is likely to have a substantial decline, while the share of the product made in other countries along the Maritime Silk Road will gradually rise. The number of goods shipped from China to North America and Europe will probably decrease, and the number and share of goods shipped from other countries will rise gradually. The result is that the structure of global ocean transportation system will change. The hub port in China including Hong Kong port will lose its position, and the main route may be reduced to a branch line, which brings new challenges to the development of Hong Kong port.

On the other hand, since the proposal of OBOR, China actively develops cooperation with countries along the Maritime Silk Road to promote the development of domestic and foreign trade. Because of the cooperation with the countries along the Silk Road, the mainland China port will be further internationalized, hub port status of Hong Kong port will be further challenged. The main route of the Maritime Silk Road is shown in figure 10.

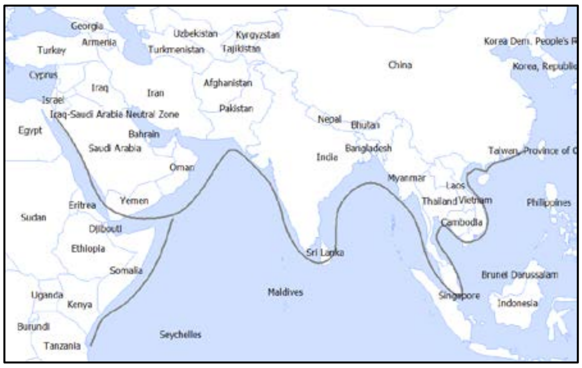


Figure 10: The Twenty-first Century Maritime Silk Road

The cooperation of the domestic ports and the countries along the Maritime Silk Road promotes the rapid growth of the port of Shanghai, the Pearl River Delta and the inland port, which can be seen that Hong Kong will be further hit.

5. Development Opportunities and Suggestions of Port Shipping in Hong Kong

5.1 Opportunities brought about ship registration and insurance industry to Hong Kong port

Compared with the mainland China, Hong Kong has a distinct advantage in ship registration. In Hong Kong, the time of registration is short and the cost is low, so many ships are registered in Hong Kong. As of the end of 2015, 48 thousands of single ship companies were attracted to register in Hong Kong, the number of ships registered in Hong Kong has reached 2247, the number of Hong Kong local ship reached 153, the total tonnage of the ship reached 1.022 tons, which bring great opportunities for the development of Hong Kong shipping.

A large number of ships registered in Hong Kong promote the rapid development of marine insurance business in Hong Kong. According to Office of the Commissioner of Insurance in Hong Kong, in 2013, the ship underwriting profit was up to $35.1 million, and in 2014, was up to $99.4 million, reversing the situation of negative profits of Hong Kong ship insurance industry for many years. At the same time, the advantages of the insurance business will further attract more ships to register in Hong Kong, forming a positive feedback between ship registration and marine insurance business. The development of Hong Kong ship registration and marine insurance business promotes the development of shipping industry in Hong Kong, and brings opportunities for the development of Hong Kong port.

Therefore, Hong Kong port should take advantage of the advantages of the ship registration and insurance industry to provide high-end shipping services, further to the ship berthing and the cargo transiting.

5.2 Opportunities brought about OBOR

As of the end of 2015, trade volume between China with the related countries along the Maritime Silk Road accounted for about 1/4 of Total Export-Import Volume, more than 50 foreign trade and Economic Cooperation Zone were invested to construct, contracted projects exceeded 3000, contracted amount undertaking service outsourcing in the related countries was up to $17.83 billion, and amount of money involved in execution was up to $12.15 billion, an increase of 42.6% and 23.4%, respectively. OBOR not only promotes the development of mainland China, but also brings opportunities for the development of Hong Kong port shipping.

In twenty-first Century, the main direction of the Maritime Silk Road was from the Chinese coastal ports to the Indian Ocean and South pacific, extending to Europe. According to Hong Kong Shipping Statistics, container throughput of the countries along the Maritime Silk Road through Hong Kong port import and export accounted for 66.5% the global container throughput through Hong Kong port import and export, accounting for more than one half. Figure 11 shows the proportion of container throughput of other countries through Hong Kong port.

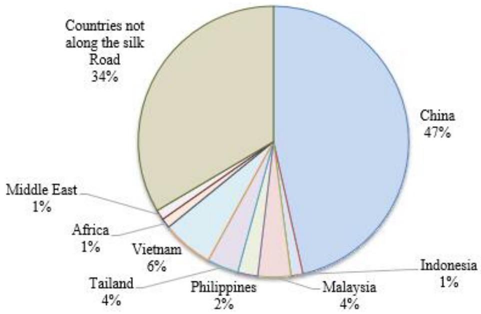


Figure 11: Container throughput of every country through Hong Kong import and export

According the figure 10, the container throughput of Asian countries accounts for 73.9. Among the countries along the Maritime Silk Road, Hong Kong port contacts close with the Asian countries, especially the Southeast Asian countries, so the focus of future development of Hong Kong should actively explore the international transfer transport business, and actively cooperate with the ports along the Maritime Silk Road to build a maritime silk road network, and enhance the connectivity and accessibility of sea transportation along the Maritime Silk Road. At the same time, Hong Kong also can not give up the cooperation with America and Africa and stick the policy of going out to attract more companies related with shipping, logistics and procurement to invest Hong Kong, building Hong Kong into the regional headquarters and operations center of these companies.

6. Conclusion

According to the data of the port container throughput, transit volume, based on spatial pattern statistics, the paper identifying the trend of the slow development of Hong Kong port shipping industry, and analyze the causes from the perspective of Hong Kong and the global economic structure and the development of China's economy and port logistics industry. Finally, combining with the development environment of Hong Kong shipping industry insurance and ship market and the current situation and the background of the “ one belt, one road”, the paper puts forward the challenge, the development opportunity and development strategy of Hong Kong port shipping industry.

The contribution of this paper can be described as followings:

Theoretical aspects: 1) Establish the theoretical system of port shipping industry trend identification. Namely, first of all, we collect the data of Hong Kong port's throughput, and identify the development trend of Hong Kong port shipping industry; second, compared the development trend of Hong Kong port and domestic and foreign ports, this paper analyzes the development speed of the port in the same context of shipping industry; and then, based on the statistical analysis of spatial pattern, this paper further identifies that the port barycenter is transferring from Hong Kong to the inland and the pivotal position of Hong Kong port in the international trunk transportation is gradually weakening; last, from the point of port function positioning, this paper analyzes the situation of Hong Kong port transit and verifies the trend of Hong Kong port development. 2) Establish the system of the cause identification of port shipping industry development trend. Namely, this paper analyzes the reasons for the slow development trend of Hong Kong port shipping industry from the perspectives of the spatial distribution of goods demand, port infrastructure, location conditions, port handling fees and port opening policy.

Practical aspects: 1) According to the present situation of Hong Kong port and the background of port shipping industry and the competitive situation, the paper analyses the port development challenges from the perspectives of Hong Kong port policy and global and national policy development (for example: One Belt, One Road). 2) Combining with the development environment of Hong Kong shipping industry insurance and ship market and the current situation and development trend of world maritime transport under the background of the “ one belt, one road”, the paper puts forward the development opportunity and development strategy of Hong Kong port shipping industry under the maritime Silk Road strategy, and provides the development direction of Hong Kong port shipping industry.

References

Zhu Dashou. Brief analysis of the development of port and shipping industry in Hong Kong. Table of contents of abstracts and conference papers of Chinese maritime Society, (1990-1991). 1992.

Lin Jingwen. The worry for Hong Kong shipping center status. Pearl River water transport, 2016(4):16-16.

Kevin Cullinane, Wang Teng Fei, Sharon Cullinane. Container Terminal Development in Mainland China and Its Impact on the Competitiveness of the Port of Hong Kong. Transport Reviews, 2004, 24(1):33-56.

Wang Yanbin. The development of Hong Kong shipping industry and the construction of international shipping center. World shipping, 2014, 37(10):19-24.

Liu Kaizhi, Xu Zhihua, Cao Xiaoshu. Opportunities and Challenges of Hong Kong's Port Development under the 21st Century Maritime Silk Road. China famous cities, 2016(2):11-18.

Zhao Zuoquan. Spatial Pattern Statistics and Spatial Economic Analysis. Science Press, 2014.

Yang huihui. Analysis on the Present Situation and Countermeasures of Shanghai Port Logistics Development. Logistics Technology, 2012(2):54-57.

Xie Shaohua. Some Thoughts on the Development of Hong Kong International Shipping Center. World shipping, 2011, 34(4):13-17.

Zhang A, Hui S L, Thai V V. Impacts of Global Manufacturing Trends on Port Development: The Case of Hong Kong. Asian Journal of Shipping & Logistics, 2015, 31(1):135-159.

Song D. W. Regional container port competition and co-operation: the case of Hong Kong and South China. Journal of Transport Geography, 2002, 10(2): 99-110.

Seabrooke W, Hui E C M, Lam W H K, et al. Forecasting cargo growth and regional role of the port of Hong Kong. Cities, 2003, 20(1): 51-64.

Wang Baojun, Shi Bin, Hilary I. Inyang. GIS-Based Quantitative Analysis of Orientation Anisotropy of Contaminant Barrier Particles Using Standard Deviational Ellipse. Soil & Sediment Contamination: An International Journal, 2008, 17(4):437-447.

The Impacts of Maritime Transportation and Regional Integration on Trade: With Special Reference to RCEP

Wei- Tzu Chiang[1], Yo-Yi Huang[2], Kuo-Chung Shang[3] and Shu-Man Chang[4]*

[1]Department of Transportation Science, National Taiwan Ocean University
[2]Institute of Applied Economics, National Taiwan Ocean University. Email: hyy@ntou.edu.tw
[3]Department of Transportation Science, National Taiwan Ocean University
[4]Department of Aviation & Maritime Transportation Management, Chang Jung Christian University

[*]*Corresponding author*

Abstract

Along with the trend of globalization, transport progress and regional integration will rise volume of trade. The proposed Regional Comprehensive Economic Partnership (RCEP) has drawn much interest both at the regional and international level. By the regional integration, RCEP member state accounted for a population of 3.4 billion people with a total gross domestic product of $21.4 trillion, approximately 30 percent of the world's GDP. Maritime performance inherently links to economies of commerce. Few studies have examined regional integration in the context of seaborne. Using the clustering analysis and gravity model, this paper investigates the evolution of likely trade-bloc phenomenon and relation between trade and marine transportation for the last decades. The major findings are summarized as follows: first, both liner shipping connectivity and logistics performance have significantly positive coefficient in the regression result for each year. Second, the intra-regional trade creations are not guaranteed, depending on the trade characteristics and the stage of economic development of the region. Third, for RCEP, the effect of intra-regional trade creation is better than EU. Instead, the nominal intra-RCEP trade was significantly below the real trading blocs in 2007, 2010, and 2015. Fourth, there exists a real trading bloc among the East Asia and Taiwan, and the bloc phenomenon becomes more and more significant especially in the 2007 and after. This result indicates to some extent that the trade flows within the Taiwan is far above the normal level implied by their corresponding economic conditions and the geographical relationship.

Keywords: Trade, RCEP, Liner Shipping Connectivity Index, Logistics Performance Index, Poisson Quasi-Maximum Likelihood

1. Introduction

We witnessed a proliferation of RTAs in the past decade, while Taiwan has mainly been on the sideline. Furthermore, mega RTAs that aim to deepen integration partnerships between countries with a major share of world trade and foreign direct investment (FDI) are under-going extensive negotiations. One very ambitious initiative is the Regional Comprehensive Economic Partnership (RCEP), which includes ten member states of the ASEAN, an oil rich Brunei, one global financial center of Singapore, the four-tiger of Indonesia, Malaysia, Philippines, and Thailand, the emerging high growth economy of Vietnam and the newly open Cambodia, Lao and Myanmar, and six other nations along the West Pacific Rim: Australia, China, India, Japan, South Korea and New Zealand. As shown in Table 1, the RCEP as a whole has more than 600 million population, composed of of an oil rich Brunei, one global financial center of Singapore, the four-tiger of Indonesia, Malaysia, Philippines, and Thailand, the emerging high growth economy of Vietnam and the newly open Cambodia, Lao and Myanmar. By population size, AEC has 8.7% of the world total, which is greater than EU, making AEC the world's largest common market. However, in terms of the economy scale of GDP, AEC is far below EU and NAFTA. Its total GDP of 2.6 trillion US dollar account for only 3.2% of the world's, ranked only the 7th place in the world. It seems that ASEAN has not been successful in making advantages from forming a large economic region. Members in the RCEP are closely economically connected to Taiwan. For instance, in 2015 exports to RCEP members consist of 57.26% of Taiwan's total exports. In addition, from 2003 to 2015 Taiwan's outward FDI to RCEP members represent 80.20% of Taiwan's total outward FDI.

Table 1: Economic Profile of RCEC Members (2015)

Country	Area	Population	GDP	GNI per capita	VOT
	(KM^2)	(Thousand)	(Billion)	(US)	(1000 Million)
Singapore	717	5,535	292.0	52,090	6,433.8
Brunei	5,770	423	12.9	38,010	9.6
Malaysia	328,550	30,331	296.7	10,570	375.1
Thailand	510,890	67,959	395.3	5,720	417.1
Indonesia	1,811,570	257,563	861.9	3,440	8.9
Philippines	298,170	100,699	292.4	3,550	128.9
Vietnam	310,070	91,703	193.6	1,990	327.4
Lao PDR	230,800	6,802	12.4	1,740	6.7
Cambodia	176,520	15,577	15.5	1,070	19.6
Myanmar	653,520	53,897	62.8	1,160	29.1
China	9,597,000	1,371,220	11,008.0	790	39,560.0
Korea	97,480	50,617	1,377.9	27,450	9,634.3
Japan	364,560	126,958	4,383.1	38,840	12,504.4
New Zealand	263,310	4,596	173.8	40,020	708.9
Australia	7,682,300	23,781	1,339.1	60,070	3,879.1
India	2,973,190	1,311,051	2,095.4	1,600	6,551.0
Subtotal	25,304,417	2,338,766	22,812.80	-	80,593.8
Taiwan	36,197	2,349	524.53	22,288	5,225.6

Source: World Bank (WDI 2016), http://asean.org, and Taiwan Statistical Data Book 2016

Table 2: Maritime Transport Performance for RCEP Members and Taiwan

County	LPI		LSCI		Port		Container handled	
	Index	Rank	Index	Rank	Index	Rank	TEU	Rank
Singapore	4.07	6	117.13	2	6.66	2	34,832,376	3
Hong Kong	3.95	9	116.76	3	6.35	5	22,300,000	6
Japan	3.94	10	68.82	15	5.4	22	20,744,461	8
Australia	3.8	18	32.02	47	4.99	35	7,524,343	24
Korea	3.69	25	113.2	4	5.23	27	23,796,846	4
China	3.6	29	167.13	1	4.55	54	181,635,245	1
New Zealand	3.52	35	20.07	67	5.47	20	3,250,908	36
Malaysia	3.51	36	110.58	5	5.57	17	22,718,784	5
Thailand	3.34	46	44.43	32	4.49	57	8,283,756	21
India	3.25	52	45.85	29	4.21	69	11,655,635	14
Vietnam	3.07	66	46.36	28	3.91	90	9,531,076	18
Indonesia	3.03	67	26.98	56	3.81	99	11,900,763	13
Philippines	2.93	72	18.27	71	3.22	135	5,869,427	27
Cambodia	2.77	88	6.69	109	3.71	102	288,905	96
Myanmar	2.35	174	6.23	112	2.62	163	244,887	97
Lao	2.23	184	2.37	129	2.18	170	-	-
Brunei	1.44	201	4.56	134	-	-	128,026	107
Average	3.21		55.73		4.26		21,453,261	
Taiwan	3.71	24	76.22	13	-	-	14,491,654	11

Source: WDI, UNCTAD and authors' calculations

The performances of maritime transportation within RCEP are shown in Table 2. On the whole, China, Singapore, Hong Kong, Malaysia, and Korea have the greatest performances within RCEP. In term of LSCI (liner shipping connectivity index, hereafter LSCI) the average performance of RCEP countries is about 55.73. China, Hong Kong, Singapore, Korea and Malaysia are ranked within the top world ve countries with the LSCI indices. Of those RCEP countries, the average performance of LPI (logistics performance index, hereafter LPI) is about 3.21. The top three countries with higher LPI index are Singapore (ranking 6), Hong Kong (ranking 9) and Japan (ranking 10). In term of quality of port infrastructure, the rankings came in the order of Singapore (ranking 2), Hong Kong (ranking 5). From Table 2, one can see that China (ranking 1), Singapore (ranking 3), Korea (ranking 4), Malaysia (ranking 5), Hong Kong (ranking 6) and Japan (ranking 8) have the highest performances, world top 10, in container handled.

Logistics originally focused on the analysis of the supply chain in order to optimise the flow of components necessary for production processes. The literature includes research on logistics in the EU. Focusing on countries in Eastern Europe, Vilko et al. (2011) linked logistics to growth, finding that a country with insufficient infrastructure can grow if that infrastructure is used in an innovative way, as in the case of Estonia. Behar and Manners (2008) use the 2005 LPI to ascertain the relationships that exist between bilateral trade and logistics. In the same vein, but unlike other papers in the literature, Behar and Manners (2008) analyze the impact of logistics performance on EU exports over the period 2005{2010 in order to detect possible advances on behalf of Member States. Various gravity equations will be estimated using the LPI and its components as proxy variables to represent trade facilitation. Abe and Wilson (2009) examine how port infrastructure affects trade and role of transport costs in driving exports and imports for the region. They found that the port congestion had significantly increased the transport costs to East Asia from both of the United States and Japan.[i] Puretas et al. (2014) find that improvement in their logistics performance is resulting in significant increases in their volume of exports. The recent literature on logistics and trade is providing a very useful body of information for both the authorities responsible for designing transport and trade policy and also interested private parties.

Therefore, this paper focus of new empirical work done for this study is on the potential impact on trade. Earlier studies that have discussed and/or provided estimates of the benefits to the RCEP plan from improved transport and supply chain connectivity are cited. Marine transportation performance inherently links to economies of commerce. Few studies have examined regional integration in the context of maritime transportation, reflecting a lack of hybrid studies involving trade economists and maritime logistics researchers. This paper attempts to examine the impact of RCEP on the flow of international trade, the performance of seaborne transportation, and the creation of additional demand for transport services for port and containerized cargoes. The implementation of RCEP is expected to increase port and containerized cargoes in long run.

The rest of this paper is organized as follows: Section 2 provides the empirical methods, introducing two complementary approaches to be adopted to identify a trading bloc, that is, the hierarchical cluster analysis and the gravity model. Accordingly, the PQML empirical gravity equation is designed and corresponding hypothesis are introduced. Section 3 provides the empirical results and section 4 concludes.

2. Empirical Method

Theoretically, a trading bloc can be de ned as a group of countries characterized by relatively higher intra-group trade than `normal' level. Thus, two empirical methods are sequentially conducted in the study. They are firstly, the hierarchical cluster analysis, and then the gravity model to investigate rigorously whether a trading bloc identified by the cluster analysis exists. Furthermore, if a `real' trading bloc and/or `nominal' RTA (such as EU, NAFTA, ASEAN even RCEP) do matter significantly in certain years, then we would like to use the gravity model to examine how the trade intensity within the group has changed over time. For a bloc of disintegrating over time, the intra-group trade intensity would be expected to be declining. On the contrary, a bloc of getting more integrated, we would expect higher and higher trade intensity within the group.

2.1 Cluster Analysis on Bilateral Trade Intensities and LSCI

The hierarchical cluster analysis based on bilateral trade (or liner shipping connectivity) intensity to identify bloc of countries with strong trade linkage. More specifically, the first step is to compute the bilateral trade intensity (denoted as T_{ij}), which is de ned as the ratio of trade volume (or liner shipping connectivity) between the countries of i and j to the total volume of world trade (or liner shipping connectivity). That is,

$T_{ij} = (X_{ij} + X_{ji})/\sum\sum X_{ij}$, X_{ij} where X_{ij} denotes the value of export from country i to j for a given commodity. The inverse of T_{ij}, i.e. $1/T_{ij}$ is then to represent the `distance' between countries i and j. The economic intuition for this setup is clear. That is, the higher the trade intensity between countries, the smaller the `economic distance' in between, and the more reasonable be regarded as being belong to the same cluster. The second step is to link the countries into hierarchical clusters according to the density linkage algorism. That is, in the beginning when each country represents its own cluster, the distance is simply the distance represented by the inverse of bilateral trade intensity de ned as above. For clusters containing more than one element, the distance is de ned as the average distance of the closest element in each cluster. All the countries will finally be linked together to form trading blocs, and the resulting blocs tend to represent long chains, as can be illustrated by a tree diagram.

The bilateral trade data are from the UN's COMTRADE data. Two years of 2007 and 2015 are selected for analysis. For every year, the RCEP countries and Taiwan in VOT share in the world trade are included for clustering. The results are described by tree diagram of Figure 1 and 2 for the bilateral trade and liner shipping connectivity respectively, and discussions will be made in section 3.1.

Each of the identified trading blocs is then based on to establish a regional dummy in the gravity equation, and will be tested econometrically to examine whether the bloc's intra-group trade intensity is increasing or decreasing over the last decades.

2.2 Gravity Equation Estimation

The gravity model has been widely adopted in trade literature to explain bilateral trade from the determinants of geographical distance, market size represented by, population, GDP and national incomes, etc., as well as the intangible distances of culture and language, etc. Using the gravity model to examine the HME can be found in Davis and Weistein (2003), Head et al. (2002), Medin (2003), Schumacher and Siliverstovs (2006), Crozet and Trionfetti (2008), Ghazalian and Furtan (2009), Huang and Huang (2011, 2016). Theoretically, if the advantage of the domestic market size matters, then we should observe a greater effect of the export country's GDP (market size variable) than that of the import country's GDP. Intuitively, if the RTA integrated market size does enhance the HME for member countries, then the HME-coefficient should be greater for the related member countries.

Let $LVOT_{ij}$ = log(VOT_{ij}) and the same notation applies to other variables. The basic gravity equation as following:

$$LVOT_{ij} = \alpha + \beta_1 LGDP_i + \beta_2 LGDP_j + \beta_3 LDIST_{ij} + \beta_4 LRPPP_{ij} + \beta_5 RGN_{ij}^k + \beta_6 CNT_{ij}^r + \mu_{ij} \quad (1)$$

where, $LVOT_{ij}$be the log of country i's trade to j, and$LGDP_i$, and $LGDP_j$are i and j's output level; $LDIST_{ij}$ the bilateral distance, $LRPPP_{ij}$ the relative price level; RGN_{ij}^k the dummy variable for regional integration, RGN_{ij}^k= 1 if both i and j belong to the same RTA, otherwise $RGN_{ij}^k = 0$. In addition, CNT_{ij}^r is a contiguity dummy, which is de ned as follows: If both country i and j are of the r cluster (for example, common language, border, or cultural background), then CNT_{ij}^r = 1, otherwise $CNT_{ij}^r = 0$ =, and $\mu_{ij}$the error terms.[ii]

Theoretically, if the estimated coefficient of β_1, is significantly greater than that of β_2, then home-market effect is empirically supported. In addition to the conventional determinants, the regional dummy is included to capture trade creation of the regional FTA. As usual, positive $_5$ represents the existence of trade creation.

We use some indices to measures country-specific maritime transport-related performances, such as liner shipping connectivity index (LSCI), logistics performance index (LPI), and container traffic by countries (TEU). UNCTAD's LSCI aims at capturing how well economies are connected to global shipping networks. The higher the index value, the easier it is to access a high capacity and high frequency global maritime freight transport system and thus effectively participate in international trade. Accordingly, the empirical equation for one-year sample is as below:

$$LVOT_{ij} = \alpha + \beta_1 LGDP_i + \beta_2 LGDP_j + \beta_3 LDIST_{ij} + \beta_4 LRPPP_{ij} + \beta_5 RGN_{ij}^k + \gamma_1 LLSCI_i + \gamma_2 LLSCI_j + \gamma_3 LLPI_i + \gamma_4 LLPI_j + \gamma_5 LTEU_i + \gamma_6 LTEU_j + \gamma_7 Border_{ij} + \gamma_8 \mathrm{ComLng}_{ij} + \mu_{ij} \quad (2)$$

2.3 PQML Approach

Instead of using the OLS method, the PQML approach is adopted to estimate the revised gravity equation of Eq. (2). Practically, the bilateral trade data contains many zero observations. The usual approach to overcome the problem of taking logarithm on a zero number, is to replace zero with a tiny number, or simply discard the sample points. However, the approach has been criticized for its biased result. Alternatively, PQML (Poisson Quasi-maximum likelihood) approach is introduced as in Santos Silva and Tenreyro (2006), Siliverstovs and Schumacher (2009), Santos Silva and Tenreyro (2011). By PQML approach the sample of zero export observations are retained, and the estimation bias from OLS can be avoided. To use the PQML on the gravity equation, Eq.(2) is rewritten in exponential form as Eq.(3) shown below

$$E\left(VOT_{ij} \middle| Z_{ij}\right) = \exp\left[\alpha + \beta_1 LGDP_i + \beta_2 LGDP_j + \beta_3 LDIST_{ij} + \beta_4 LRPPP_{ij} + \beta_5 RGN_{ij}^k + \gamma_1 LLSCI_i + \gamma_2 LLSCI_j + \gamma_3 LLPI_i + \gamma_4 LLPI_j + \gamma_5 LTEU_i + \gamma_6 LTEU_j + \gamma_7 Border_{ij} + \gamma_8 ComLng_{ij} + \mu_{ij}\right] \quad (3)$$

where Z_{ij}= (1; GDP_i; GDP_j; $DIST_{ij}$;…) denotes the vector of all the explanatory variables. Thus, the PQML procedure offers a viable alternative to the traditional OLS estimation procedure for consistent estimation of the parameters of the gravity model in the original multiplicative form. An additional advantage of the PQML estimator is that because there is no more need for logarithmic transformation of the dependent variable, the problematic handling of observed zero trade flows is no longer an issue in this procedure.

By Eq.(3), we would expect $\beta_1 > \beta_2$ to see the existence of the conventional HME; and $\beta_3 < 0$(distance effects) ; $\beta_5 > 0$ (trade creation under regional integration); and $\beta_4 > 0$ (relative price level effects); $\gamma_i > 0$ (maritime transport effect).

To summarize, the main hypothesis to be examined in this paper are the following:

1. $\beta_1 > \beta_2$, for the existence of conventional HME,
2. $\beta_5 > 0$ for or conventional trade creation effect under regional integration, such as EU, ASEAN, RCEP, etc. and
3. $\gamma_i > 0$ for a enhanced effect on trade under better performance in maritime transport or logistic.

Keeping in mind the theoretical predictions about the transport effect, we expect positive coefficients for the LPI, LSCI, TEU. Theoretically, better efficiency of transport modes for the export and/or import country implies reducing transport time and lower trade costs. That is, the coefficient of transport variables are expected to be positive ($\gamma_i > 0$) in equation (3) to re ect reduction in trade barriers.

2.4 Data

The bilateral trade data are from the UN COMTRADE database. Three years of 2007, 2010 and 2015 are selected for analysis. We construct global trade for each country during the sample period, includes 182 countries. Observations are used for overall one-digit SITC code, including 10 industries. For every year, the RCEP and Taiwan countries in VOT share in the world trade are included for clustering, to be listed in Table 3, and Table 4 for the liner shipping. The results are described by tree diagram of figure 1 and 2 for the trading blocs and shipping blocs respectively, and discussions will be made in section 3 and 4. Each of the identified trading blocs is then based on to establish a regional dummy in the gravity equation, and will be tested econometrically to examine whether the bloc's intra-group trade intensity is increasing or decreasing over the last three decades. It will be helpful to introduce the gravity model before we proceed further.

To estimate the gravity equation of (3), we need data on bilateral trade flows (VOT_{ij}), geometrical distance between any pair of countries to represent the transport cost ($DIST_{ij}$),[iii] general price level of the import countries (PPP_i),[iv] and more importantly the performance of maritime transport of each country. Variables to be used in the regression is reported in Table 3.

Table 3: List of variables

Variables	Description
GDPi	GDPi The export country's gross domestic product, retrieved from the World Development Indicators, World Bank.
GDPj	GDPj The import country's gross domestic product, also retrieved from the World Development indicators, World Bank.
DISTij	DISTij The transport distance between country i and j, the sum of sea and inland routes that is calculated between major ports.
RPPPij	RPPPij The ratio of country i's real exchange rate and country j's real exchange rate, sourced from the World Development Indicators, World Bank. That is, the relative real exchange rate between country i and j.
LSCIj	LSCIj The country i's liner shipping connectivity index, also retrieved from the WDI. LPIj The country i's logistics performance index, also retrieved from the WDI.
LPIj	LPIj The country i's logistics performance index, also retrieved from the WDI.
TEUi	TEUi The country i's TEU of container handled, also retrieved from the WDI.
EU	EU Regional integration dummy, Europe Union, member countries Austria, Belgium, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Poland, Portugal, Slovak Republic, Slovenia, Spain, Sweden, United Kingdom.
NAFTA	NAFTA RI dummy. North American Free Trade Area, including US, Canada and Mexico.
RCEP	RCEP Dummy variable equal to 1 if RCEP countries.
EAcore	EAcore Dummy variable equal to 1 if the country belong the core of trading blocs in RCEP and Taiwan.
Borderij	Borderij Dummy variable equal to 1 if countries i and j share a common land border.
ComLngij	ComLngij Dummy variable equal to 1 if countries i and j have a common language.
EAcore	EAcore Core trading bloc dummy variable in East Asia. EAcore, including Japan, Korea, Hong Kong, Singapore

See Figure 1A and 1B

3. Empirical Method and the Results

3.1 Empirical Results from Cluster Analysis

a) Bilateral Trade Flows among RCEP and Taiwan

The results of the hierarchical cluster analysis of bilateral trade ows (VOT) among RCEP and Taiwan for 2007 and 2015 are described by Dendrograms (tree diagrams) in Figure 1A and 1B respectively. Theoretically, the gure reveals the trading intensity within a given cluster. The higher the cluster fusion density the more intensive the intra-cluster trade ows. A somewhat arbitrary level of density threshold is taken while reading the outcome, as represented by the dotted line in each gure. Two important features of the trade could be identi ed from the results:

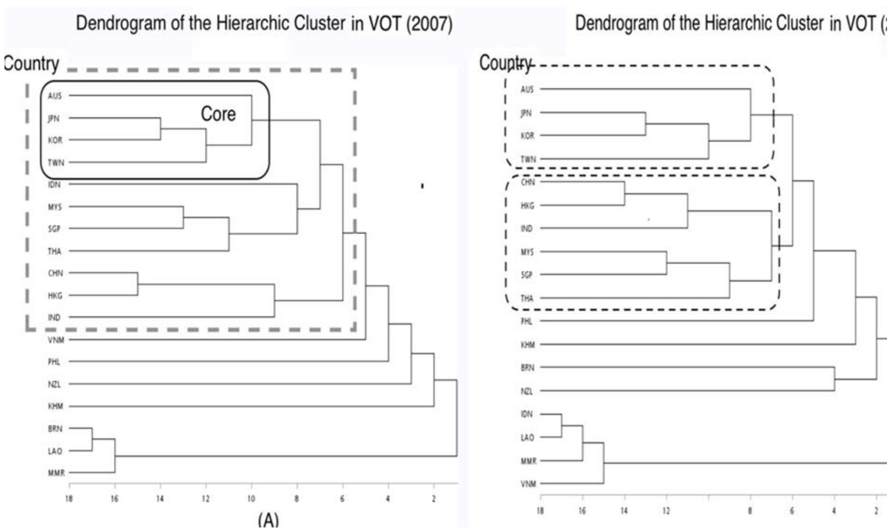
i. Two-bloc phenomenon in bilateral trade

Two distinct trading blocs could be identi ed during the last decades. First, as shown in the result for 2007 (Figure 1A), we could easily pin down only one trading blocs in RCEP. The blocs is mainly composed of countries in East Asia i.e., Japan, Four Asian Tigers (Korea, Hong Kong, Singapore and Taiwan), China, Australia and Tiger Cub Economies (Malaysia, Thailand, Indonesia), in which the rst four countries (Japan, Korea, Taiwan and Australia) are relatively more integrated than the other two and hence denoted as the core of the group.

ii. Rising China-Tiger Cub Economies Bloc

Besides the case in 2007, it seems that the trading blocs are to some extent reecting a geographical distribution. That is, a country seems to trade more with closer countries. The two-bloc pattern appears in the results for 2015 (Figure 1B) although some minor changes in the country composition and the degree of trade intensity within each group can be observed in the gures. In sum, according to the bilateral trade intensities, only one trading bloc in the industry could be identi ed by the cluster analysis. However, the core countries vary over the last decades. There are two bloc phenomenon in 2015, the core countries were mainly composed of the Japan, Korea, Taiwan and Australia from East Asia. Then, the core countries gradually changed to countries from East-South Asia, leading by Japan and then followed by other Asian countries such as South Korea, Taiwan, China, Hong Kong, Indonesia, Singapore, and Malaysia.

Figure 1: Cluster Analysis in Bilateral Trade Flows among RCEP and Taiwan



(B)

According to the cluster analysis, the two-bloc phenomenon is composed of a EA group in trade. Each of the identi ed core trading blocs is then based on to establish a regional dummy in which is mainly composed of countries in East Asia, hereafter called bloc EA_{core}. The corresponding EA_{core} bloc dummy is designed as below:

EA_{core}, representing the dummy variable of the East Asia bloc for year 2007 and 2015, takes value one if both trade partners, such as Japan, Korea, Hong Kong, Singapore, Taiwan, China, Malaysia, Thailand and Indonesia, belong to EA_{core} bloc for 2007 identified by cluster analysis (see Figure 1A), otherwise takes value zero. In the gravity equation, and will be tested econometrically to examine whether the bloc's intra-group trade intensity is increasing or decreasing over the last decades. It will be helpful to introduce the gravity model before we proceed further.

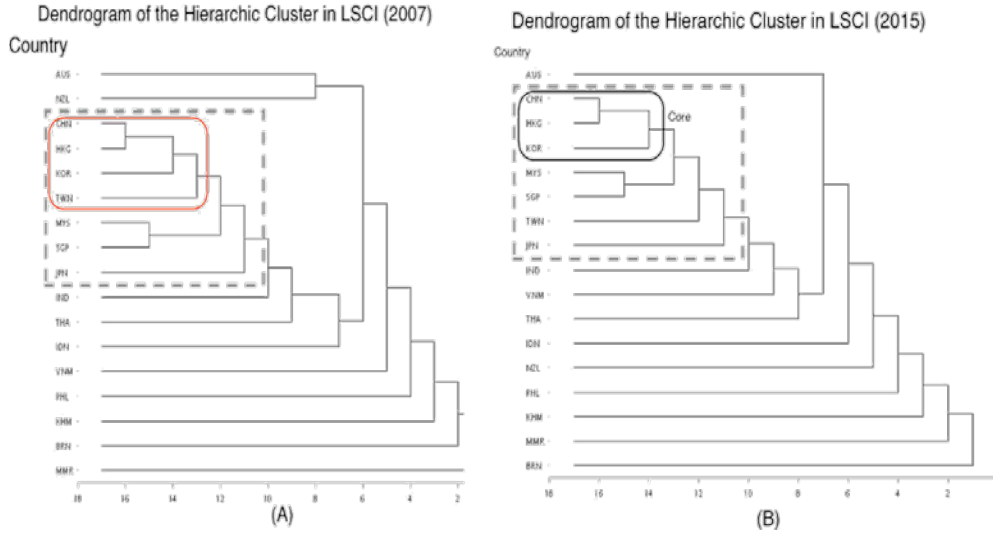
b) The relations of LSCI among RCEP and Taiwan

The results of the hierarchical cluster analysis of LSCI for 2007 and 2015 are described by Dendrograms (tree diagrams) in Figure 2A and 2B respectively. In the liner shipping market, as shown in the result for 2007 (Figure 2A), we could easily pin down only one LSCI blocs in RCEP. The blocs is mainly composed of countries in East Asia i.e., China, Hong Kong, Korea and Taiwan, Japan, Malaysia, Singapore, in which the first four countries (China, Hong Kong, Korea and Taiwan) are relatively the Chinese Three as the core of the group in liner shipping.

In addition, a roughly comparison between the corresponding density level for the year of 2007 and 2015, seems to indicate that the LSCI density within the North Asia Bloc seems to decline over the period; on the contrary the liner shipping intensity within the South Asia bloc increases. A rigorous method to confirm this observation is to use the gravity model to estimate empirically the trading bloc coefficient, and test whether the bloc coefficient has declined or not.

However, as will be illustrated later in the gravity model, there still exists a relatively higher intra-group trade even if the geographical factor (distance between countries) and the market size (GDP and GNP per capita) are taken into consideration.

Figure 2: Cluster Analysis in Liner Shipping Market among RCEP and Taiwan



3.2 Empirical Strategy

To focus in the most recent decade integration e ect, we select years of 2007, 2010 and 2015 as the observation windows. Strategically, we run the PQML gravity regression on each individual year, and analyze if the RTA, HME, maritime-transport have changed during the period, as designed below. Four types of model are designed. Firstly, Model (a) is the base model, only the basic gravity variables are included. In addition to $LGDP_i$; $LGDP_j$, $LDIST_ij$, $Border_{ij}$, $ComLng_{ij}$.

In Model (b) and (c), we add seaborne transportation indices, LSCI, LP I and T EU. For example: $LLSCI_i$ (export country's liner shipping connectivity index in UNCTAD) and $LLSCI_j$ (importer's liner shipping connectivity index) to capture the liner shipping connectivity difference between trade partners. Theoretically, a country with better performance in maritime transport should be able to export more. We expect a positive coefficient of ($LLSCI_i$ $LLSCI_j$) be positive, while the country with better performance in liner shipping.

Model (b) and (c) extends model (a), by including two types of regional dummy variables. The rst type is the nominal RGN dummy, including EU, NAFTA and RCEP. As de ned before, the RGN dummy takes value one if both the import and export countries are the members of the underling RGN, otherwise value zero. RGN_k to estimate the e ect of the RTA-induced market size effect. The second type is a core trading-blocs variable, EA_{core}, among RCEP and Taiwan in Figure 1. In addition, we consider Taiwan in Asia and the variable can apply to the of Taiwan. More specifically, dummy EA_{core} =1, if i refers to cluster in trading blocs, otherwise EA_{core} =0. If the estimated coefficient (EA_{core}-RCEP) is positive, then the real trading-blocs induced e ect is empirically supported.

3.3 Empirical Results

Table 5 to 7 report the regression result of the corresponding gravity equations for each year of 2007, 2010, and 2015. In addition to the standard results of the gravity model for the gravity coefficients, that is, positive coefficient of GDP, and negative coefficient of the distance (LDIST), several important findings regarding the maritime transportation and regional blocs identified in the cluster analysis can be found from Table 5 to 7.

Table 5 provides estimation results for alternative specifications of the PQML regression model in equation (3). Columns 2 (Model a) present results for the basic gravity model, Columns 3 (Model b) with country-level measures of seaborne transportation and the real trading bloc among the East Asia, EA_{core}. Columns 4 (Model

c) present regional integrations, EU, NAFTA and RCEP. In addition to the normal results for those standard gravity variables, GDP, and the distance, we can easily find that all the identified blocs, one in every year, have significantly positive coefficient. That is, the bloc found by the cluster analysis is also empirically supported rather nominal RECP by the gravity equation.

Another interesting experiment is to check the coefficient of distance. As commonly interpreted in the use of the trade gravity model, bilateral distance represents trading costs. As shown in the Model (a) of Table 5 to 7, the coefficients for LDIST are about the same among 2007 (-0.622), 2010 (-0.634) and 2015 (-0.666). In absolute values, these two models have the smaller distance elasticities. When both Model (b) and (c), the coefficients of distance are about 0.4. These two coefficients are significantly different from the two groups. We could easily find from Model (c) that the coefficient for LDIST significantly declines from the 0.443 for 2007 to 0.397 for 2015 in absolute value.

3.4 Logistics Effect and Maritime Transportation Effects

The logistics efficiency and capacity of transport modes and terminals have a direct impact on transport costs. Both LSCI and LPI have significantly positive coefficient in the regression result for each year in Table 5, 6 and 7. However, TEU has not. In addition, a roughly comparison between the corresponding density level for the year of 2007, 2010 and 1 2015, seems to indicate that the maritime transport within LSCI seems to decline over the period; in contrary the estimated coefficient for LPI-induces trade of exporters increases over the periods, that is, 0.966 for 2007, 1.632 for 2010, and 1.504 for 2015 as shown in Table 5, 6 and 7.

In sum, we find that very robust results on liner shipping which are also highly significant, with the expected sign and elasticity that is somewhat higher than for the TEU of container handled. Better infrastructure implies lower transport costs, efficiency and positive economic consequences. More developed transport systems tend to have lower transport costs since they are more reliable and can handle more movements.

3.5 Regional integration Effects v.s. Trading Blocs

By clustering analysis on the bilateral trade intensity, and complemented with the gravity equation estimation, this paper investigates the evolution of trading pattern in the normal regional integration, and nominal trading bloc. The major findings are as follows: for nominal regional integrations, we find that the effects of intra-regional trade creation, such as EU, NAFTA and RCEP, are all declining in terms of in-group trading intensity (Model (c) in Table 5, 6 and 7); in contrast, the EA_{core} is getting more integrated in terms of the intra-group trade intensity (Model (b) in Table 5, 6 and 7).

Table 5: Estimation of the PQML gravity equation in 2007 (Dependent variable: VOT_{ij})

Variable	Model (a)		Model (b)		Model (c)	
$LGDP_i$	0.707**	(27.43)	0.484**	(12.80)	0.431**	(10.77)
$LGDP_j$	0.740**	(23.58)	0.495**	(9.46)	0.442**	(8.15)
$LPPP_{ij}$	-0.0641**	(-2.11)	-0.0466*	(-1.72)	-0.0449*	(-1.70)
$LDIST_{ij}$	-0.622**	(-27.29)	-0.398**	(-12.59)	-0.443**	(-12.13)
adjcent			0.818**	(6.14)	0.522**	(4.60)
comlng			0.536**	(4.99)	0.424**	(3.42)
$LLSCI_i$			0.301**	(6.23)	0.353**	(6.24)
$LLSCI_j$			0.265**	(6.21)	0.307**	(6.18)
$LLPI_i$			0.858**	(3.06)	0.966**	(3.36)
$LLPI_j$			1.348**	(5.20)	1.474**	(5.46)
$LTEU_i$			0.0318	(1.28)	0.0419	(1.45)
$LTEU_j$			0.0516**	(3.06)	0.0654**	(3.32)
RCEP					0.532**	(4.27)
EAcpre			0.855**	(7.90)		
EU					0.0687	(0.72)
NAFTA					0.959**	(3.64)

Intercept	-14.15**	(-11.38)	-9.922**	(-7.28)	-7.721**	(-5.30)
Observations	99980		99980		99980	
Pseudo R2	0.57		0.63		0.63	

Note: 1. Superscripts * and ** denote signi cant level of 5% and 1%.
2. Numbers in parentheses are Z-value in PQML.

Table 6: Estimation of the PQML gravity equation in 2010 (Dependent variable: VOT_{ij})

Variable	Model (a)		Model (b)		Model (c)	
$LGDP_i$	0.729**	(26.94)	0.485**	(12.23)	0.440**	(10.32)
$LGDP_j$	0.732**	(22.12)	0.441**	(7.91)	0.394**	(6.74)
$LPPP_{ij}$	-0.0471	(-1.17)	-0.0535	(-1.42)	-0.0484	(-1.37)
$LDIST_{ij}$	-0.634**	(-28.41)	-0.384**	(-12.15)	-0.438**	(-11.67)
adjcent			0.825**	(6.01)	0.526**	(4.43)
comlng			0.469**	(4.33)	0.356**	(2.63)
$LLSCI_i$			0.208**	(4.08)	0.235**	(3.78)
$LLSCI_j$			0.221**	(5.04)	0.245**	(4.61)
$LLPI_i$			1.525**	(4.82)	1.632**	(5.05)
$LLPI_j$			1.694**	(5.12)	1.832**	(5.22)
$LTEU_i$			0.0701*	(1.80)	0.0932*	(1.87)
$LTEU_j$			0.112**	(3.31)	0.139**	(3.25)
RCEP					0.497**	(3.68)
EAcpre			0.810**	(6.82)		
EU					0.0349	(0.39)
NAFTA					0.955**	(3.48)
Intercept	-14.54**	(-11.42)	-11.25**	(-8.93)	-9.604**	(-7.16)
Observations	107376		107376		107376	
Pseudo R^2	0.55		0.62		0.63	

Note: Refer to Table 5.

Table 7: Estimation of the PQML gravity equation in 2015 (Dependent variable: VOTij)

Variable	Model (a)		Model (b)		Model (c)	
$LGDP_i$	0.870**	(28.01)	0.680**	(18.10)	0.640**	(16.78)
$LGDP_j$	0.840**	(24.09)	0.654**	(11.53)	0.618**	(11.04)
$LPPP_{ij}$	-0.0371	(-1.29)	-0.0267	(-1.12)	-0.0339	(-1.08)
$LDIST_{ij}$	-0.666**	(-21.61)	-0.324**	(-6.64)	-0.397**	(-8.49)
adjcent			1.128**	(5.75)	0.699**	(4.18)
comlng			0.189	(1.30)	0.2	(0.95)
$LLSCI_i$			0.114**	(2.40)	0.127**	(2.23)
$LLSCI_j$			0.164**	(3.65)	0.186**	(3.50)
$LLPI_i$			1.344**	(2.67)	1.504**	(2.94)
$LLPI_j$			1.955**	(4.55)	2.055**	(4.46)
$LTEU_i$			0.0514	(1.49)	0.0749*	(1.73)
$LTEU_j$			0.0101	(0.62)	0.0237	(1.28)
RCEP					0.633**	(4.21)
EAcpre			0.806**	(4.87)		
EU					0.0763	(0.68)
NAFTA					0.758**	(2.10)
Intercept	-21.35**	(-14.97)	-20.92**	(-14.12)	-19.35**	(-12.14)
Observations	81165		81165		81165	
Pseudo R^2	0.66		0.66		0.67	

Note: Refer to Table 5.

Another interesting experiment is to check the intra-group trade intensity for the bloc of 2007, i.e., the bloc dummy of EA_{core}. In addition to the two-bloc phenomenon exists in bilateral trade ows, that is, two distinct trading blocs could be identi ed during the last decades: the rst one called Core Bloc, is mainly composed of countries in East Asia, and the other one, calledChina-Tiger Cub Economies, mostly around the East-South Asia in Figure 1B. The corresponding results are reported in Model (b) and Model (c) of Table 5, -Table 6, and -Table 7. The bloc dummy included in each year's gravity equation is the EA_{core}. For RCEP, the e ect of intra-regional trade creation is better than EU in the bilateral trade intensity. Instead, the intra-RCEP trade was signi cantly below the trading blocs, EA_{core} in 2007, 2010 and even more so in 2015, indicating the bilateral completion position among RCEP members. We could easily nd Model (c) from Table 5, Table 6, and Table 7. that the coefficient for the RCEP significantly decreases from the 0.532 for 2007, to 0.5 for 2010, and 0.633 for 2015. In contrast, the estimated coe cient for the bloc dummy of EA_{core} also decreases over the periods, that is, 0.855 for 2007 as shown in model (b) of Table 5, 0.81 for 2010, as shown in Table 6, and 0.806 for 2015.

We also find that the estimated coe cient of (EA_{core} RCEP) is positive, then the real trading-blocs induced effect is empirically supported.

4. Concluding Remarks

Using 2007, 2010 and 2015's worldwide trade data, we have established a modi ed gravity model by considering FTA/CM of RCEP, EU and NAFTA as regional dummy and designing a real trading bloc induced variable. In addition, instead of using the commonly adopted OLS estimation, we apply the PQML approach to estimate the gravity equation to overcome the problem of large numbers of zero-export observations. The empirical results show that the intra-regional trade creations are not guaranteed, depending on the industry characteristics and the stage of economic development of the region.

The major findings are summarized as follows: First, both liner shipping connectivity and logistics performance have significantly positive coefficient in the regression result for each year. In other words, the maritime transportation matters for trade. Second, the intra regional trade creation are not guaranteed, depending on the trade characteristics and the stage of economic development of the region. Third, for RCEP, the effect of intra-regional trade creation is better than EU. Instead, the nominal intra-RCEP trade was significantly below the real trading blocs in 2007, 2010, and 2015. Fourth, there exists a real trading bloc among the East Asia and Taiwan, and the bloc phenomenon becomes more and more significant especially in the 2007 and after. This result indicates to some extent that the trade flows within the Taiwan is far above the normal level implied by their corresponding economic conditions and the geographical relationship.

References

Abe K. and J. S. Wilson (2009), “Investing in Port Infrastructure to Lower Trade Costs in East Asia," Working paper.

Anderson, J. A. and E. van Wincoop (2003), “Gravity with Gravitas: a Solution to the Border Puzzle," American Economic Review, 93, 170-192.

Baier, S. L. and J. H. Bergstrand (2001), “The Growth of World Trade: Tari, Transport Costs, and Income Similarity," Journal of International Economics, 53, 1-27.

Balistreri, E. J. and R. H. Hillberry (2001), “Trade Fricitions and Welfare in the Gravity Model: How Much of the Iceberg Melts?" Mimeo, U. S. International Trade Commission.

Behrens K., (2005), “Market Size and Industry Location: Traded vs non-Traded Goods," Journal of Urban Economics, 58, 24-44.

Behar, A. and P. Manner (2008), “Logistics and exports," African economics working paper series 293. CSAE WPS/2008-13. University of Oxford, Oxford.

Behar, A. and A. J. Venables (2010), “Transport costs and international trade," in: Palma A, Lindsey R, Quinet E, Vickerman R (eds) Handbook of transport economics, 97-115, Edward Elgar.

Bergstrand, J. H. (1985), “The Gravity Equation in International Trade: Some Microeconomic Fundations and Empirical Evidence," Review of Economics and Statistics, 67, 473-481.

Bergstrand, J. H. (1989), "The Generalized Gravity Equation, Monopolistic Competition, and the Factor-Proportions Theory in International Trade," Review of Economics and Statistics, 71, 143-153.
Branstetter L. (2006), "Is Foreign Direct Investment a Channel of Knowledge Spillovers? Evidence from Japan's FDI in the United States," Journal of International Economic, 68, 325-344.
Buys, P., Diechmann, U. and D. Wheeler, (2010), "Road Network Upgrading and Overland Trade Expansion in Sub-Saharan Africa," Journal Africa Economics, 19 (3), 399-432.
Feenstra R., Markusen, J., and A. Rose (2001), "Using the Gravity Equation to Differentiate among Alternative Theories of Trade," Canadian Journal of Economics, 34, 430-447.
Felipe, J. and U. Kumar (2012), "The role of trade facilitation in Central Asia: a gravity model," East Eur Econ 50, 5-20.
Feenstra R. (2002), "Border Effects and the Gravity Equation: Consistent Methods for Estimation," Scottish Journal of Political Economy, 49, 491-506.
Francois, J. and M. Manchin, (2006), "Institutional Quality, Infrastructure and the Propensity to Export," Mimeo.
Hertel, T. and T. Mirza (2009), "The role of trade facilitation in South Asian economic integration. Study on intraregional trade and investment in South Asia. ADB, Mandaluyong City.
Head K., and J. Ries (2001), "Increasing Returns versus National Product Differentiation as an Explanation for the Pattern of U.S.-Canada Trade," American Economic Review, 91, 858-876.
Huand, Y. Y. and D. S. Huang (2011), "Technology Advantage and Home-market Ef-fects: An Empirical Investigation," Journal of Economic Integration, 26(1), 81-109.
Hummels, David (1999), "Toward a Geography of Trade Costs," mimeo, University of Chicage.
Lai, H. and S. C. Zhu (2006), "The Determinants of Bilateral Trade," Canadian Journal of Economics, 37(2), 120-137.
Nordas, H. K. and R. Piermartini (2004), "Infrastructure and Trade," Sta Working Paper No. ERSD-2004-04, WTO.
Redding, S. and A. J. Venables (2002), "Economic Geography and International In-equality," mimeo, London.
School of Economics. Puertas, R. and Mart , L. and L. Garc a (2014), Logistics performance and export competitiveness: European experience," Empirica, 41, 467-480.
Raballand, G. (2003), "Determinants of the Negative Impact of Being Landlocked on Trade: An Empirical Investigation Through the Central Asian Case," Comparative Economic Studies, 45, 520-536.
Santos Silva J. M. C., and S. Tenreyro (2006), "The Log of Gravity," The Review of Economics and Statistics, 88, 641-658.
Siliverstovs B., and D. Schumacher (2009), "Estimating Gravity Equations: to Log or not to Log?" Empirical Economics, 36, 645-669.
Schumacher D., and B. Siliverstovs (2006), "Home-Market and Factor-Endowment Ef-fects in a Gravity Approach," Review of World Economics (Weltwirtschaftliches Archiv), 142(2), 330-353.
Shepherd, B. and J. S. Wilson (2006), "Road Infrastructure in Europe and Central Asia: Does Network Quality A ect Trade?" World Bank Policy Research Working Paper 4104.
Yu Z. (2005), "Trade, Market Size, and Industrial Structure: Revisiting the Home-Market E ect," Canadian Journal of Economics, 381, 255-272.

[i] In their analysis suggests that cutting port congestion by 10 percent could cut transport cost in East Asia by up to three percent. This translates into a 0.3 to 0.5 percent across the board tariff cut.
[ii] See Huang and Huang (2011, 2016) for the discussion, empirical evidence and the references therein.
[iii] For simplicity, we consider only the bilateral distance to capture the effect of trade barrier. Other variables for trade barrier are common language, colonial ties, FTA etc.
[iv] Following the related literature to resolve the CES price index, three approaches have been taken: (i) the GDP price index is use to capture the price effect in gravity equation, as in Bergstrand (1985, 1989) and Bair and Bergstrand (2001), (ii) estimated border effects are used to measure the price e ect, as in Anderson and van Wincoop (2003) and Balistreri, Hillberry (2001) and Feenstra (2002); and (iii) fixed effects are used to account for the price effect as in Harrigan (1996), Hummels (1999), Redding and Venable (2002), Lai and Zhu (2006).

IFSPA 2017

ifspa.2017@polyu.edu.hk
www.polyu.edu.hk/lms/icms/ifspa2017

ISBN 978-962-367-811-7
9 789623 677967