IFSPA 2019

International Forum on Shipping, Ports, and Airports (IFSPA) 2019

BEYOND BREAKTHROUGHS, ABOVE EXCELLENCE

20 - 24 MAY 2019 | HONG KONG

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Proceedings of the

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Beyond Breakthroughs, Above Excellence

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Edited By:

Prof. Chin-Shan Lu

Dr T. L. Yip

Dr Dong Yang

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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, the Department of Logistics and Maritime Studies and Faculty of Business of The Hong Kong Polytechnic University. It aims to invite international academics and practitioners to discuss and exchange views on issues related to global maritime and aviation economics, policy and management. The conference also serves as a good platform for networking and promoting academic-industry collaboration.

The roots of IFSPA can be dated back to 2006 when it was started as a workshop with the objective to promote high-quality research papers. Since then it has experienced significant successes and has attracted more than 900 participants from different countries and regions of the world.

Preface

The 10th International Forum on Shipping, Ports, and Airports (IFSPA) 2019 was successfully held from 20-24 May 2019, in Hong Kong. The proceedings contained a collection of 26 full papers out of 93 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 2019 was "Beyond Breakthroughs, Above Excellence". 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 maximization of competitive advantage, economic benefits and sustainable developments of transport, logistics, shipping and trading industries worldwide.

This year the Forum comprised of 5 Keynote Sessions, 2 Industrial Sessions, 3 Special Sessions, and 20 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 Canada, Chile, India, Japan, Netherlands, Singapore, South Korea, Taiwan, Thailand, the United Kingdom 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 organizations, 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 government 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 2019 Organizing 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 Organizing Committee and Conference Secretariat who had offered both moral and technical support to the conference and this proceeding. In particular, we would like to thank Vera Tsui and Tsz-him Chan.

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IFSPA 2019 is proud to have invited the following worldwide prestigious scholars and practitioners as Keynote Speakers for this event:

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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 2019.

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Contents

Shipping Connectivity for East Asia and the Indian Ocean Region in Relation to the 21st Century Maritime Silk Road

Wei Yim Yap

School of Business, Singapore University of Social Sciences, Singapore
Email: wyyap@suss.edu.sg

Abstract

Shipping connectivity plays a crucial role in China's attempts to promote economic and social development in the context of the 21st Century Maritime Silk Road (MSR). Recent years saw China taking a more proactive approach to expand and entrench its commercial interests in Southeast Asia and the Indian Ocean region under the pretext of the MSR. As such, the research aims to provide a timely examination of the state of shipping connectivity between major ports in China with countries along the MSR and identify those ports which are better connected to the regions of interest to benefit from expanding trade ties as a result of the MSR-drive. This study is the first to examine in detail the status of shipping connectivity along the MSR by taking into account dynamics of connectivity by maritime regions and countries in addition to port-pairs. Key Chinese container ports included in the analyses accounted for 70.3% of total container throughput handled by China in 2016. Our results showed Shanghai, Shenzhen, Ningbo and Hong Kong to be relatively better connected to countries along the MSR located in Southeast Asia and the Indian Ocean region. Results for Hong Kong revealed the port to hold significant lead for regional trades and particularly for Southeast Asia. The analysis also suggested Southeast Asia could play an important role in the MSR with it being a key conduit for maritime connectivity between China and the Indian Ocean region. Implications for policy makers, shipping lines, port authorities and terminal operators are discussed.

Keywords: 21st Century Maritime Silk Road, shipping connectivity, liner services, Indian Ocean, East Asia, Southeast Asia

1. Introduction

The 21st Century Maritime Silk Road (MSR) initiative was announced by China in 2013 to promote economic and social development by leveraging on geographical proximity and historical ties between the country and those located along the MSR (ASEAN-China Centre, 2013). The initiative recognizes the crucial role of developing and strengthening trade relations between countries (State Council of the People's Republic of China, 2015). In this, shipping connectivity becomes an important facilitator for international trade. In particular, the initiative will have consequences for the evolution of port and shipping connectivity for Southeast Asia and the Indian Ocean region in view of their location relative to the MSR. In terms of geographical coverage, this would include countries located in Southeast Asia, South Asia, the Middle East, East Africa and Southern Africa. A list of countries with direct maritime access in these regions in relation to the MSR is shown in figure 1.

China has significant economic relations with many countries in these regions. These are enabled by maritime linkages provided through shipping connectivity linked to China. Trade profiles from these countries revealed China to be a key trade partner particularly for merchandise imports with the country mostly ranked among the top five import sources for various countries shown in figure 1 (WTO, 2018). Even so, there remains enormous diversity in the levels of shipping connectivity seen in the countries. As such, efforts to promote economic and infrastructure development by the MSR could see trade relations expand along with improved shipping connectivity. The beneficiaries would also include Chinese ports that are well connected to these regions in view of the potential growth in maritime trade.

Figure 1: Countries in Southeast Asia and the Indian Ocean Region in Relation to the MSR
Source: Wei Yim Yap

Recent years saw China taking a more proactive approach to expand and entrench its commercial interests in Southeast Asia and the Indian Ocean region under the pretext of the MSR. Data from the American Enterprise Institute (2018) found Chinese investments in port-related projects involving Sri Lanka, UAE, Indonesia, Pakistan, Malaysia and Djibouti to total US$4.7 billion between 2013 to mid-2017. Including investments in other projects would see the total amount reach about US$100 billion for 2015 (National Bureau of Statistics of China, 2018). The emphasis on infrastructure projects which were targeted to improve market access and efficiency could thus provide the preconditions for sustained economic growth and development. Prospects for investments and trade ties are also expected to improve, thereby boosting shipping activity and connectivity for these regions including connectivity linked to China. In view of these developments, the research aims to provide a timely examination of the state of shipping connectivity between major ports in China with countries along the MSR and identify those ports that are better connected to the regions of interest which could benefit from expanding trade ties as a result of the MSR-drive. The paper is organized as follows. A review of literature is presented in the following section. Section three presents the research methodology while results of the study are presented in section four. Section five presents the research conclusions.

2. Literature Review

The importance of understanding the impact of the MSR on port and shipping connectivity stems from the multi-national and multi-dimensional nature of its extent and implications on international trade and logistics. Wei and Sheng (2017) noted the complexity and scale of maritime logistics network of the MSR to encompass more than half of the world's maritime shipping network. Ruan *et al.* (2017) highlighted the need for the port sector to respond with strategies to cater to new opportunities that are offered by the MSR. Lee *et al.* (2017) highlighted potential structural changes that could affect trade flows with ramifications for infrastructure development, international logistics, hinterland transportation, port competition and strategic plans for regional cooperation. While the studies provided a conceptual framework and considered connectivity from various perspectives including dry ports and capacity sharing through port networks, there is a need to examine the impact of the MSR on countries affected along its proposed route which would include those of Southeast Asia and the Indian Ocean region. In particular, empirical evidence remains lacking from the perspective of connectivity by maritime regions and countries involved and how these are related to the network of ports in China.

Ducruet *et al.* (2010) noted that logistics served as the backbone of the world economy and held a central role held in facilitating seaborne containerized trade. Actualizing such trade flows was made possible by the organization and management of international logistics networks which in turn relied on a host of shipping networks connected to various geographical regions in the world. This observation was corroborated by the findings of Xu *et al.* (2015) who found significant regional inequalities across the global shipping network. The authors observed that compared to other regions in the world, East Asia held a dominant position with the largest amount of inter-regional flows. The authors further identified Southern Africa and West Asia as emerging regions that saw significant improvements in connectivity. These findings are noteworthy given the geographical emphasis of the MSR which includes many countries in these regions.

Research on shipping networks and its evolution have been undertaken using different approaches. The list of works included those from the perspective of value-driven chain systems (Robinson, 2002), shipping lines (Fremont, 2007), port selection modelling (Tavasszy *et al.*, 2011), slot capacity operated by container shipping lines (Yap and Zahraei, 2018), hinterland access (Van der Horst and Van der Lugt, 2011), network centrality (Li *et al.*, 2014), network hierarchy structures (Hu and Zhu, 2009), network flows (Wang and Cullinane, 2016) and degree of internationalization by shipping lines (Prockl *et al.*, 2017). The studies explored network structures, parameters of connectivity and relative positions of ports applied at the global level or to specific geographical regions. Geographical location in the global flow of containerized trade and locality conditions were found to be important factors that contribute to the hub status for certain ports. Notteboom and Rodrigue (2008) also observed that trade imbalances, capacity constraints and restrictions to accessibility could impede the full benefits of containerization from being enjoyed. Tang et al. (2011) further developed a set of parameters to encapsulate connectivity which include the elements of cargo traffic, trade volume, port calls, turnaround time, operating hours, port draft, port charges and intermodal transport capabilities.

The literature revealed a wide range of issues and methodologies employed to analyze shipping connectivity. However, research devoted to the Indian Ocean region remains limited as compared to major container handling regions and trade routes. Analyses of shipping connectivity that takes into consideration richer dynamics offered by maritime regions and countries would offer deeper insights into the state of these linkages. The MSR has the potential to see economic development and growth taking hold especially for developing countries in the Indian Ocean region which could bring about greater cargo traffic and shipping connectivity as these countries gain greater market access to international trade. As such, the paper aims to narrow the gaps and contribute to the literature focused on this growing region of importance for international transportation and international trade.

3. Research Methodology

The research aims to analyze the state of shipping connectivity between China and countries located in Southeast Asia and the Indian Ocean region in the context of the MSR. Previous studies focused mostly on connectivity involving specific port-pairs. The proposed method consists of examining connectivity at three levels which are maritime regions, countries and specific ports connected to provide a holistic appraisal for the state of shipping connectivity, in this case for major Chinese container ports. These are Shanghai (SHA), Shenzhen (SZX), Ningbo (NGB), Guangzhou (GZG), Qingdao (TAO), Tianjin (TJP), Xiamen (XMN) and Dalian (DLC). These ports are located in major container-handling areas in the country which are the Yangtze River Delta (YRD), Pearl River Delta (PRD), Bohai Bay, Yellow Sea and Taiwan Strait. Together, they handled 153.3 million TEUs of containers in 2016 accounting for 70.3% of total container throughput handled by China (China Maritime Services Network, 2018). As such, these ports could be said to represent the state of shipping connectivity for China. In addition to these ports, we have included Hong Kong as the Special Administrative Region is part of China and the fourth busiest container port in the world.

The approach to compute and analyze connectivity utilizes data for container shipping services that connect between the selected ports in China and with countries of interest that are highlighted in figure 1 above. The emphasis is on container shipping services that were calling at major ports in China and were identified by the service name, port-of-rotation, ships deployed and frequency of call. The data was source from Alphaliner (2017) over a period of three months from September to November 2017 and corroborated with information published on websites of various shipping lines including the top twenty container shipping lines. Based on these information, container shipping services were categorized according to which maritime regions, countries and specific ports they called at. Data obtained from these parameters would be used to compare shipping connectivity between the selected ports in China and determine which of these are likely to be better positioned to benefit from initiatives aimed at promoting development and trade growth along the MSR. To summarize, the research framework is presented in figure 2:

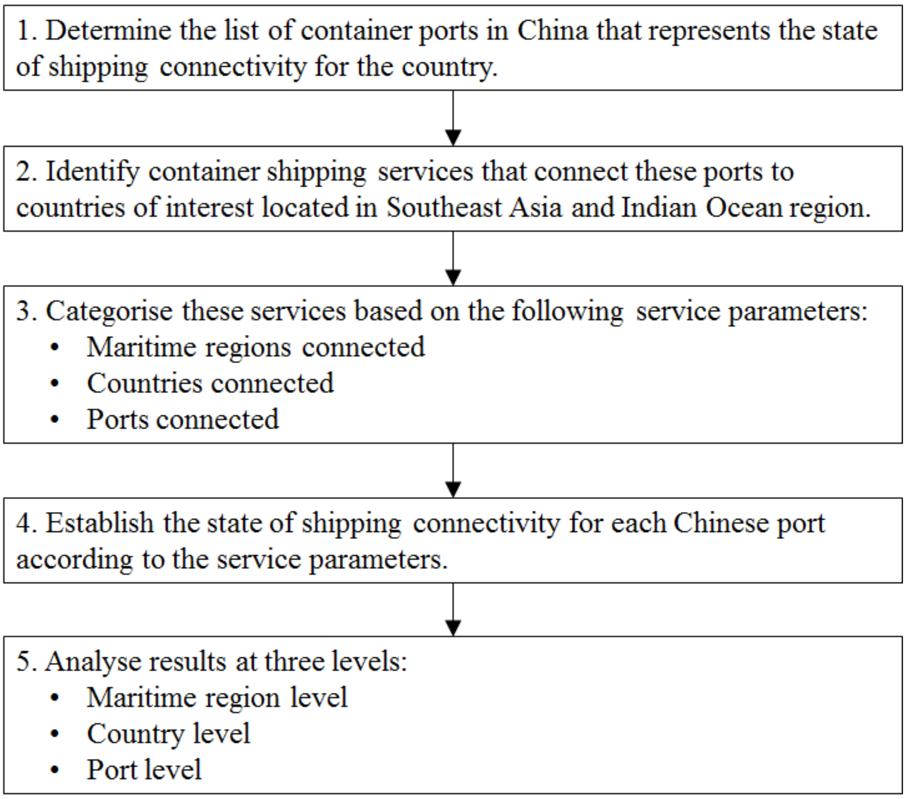

Figure 2: Research Framework

Many countries of interest listed in figure 1 are international partners of cooperation with China under the MSR initiative (Belt and Road Portal, 2018). Countries with the closest proximity to China in maritime terms would be those in Southeast Asia followed by countries in South Asia. Located further along the MSR would be countries from the Middle East, East Africa and Southern Africa. Countries in the Middle East were further categorized into those that border the Persian Gulf, Arabian Sea and Red Sea and Gulf of Aden given that ports in these regions are located in separate maritime expanses. The total number of shipping services connected by maritime regions and countries for port i in China ($L_{ij_{CR}}$) can be represented by:

$$L_{ij_{CR}} = \sum_{R=1}^{q} \sum_{C=1}^{d} \sum_{i=1}^{m} \sum_{j=1}^{k} U_{ij_{CR}} \qquad (2)$$

for shipping service $U_{ij_{CR}}$ which is deployed to include calls made between a particular Chinese port i and a non-Chinese port j located in country C in maritime region R. These maritime regions and respective countries being:

Southeast Asia:	Brunei (2), Cambodia (2), Indonesia (55), Malaysia (17), Myanmar (1), Philippines (38), Singapore (1), Thailand (12), Vietnam (12).
South Asia:	Bangladesh (4), India (26), Maldives (1), Pakistan (3), Sri Lanka (1).
Persian Gulf:	Bahrain (1), Iran (11), Iraq (4), Kuwait (2), Qatar (5), Saudi Arabia (2), UAE (12).
Arabian Sea:	Oman (4), UAE (2).
Red Sea and Gulf of Aden:	Djibouti (1), Egypt (7), Eritrea (2), Jordan (1), Saudi Arabia (6), Sudan (2), Yemen (4).
East Africa:	Kenya (1), Mozambique (5), Tanzania (4).
Southern Africa:	Madagascar (9), South Africa (8).

Total number of ports associated with each country embedded within a maritime region is presented in parentheses. In the case of Saudi Arabia and UAE, these countries have direct access to more than one maritime region. For example, the ports of Dammam and Jubail in Saudi Arabia are located in the Persian Gulf while the other six ports including Jeddah are located in the Red Sea. Similarly, the ports of Fujairah and Khor Fakkan in UAE are located in the Arabian Sea while the other UAE ports are located in the Persian Gulf.

4. Results and Discussion

4.1. Connectivity by Maritime Region, Country and Port

Results for shipping service connectivity for the seven maritime regions were presented in the appendix. We examine first connectivity by east-west services given the differences in vessel and service configurations exhibited by such trades as opposed to regional trades. East-west trades saw the largest container vessels deployed which necessitated a different set of service configurations typically involving calling at regional hubs while regional services deployed smaller vessels and are likely to call at a wider range of ports. Based on information presented in figure 3, connectivity levels could be categorized into four distinct tiers involving 11 countries in 6 maritime regions. At the highest tier was connectivity between Singapore in Southeast Asia and the selected ports in China. This could be attributed to Singapore's strategic location at the tip of the Malayan peninsular to serve east-west trades particularly for those that connect between East Asia and Europe as well as acting as a transshipment hub for Southeast Asia.

The second tier consisted of connectivity to Malaysia in Southeast Asia and Saudi Arabia in the Middle East. Results showed connectivity to be mainly with the Malaysian ports of Tanjung Pelepas and Port Klang located along the Straits of Malacca and the Saudi Arabian port of Jeddah which is located in the Red Sea. This was due to the favorable location of these ports to serve main east-west trades while acting as traffic hubs for their respective regions and also to incumbency and policy-driven factors. Apart from Malaysia and Saudi Arabia, our analysis also found Vung Tau in Vietnam to be an important port-of-call for east-west services and particularly for those connected to Shenzhen. The third tier of connectivity involved the UAE, Oman and Sri Lanka. In the lowest tier were connectivity provided to Thailand, South Africa, Indonesia and India.

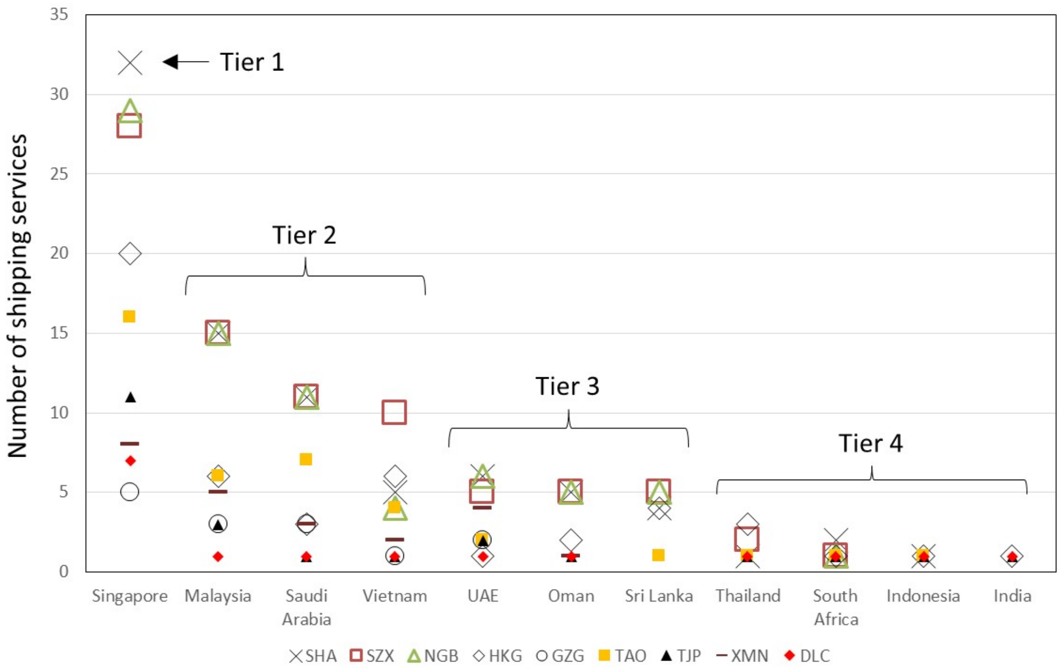

Figure 3: Country Connectivity for East-west Services
Source: Wei Yim Yap

Turning to inter-regional services, results showed an extensive state of connectivity with Southeast Asia involving 181 shipping services. Seen from the perspective of the MSR, geographical proximity of the maritime region suggests a vital role for Southeast Asia to serve as an important conduit of maritime trade between China and rest of the Indian Ocean. Results showed the leading ports in China to be Shanghai, Shenzhen, Ningbo and Hong Kong. In fact, Hong Kong had the highest number of inter-regional services at 123 with 64 connected to Vietnam. These services involved calling at the ports of Haiphong (35 services) and Ho Chi Minh City (30 services) (refer to table 1). This was followed by connectivity for Shanghai and Shenzhen to Vietnam and Malaysia and involved the same Vietnamese ports of Haiphong and Ho Chi Minh City as well as the Malaysian ports of Port Klang and Tanjung Pelepas. Ningbo was also found to have strong connectivity to Malaysia. From the perspective of countries in Southeast Asia, Singapore had the highest number of connectivity with 80 services and the leading ports in China were Ningbo, Shanghai, Shenzhen and Hong Kong. For Singapore, many of these services extended to other regions in the Indian Ocean region such as Africa, South Asia and the Middle East. The same could be observed for Port Klang and Tanjung Pelepas.

Table 1: Connectivity by Inter-Regional Services to Countries in Southeast Asia

Country	**Total**	HKG	SZX	SHG	NGB	TAO	XMN	GZG	TJP	DLC
Singapore	**80**	35	40	41	**44**	22	8	22	15	7
Vietnam	**67**	**64**	47	39	19	11	16	6	6	3
Malaysia	**56**	**42**	38	38	39	21	9	19	13	6
Thailand	**34**	**27**	18	20	11	8	9	3	4	2
Philippines	**25**	**18**	16	**18**	10	11	7	5	8	4
Indonesia	**17**	**14**	11	13	9	8	4	2	5	3
Cambodia	**6**	**4**	3	**4**	2	-	-	1	1	-
Myanmar	**2**	**2**	**2**	1	1	-	-	-	-	-
Brunei	**2**	**2**	1	-	-	-	-	-	-	-
Total shipping services	**181**	**123**	**103**	**89**	**73**	**47**	**34**	**33**	**28**	**13**

Source: Wei Yim Yap

South Asia had the second largest connectivity by regional services after Southeast Asia totaling 28 with Shanghai, Shenzhen and Ningbo being in the lead (refer to figure A1.2 in the appendix). 50% of these services consisted of direct connections to the region with the remainder involving onward connections to Southern Africa, West Africa and the Persian Gulf. With reference to table 2, the highest connectivity at the country level was seen for India with 18 shipping services, followed by Sri Lanka (16 services), Pakistan (8 services) and Bangladesh (2 services). Shenzhen's lead in connectivity was slight as Ningbo and Shanghai both had almost similar number of services connected to the region particularly for Sri Lanka. Major ports-of-call were Colombo, Nhava Sheva, Karachi and Mundra where they served as maritime gateways for their respective local or national hinterlands. In the case for Colombo, the port is also a major transshipment hub for South Asia. As for the other maritime regions, connectivity levels were low by comparison (refer to figures A1.3, A1.4, A1.5, A1.6 and A1.7). For these regions, Shanghai, Shenzhen and Ningbo led the other Chinese ports although many of the services would make parallel calls involving at least two of the three ports.

Table 2: Connectivity by Inter-Regional Services to Selected Countries in the Indian Ocean

Country	**Total**	NGB	SHG	SZX	GZG	HKG	TAO	TJP	XMN	DLC
India	**18**	12	11	**13**	3	9	8	4	1	1
Sri Lanka	**16**	**11**	**11**	**11**	7	7	6	5	2	2
UAE	**13**	**13**	12	12	1	4	1	2	2	1
South Africa	**11**	**9**	8	4	6	3	3	4	2	1
Saudi Arabia	**9**	**9**	7	8	2	2	3	1	1	-
Pakistan	**8**	6	5	**7**	1	6	3	-	-	-
Iran	**6**	**5**	**5**	**5**	-	3	1	1	1	-
Total shipping services	**56**	**45**	**42**	**34**	**21**	**19**	**19**	**13**	**7**	**4**

Source: Wei Yim Yap

4.2. Implications

There are three major implications for policy makers, shipping lines, port authorities and terminal operators. Firstly, the study highlighted a potential strategic role of Singapore, Port Klang and Tanjung Pelepas which are located in Southeast Asia in facilitating maritime trade and shipping connectivity between China and the rest of Southeast Asia and the Indian Ocean region. The is evidence by the fact that most shipping services connecting between East Asia with other countries along the MSR would call at the three container ports situated along the Straits of Malacca. As such, efficiency gains achieved in these ports could have wider ramifications for the MSR and could cascade throughout these regions. With growing maritime trade taking place, ensuring navigational safety and security and sufficient terminal and anchorage capacity will be important.

Secondly, the study identified major ports in the PRD and YRD to be well connected in the context of the MSR compared to other container-handling regions in China. Hong Kong and Shenzhen which are located in the PRD led in terms of shipping connectivity to Southeast Asia. Turning to the YRD, Shanghai was the best connected to east-west trade routes that served countries along the MSR while Ningbo had the best connectivity to countries in the Middle East and Africa as well as comparatively strong connectivity to South Asia. Altogether, the four ports stood out with relatively better connectivity to countries on the MSR compared to other ports in China. As such, these ports are likely to benefit most from increasing maritime trade between these regions.

Thirdly, Qingdao, Tianjin and Dalian which are located in the north in Bohai Bay and Yellow Sea were found to have weaker connectivity along the MSR compared to the other major Chinese ports.
Thirdly, our analysis revealed major ports-of-call for east-west trades in the countries of interest to be traditional hubs for gateway and/or transshipment container traffic such as Singapore, Port Klang, Tanjung Pelepas, Vung Tau, Jeddah and Colombo. In addition, Singapore, Port Klang, Tanjung Pelepas and Colombo were also revealed to be important ports-of-call for regional services. Other important ports-of-call revealed by the

analysis include Haiphong, Ho Chi Minh City, Laem Chabang, Manila, Jebel Ali, Jakarta, Surabaya, Nhava Sheva, Karachi and Mundra. In view of economic development taking place in these regions, there would be implications for shipping lines to capitalize on growing opportunities for maritime trade that these ports offer.

5. Conclusion and Recommendations for Future Research

This study is the first to examine in detail the status of shipping connectivity along the MSR by taking into account dynamics of connectivity by maritime regions and countries in addition to port-pairs. The study showed the ports of Shanghai, Shenzhen, Ningbo and Hong Kong to be relatively better connected to countries along the MSR located in Southeast Asia and the Indian Ocean region. Connectivity for Shanghai, Shenzhen and Ningbo were found to share similar characteristics be it from the maritime region or country levels. These ports led in terms of connectivity by both east-west and regional services. As for Hong Kong, the port saw relatively better connectivity for inter-regional trades particularly for those connecting between East Asia and Southeast Asia.

The study recognizes the dynamic nature of shipping networks as operators anticipate and react to changes in trade flows. Developments in the MSR are bound to affect maritime trade along its route which includes many countries in the Indian Ocean region, a region which has attracted limited attention in the literature. It is recommended that future research could consider the changing dynamics of shipping connectivity in these regions to provide a better understanding on the impact of the MSR. Implications for geopolitics, foreign direct investments, international trade and development policies as well as policies related to market intervention, capacity building and trade promotion warrants further research. Understanding the evolving trade relations and dynamics by the MSR could shed new insights for the fields of transportation and logistics studies pertaining to maritime and supply chain networks.

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Appendix

Results for connectivity by shipping services by maritime regions*

Figure A1.1 Southeast Asia

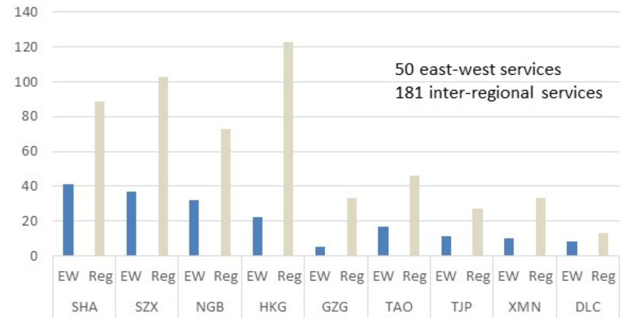


Figure A1.2 South Asia

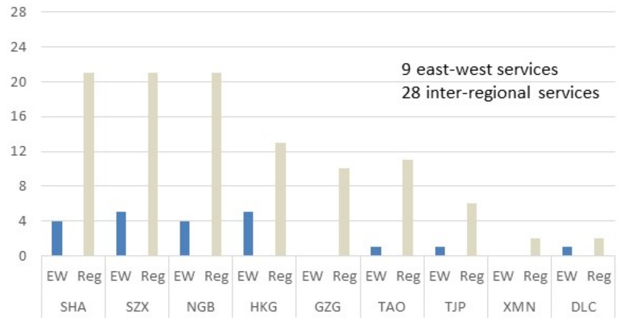


Figure A1.3 Persian Gulf

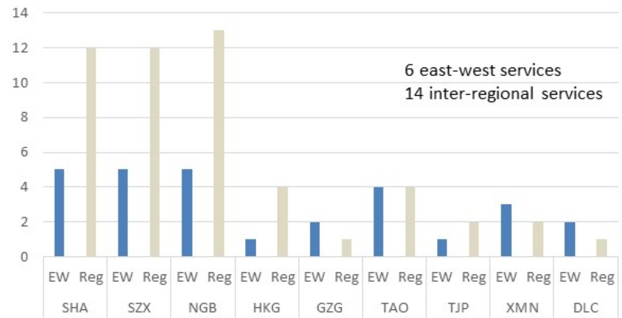


Figure A1.4 Red Sea and Gulf of Aden

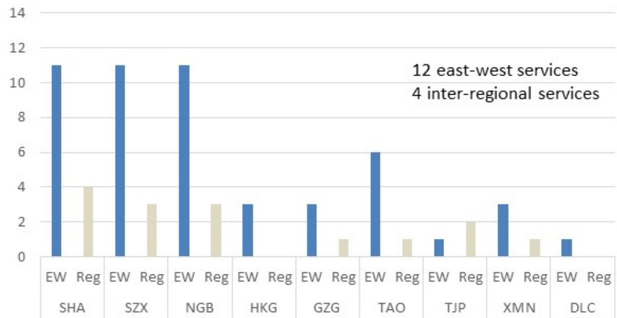


Figure A1.5 Southern Africa

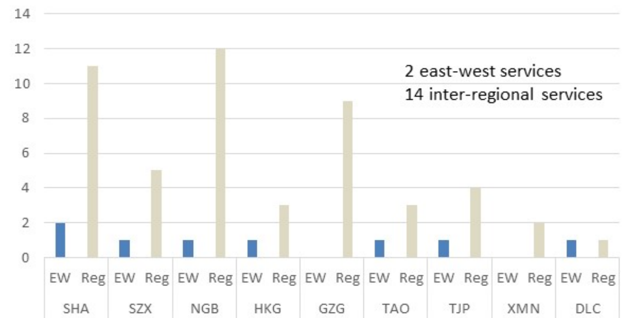


Figure A1.6 Arabian Sea

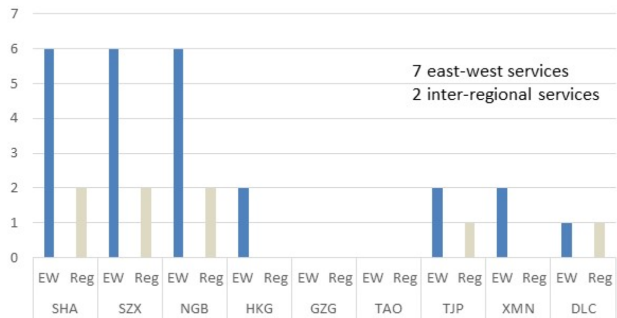
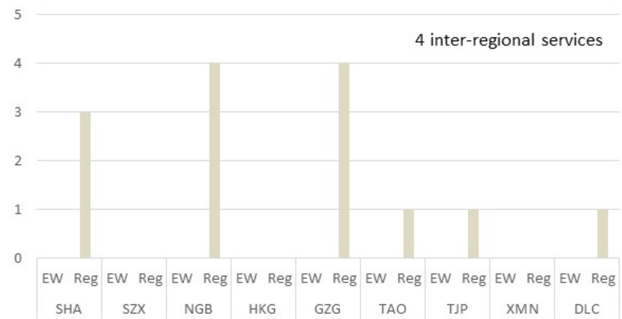


Figure A1.7 East Africa



* EW denotes east-west services
Reg denotes inter-regional services

Maritime Autonomous Surface Ships (MASS) and Its Implementation in Hong Kong

Y.K. Stephen Li [1], and K.S. FUNG [2]

[1] Department of Logistics and Maritime Studies, The Hong Kong Polytechnic University, Hong Kong SAR
[2] Department of Engineering, Hong Kong Institute of Vocational Education (Chai Wan), Hong Kong SAR
Email: [1]stephen.yk.li@gmail.com

Abstract

In the past decade, there was a rapid development in the autonomous land vehicle and surface vessels. Autonomous land vehicles are being tested and running in different countries currently; while the world first autonomous surface ship is expected to conduct the testing in 2019 and deliver to commercial operation in Norway by 2020. Then it will gradually move from manned operation to fully autonomous operation by 2022. Unlike the land vehicles, the autonomous surface ships are more complicated.

Similar to aviation industry, auto-pilot has a long history in marine industry. In 2016, the Autonomy Level guideline was launched in United Kingdom and provided the route to classification for the autonomous ships. Meanwhile, funded by Finnish Funding Agency for Technology and Innovation, the Advanced Autonomous Waterborne Application (AAWA) had summarized their research on the technological, safety, legal liability and economic aspects of remote and autonomous operation. They proposed the specification and preliminary designs for a proof of concept demonstrator and a remote controlled ship for commercial use by the end of the decade. In 2017, a report by Global Maritime Technology Trends (GMTT2030) in United Kingdom analysed the transformational technologies and offered their perspectives on the future of autonomy, its impact and the timescales. In 2018, there were concerns raised by trade unions of shipping industry around the world. From the result of their survey, they have expressed their view on human factor from the front line operator's side.

Recently, there are many conferences and meetings on autonomous surface vessel focusing on regulation, technology, human factor, legal and regulatory framework for such ships around the world separately. This report will summarise the current development of the autonomous surface ships, in term of the design and technology; their interaction and co-existence with manned ships; the local and international law and regulation; the pros and cons of unmanned ship when it is compared with traditional ship; the operation of crew and engineers; the supporting infrastructure; the shore-based support and etc… Finally, taking Hong Kong as an example, this report will examine the current status and attempt to present a proposal for a safe, secure, environmentally friendly, efficient and sustainable regime when introducing the autonomous surface ships in Hong Kong

Keywords: Autonomy, surface ship

1. Introduction

Autonomy vehicle has been used successfully long time ago in a "control" environment, such as a plant or a warehouse, or even within a container terminal recently. In an "open" environment, despite the auto-pilot has a long history being applied in aviation and marine industry, the level of autonomous in commercial transportation is still in a developing stage. It is observed that the marine industry is lagged behind when compared with the land vehicle.

In 2015, a Maritime Unmanned Navigation through Intelligence in Networks [1] project has been co-funded by European Commission for an in-depth analysis of the autonomous vessel on safety and security impacts, economic impacts and applicable areas of law. It founded that an autonomous vessel is technically feasible in term of hazard identification and corresponding risk control options. It also found that it would be economic viable in certain circumstances. For the legal aspect, it concluded that the existing legal framework will require some formal amendments but no fundamental substantive obstacles.

A joint human-automation framework [2] was studied in 2017 and proposed the migration from human supervision to partial supervision / autonomy stage and finally, the human intervener / fully autonomy stage.

In order to move forward to a fully autonomy sea transportation, shore supports are also required. In 2017, the world's biggest automated container terminal started her operation in Shanghai. Automated service piers were also studied to a local operation.

1.1 Level of Autonomy

In the past few years, level of autonomy has been defined for road vehicles [3] and the marine industry [4, 5]. Despite different levels of autonomy, it could be observed that the operation decision is handed over to the system from human at the highest level.

1.2 Autonomy and Technology

Autonomy starts with a navigation, guidance and control system together with for a dynamic unmanned vessel and algorithm. It includes the guidance system providing navigation and obstacle detection and avoidance (ODA) system.

In 2012, a control system adopting COLREGs, defined by the International Maritime Organisation was studied [6, 7].

In 2016, the Advanced Autonomous Waterborne Applications (AAWA) [partners developing a set of electronic integrated system for a safety navigation and avoid collisions. The integrated system included three areas : the sensors technology using different types of radars, high definition visual cameras, LiDAR (Light Detection and Ranging), thermal imaging; a control algorithms based on the maritime rules and regulations for navigation and collision avoidance; and a communication and connectivity for human input from land, to intervene when needed.

2. Implementation of Unmanned Vessel

Unmanned cars and aircraft have been commonly seen today and few are employed in road transportation as well as military engagement. Last year in China, Shenzhen has deployed unmanned bus in a test trial for in town transportation, the service received much welcome by the community and proved to be successful. In Europe and the United States, there are also researches into small unmanned underwater and military vessels, some of them are already made available and in use.

In maritime industrial sector, there had been also researches into the unmanned surface and underwater vehicles. Initially these researches employed the idea of remoted control functions on relative small crafts but as the demand grew larger, the size of these crafts are increasing.

Developing a large unmanned cargo vessel involves similar idea but the implication would be far greater than land and aviation. Since over 80% of worldwide cargo transportation is carried out by sea it is considered to be one of the main driving forces of today's global economy. It would be a great step forward that a reliable and sustainable transportation system of unmanned vessels can be introduced in the sea transport.

In Norway, a ship similar to the actual size of a cargo vessel is being built as an unmanned cargo carrying vessel. “Yara Birkeland”, is an autonomous container ship under construction and due to be launched in 2019. The “Yara Birkeland” project is planned to be the first fully autonomous logistics concept from industrial site operations, port operations and vessel operations in the world.

Comparing with the current cargo ships, the reliability and capability of the Artificial Intelligence Components (AIC) in terms of safety, ecological and cost effectiveness would be a main concern for the merit to develop unmanned shipping.

Scepticism regarding unmanned vessels would exist and thus one must perceive those unmanned vessels are at least as safe as or even safer than the current cargo ships. It is also expected that the future unmanned vessel should be able to resolve some of the problematic issues that are facing with the current shipping.

Operationally, an unmanned vessel will chiefly be guided by AIC with automated navigational system on-board which make decision based on the detected surrounding situations. In case of an un-predetermined situation occurring to the unmanned vessel, it will automatically alert the Shore Command Centre (SCC). The SCC is a backup facility in which the unmanned vessel would be operated at ashore. Using communication satellites as bridges the unmanned ship and SCC will be constantly linked up.

The possibility to navigate below the sea surface during the ocean passage will also be explored in the latter part of this paper. Using battery as its means of propulsion the unmanned vessel might sail beneath the sea surface in the designated ocean route at a pre-assigned depth. Because of being submerged, the resistance between the surface water and the hull would be greatly reduced and the speed improved. Besides, the submerged vessel would be able to avoid adverse weather condition and dense surface traffic.

2.1 Safety of Navigation

Today, the responsibility of ship officer is ever increasing because of various navigational duties and paper work throughout the voyage. During coastal voyages, schedules would be even tighter. Frequent port call and prolong hours of navigation in busy coastal water would render stress to the navigating officers. Since the number of navigating officers on board are barely sufficient, these stresses could build up as a result of heavy workload causing fatigue and exhaustion.

Furthermore, the navigating officer are often left to remains the sole responsibility on the bridge while requiring to tender to situations that might not be properly perceived and responded to. Although the STCW Convention has imposed stringent competency requirements to the navigating officers, things may go wrong when under constant stress condition. On the other hand ocean crossing passage are quite the contrary. At sea workload on navigation is less threatening as there are only little traffic during an ocean passage. Although this could allow opportunity for the navigating officer to relax but there are possibilities that it could also result in a low situation awareness.

As a result occasionally accidents such as ship collisions and groundings do occur. Investigation to these accidents reveals that over 80% are caused by human error. Common human factors such as fatigue, error of judgment and low situation awareness often contribute to the cause of marine accidents.

One of the motives behind the research of unmanned vessel is to enhance the safety of navigation and resolve the problem of human errors in maritime accidents. With the introduction of unmanned vessel and autonomous collision avoidance navigational system and because the vessel is to operate without human intervention, it is envisage that the problem of human error should be alleviated.

2.2 Shortage of Seafarer

The supply of ship officers to the shipping industry will not be sufficient in future years. A study by Drewry

Shipping Consultants has sounded the alarm that owing to the number of new buildings coming on line and youngsters' reluctance to go to sea, the shortage of ship officers will be worsened in the years to come. The study found that the current moderate shortage for ship officers in the world merchant fleet will not be resolved unless training is increased or measures are taken to address the situation and that the current worldwide supply in the next five to ten years will probably not satisfy future demand for officers.

2.3 Harmful Exhaust Emission

One of the fundamental motivations to the development of an unmanned vessel is to contribute a more sustainable maritime transport industry by reducing fuel consumption cost and harmful exhaust gas emission.

At present, fierce competition between shipping companies has put a lot of economic pressure on all parties involved in maritime transportation. Cost of bunker fuel being one of the major causes. At the same time, the IMO imposes stringent requirements to ships for reducing of harmful exhaust emission. Whilst the global requirement of 0.50% sulphur cap on exhaust emission will enter into force in 2020, more than 70,000 ships will be affected by the new requirement.

This necessity to reduce costs and harmful emissions would cause shipping companies to consider the alternatives of propulsion means such as battery through slow steaming.

2.4 Operation of Unmanned Vessel

During the initial stage, most of the main control functions such as pre-planning of voyage and choice of routes will still be performed by the SCC. However, on scene navigation control functions such as pre planned actions for collision avoidance and course setting will be taken over by the Sensor System on board. The Sensor System is supported by the radar, high definition visual cameras, LiDAR, thermal imaging and AIC etc..

In principle, the detection functions are based on existing and reliable navigational sensors with the radar still being the main source of information. From a navigational safety perspective, the system must ensure that a single technical failure is not compromise the whole unmanned ship's capability to meet the safety-critical functions so that the vessel will be constantly operated under all safety parameters.

For routine operation of unmanned shipping, three implementation stages on departure, ocean passage and arrival would be identified. A team of navigation crew will board the unmanned vessel after it completes the ocean passage and approaches to the coastal water of the destination port. The crew will then navigate the vessel in a conventional manner until it arrives the berth. Loading or discharge of cargo will be carried out after berthing. Upon departure, the crew will navigate the vessel away from the busy coastal water to a position where the ocean passage commences. The crew set the vessel to unmanned execution mode for ocean sea navigation under full auto mode and disembark. After that the ship will sail by itself in unmanned mode until it reaches the coastal water of the destination port.

During the full autonomous mode while at ocean sea passage, status of vessel will be constantly transmitted to shore via satellite communication to enable safe monitoring. The vessel will now proceed on its pre-planned track according to the voyage plan and the environmental data is obtained and monitored by its auto detection sensors such as radar and collision avoidance systems.
The setting and design of the AIC and Sensor System should be based in accordance with the appropriate international legal requirements, such as the International Prevention of Ship Collision Regulations. If a close quarter situation with another vessel is encountered, the Sensor System will recognize the traffic situation and the AIC will respond to it according to Collisions Regulations. Should floating objects or fishing nets be discovered, the vessel will carry out a respective evasive manoeuvre as well.

As soon as a situation is encountered which the Sensor System is not capable of dealing with, human assistance can be sought from the SCC through the AIC. The vessel will be switched automatically into remote control mode and communicate to a shore-side human operator in the SCC via communicate satellites. If required, the human operator will deal with the situation and give direct actions and command to the vessel via the SCC. It is envisaged that the intervention through SCC should gradually reduce as the auto mode Sensor System are further developed to meet different type of situations.

The concept of the SCC envisages a backup facility in which the unmanned vessel would be operated. Other than autonomous function of the unmanned shipping, the operator might supervise a number of ships of similar types in the SCC. The SCC is to be set up like a full scale ship's bridge ashore and be executed by a trained operator who may be an experienced master or watch-keeping officer. The role of the SCC is to back-up the safety function of the automatic system on board is to ensure un-predetermine situations are properly dealt with. During the voyage, the navigational processes and relevant actions taken must be recorded and mapped to facilitate future improvement of the system.

2.5 Vulnerability to Hijacking Control

In the maritime sector, remote control and autonomous navigational system on board the unmanned vessel brings benefits for safety and efficiency such as artificial intelligence components and sensor system, however, as unmanned ships are interconnected through land and satellite networking, it is possible that they would be exposed to cyber threats.

In 2016, after consultation with the members on what maritime cybersecurity guidelines should look like, the IMO issued the interim cybersecurity risk management guidelines. These guidelines enable services that are critical for safety and rescue operations, navigation and communication in a physically remote environment to be protected from cyber threats.

Although cyber security attacks on maritime infrastructure have not yet gained critical momentum, a cyberattack response and prevention plan by first identifying vulnerabilities are to be maintained. The informational technology and security experts should run regular incident tests to identify weaknesses and strengthen the on board security program to avoid possible attack from hackers.

2.6 Support of the International Maritime Organisation (IMO)

In recent years the IMO has developed guidelines for assessing the risks relating to maritime safety of the autonomous vessels. As the introduction of a concept for unmanned vessels will surely benefit the future development of technology, a thorough review is necessary to identify those hazards which are affected by the operation when these unmanned vessel actually comes into the picture.

Another proposals of IMO's e-Navigation concept is for Automatic Identification System to extend its function to ships in which it would additionally display their intended routes to the SCC or other reception facilities. This service will no doubt be another great benefit to vessel interaction in the development of the AIC of unmanned shipping.

As for the time being, the IMO may consider the introduction of the following measures:

Similar to Traffic Separation Scheme that had been designated in congested traffic water areas, the IMO should consider to designate ocean routes for unmanned vessel. Requirement should be established for member states to register main ocean routes in the Exclusive Economic Zones and High Sea. The designated ocean routes are to be used exclusively for unmanned vessels transiting the sea area under the revised Collision Regulations. Furthermore, for safe operation of the unmanned vessels, special rules and regulations are to be introduced both in surface and submerged conditions.

It is envisaged that future hull structure of unmanned vessels would be designed to fit for both surface and under water navigation. Using battery as its means of propulsion, it is believed that the unmanned vessel should be free from any emission and reduce air pollution to the environment.

2.7 Pros and Cons

To summarise, the following are the pros and cons for developing unmanned shipping:

Pros

- Elimination of harmful emissions;
- Decrease of human error risk and the resulting associated accidents;
- Reduction of fuel costs;
- Offsetting the expected shortage of seafarers in the future;
- Reduction of total operating expenses; and
- Increase the reliability and efficiency in future sea transport.

Cons

- Technology still under development;
- Possible reduction of seafarer jobs;
- Unknown safety risks due to uncertain technology reliance; and
- Vulnerability to computer hackers hijacking control.

2.8 More Thoughts on Unmanned Vessel to be Engaged in Submerged Mode

As no crew will remain on board the unmanned vessel during the ocean passage, it might navigate beneath the sea surface during navigation. The advantage of navigate at some depth under the surface is that the vessel will not be susceptible to adverse surface weather condition and wave resistance, as a result less propulsion power is needed and the underwater speed can be better enhanced during the entire sea passage.

It is understood that a surface vessel would be slower than a submerged vessel when they are of the same propulsion power. Apart from influence of adverse weather condition the surface vessel would be constantly affected by the surface water resistance created between the hull and the surrounding water. Turbulent drag and surface tension are the two major factors that reduce surface speed. As the bow pierce through the water surface there is a lot of turbulence alongside the length of hull of a surface vessel which would cause quite a bit of drag resistance.

On the other hand as the ship moves forward it forces the water wave to rise up the hull instead of parting to allow an unimpeded passage of the ship's hull. This is due to surface tension of the water which absorb a great deal of propulsion energy generated by the vessel and this drag becomes the second major factor slowing the ship down when it is sailing on the water surface.

Turbulent drag and surface tension both dissipate when a vessel submerges and maximum speed can go up to about 40% of the surface vessel. By going submerged the vessel would also be free from the influence of rough sea and wind that could further reduce its speed. In other words, a submerged vessel does not create significant waves when it is below sea surface and thus does not lose energy to the wave propagation like surface craft do.

3. Legal Aspects Concerning Unmanned Ships in Hong Kong

The major international treaties and Hong Kong legislation that are in force and are applicable to the Shipping operations in Hong Kong are set out in Annex I of this paper. In order to limit the scope of our study, we only confine ourselves with the study of cargo ships engaged on international voyages. If these "unmanned" ships can comply with the laws and regulations listed in Annex I, they can operate in Hong Kong or if not, these international laws and domestic legislation are need to be amended or modified with clarifications to cater for "unmanned" cargo ships before these ships can be operated in international waters or in the waters of Hong Kong.

3.1 Master's Role on board Ship

The master of a ship has the sole command of the ship but also has all the responsibility concerning all matters that happens to the ship or that requires by the laws and regulations. The maritime legislation considers the master of a ship is a person in charge of the ship, who has ultimate authority and responsibility to make decisions with respect to ship's health, security, safety and environmental protection matters. Cap. 1 Interpretation and General Clauses Ordinance of the Hong Kong Law provides the following:
"master", when used with reference to a vessel, means the person (except a pilot) having for the time being command or charge of the vessel.

Under SOLAS, the master of the ship is required to perform a number of duties related to the ship. The SOLAS and MARPOL conventions are enforced in Hong Kong through Cap.369 and Cap.413 Ordinance, etc. and their subsidiary legislations. These duties and responsibilities, required under SOLAS and the Hong Kong legislation, are set out in Annex II and Annex III respectively in this paper.

As we can see from Annex I, II, III and above, the master of the ship is vested with duties, powers, responsibilities or discretions which he is obliged to discharge or exercise for the safe operation of the ship under international treaties and domestic legislation. Do the existing international maritime regulations require that the master or officers or crew necessarily be on board the ship during a voyage or on a sea passage? Some people say without the master or officers or crew on board may render the ship unseaworthy. The unmanned ship may not be able to comply with the Collision Regulations (COLREGs) as the action required for collision avoidance shall, if the circumstances of the case admit, be positive, made in ample time and with due regard to the observance of good seamanship. ~~and~~ When the traditional role of the master of the ship will not be there and the master's responsibilities and liabilities etc. will be transferred to other shore-based operators. Compulsory pilotage is another issue that may have an impact on the operation of unmanned ships as compulsory pilotage requirements or regulations vary from port to port.

The IMO has now taken a more proactive and leading role on MASS due to the rapid technological developments in recent years. The Maritime Safety Committee (MSC) and the Legal Committee (LEG) have now agreed on regulatory scoping exercises and gap analysis to see if, where and how unmanned ships will fit in existing maritime conventions and regulations. Furthermore, the impact on the controls of United Nations Sanctions and embargoes on unmanned ships should also be studied by the United Nations and the IMO for the prevention of using the unmanned ships for illegal sea transportation.

4. Conclusions

This paper has demonstrated the potentials of unmanned vessels and its competitive advantages over existing cargo ships. Besides its contribution to reduce fatigue and workload of navigating officers, the improvement of navigational safety by eliminating human errors and reduction of harmful exhaust emission can make shipping safer and more sustainable. Going one step further, by setting the vessel into submerged mode during the ocean passage, it could improve the speed thus enhancing the efficiency of sea transportation. However, as the technology is still under development, it is too early for a final evaluation. That said, as the international regulation body, IMO is required to gain acceptance to future unmanned shipping and to designate routes and impose regulations for their safe operation.

The maritime traffic density in the waters of Hong Kong is very high and the traffic patterns in Hong Kong is also complex. We do not anticipate that unmanned ships will operate within the port of Hong Kong and commercial unmanned cargo ship operation in international waters or high seas may become a reality after IMO has resolved the legal issued identified by the regulatory scoping exercises and gap analysis. However, we anticipate that with the rapid development of the artificial intelligence system and other control technologies, IMO will re-visit the "Principles of Safe Manning" as adopted by IMO resolution A.890(21) as amended by resolution A.955(23) to take into account the operation of Shore Command Centre and Shore-based Operators and to allow further reduction of the number of crew on board. The reduced minimum safe manning scale on board ship will definitely become a reality well before fully autonomous ship operation.

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Table 1: LR Code for Unmanned Marine Systems - Autonomy Levels [3]

Autonomy Levels (AL)	Manual to Fully autonomous	Description
AL 0)	Manual	• No autonomous function. • All action and decision-making performed manually • Human controls all actions
AL 1)	On-board Decision Support	• All actions taken by human operator, but decision support tool can present options or otherwise influence the actions chosen. • Data is provided by systems on board.
AL 2)	On & Off-board Decision Support	• All actions taken by human operator, but decision support tool can present options or otherwise influence the actions chosen. • Data may be provided by systems on or off-board.
AL 3)	‘Active’ Human in the loop	• Decisions and actions are performed with human supervision. • Data may be provided by systems on or off-board.
AL 4)	Human on the look	• Decisions and actions are performed autonomously with human supervision. • High impact decisions are implemented in a way to give human operators the opportunity to intercede ad over-ride
AL 5)	Fully autonomous	• Rarely supervised operation where decisions are entirely made and actioned by the system
AL 6)	Fully autonomous	• Unsupervised operation where decisions are entirely made and actioned by the system during the mission

The Challenge of Minimizing Financial Losses due to Accidents at Sea – Observing Regulatory Compliance or Making a Profit? Developing a Model Safety Culture in Merchant Shipping

Deb Nayaran Goswami[1], Dr. Stephanie Jones[2], and Dr. Jose Tongzon[2]

[1]DBA student, Maastricht School of Management. Maastricht, NL.
[2]As Supervisor and Professor DBA and Research Dept. Maastricht School of Management, NL.
Email: [1]dg491@live.mdx.ac.uk

Abstract

Merchant shipping has always been exposed to the risk of accidents, but despite technological improvements, advanced training, and strict safety regulations (such as the International Safety Management [ISM] code and Marine Labour Convention [MLC] Code), accidents still occur and safety at sea continues to be a major issue for seafarers, individual ships and the shipping companies operating them.

After preliminary analysis of accidents affecting seafarers, ships and shipping companies, five main elements have been identified to give focus to this research study. Firstly, the extent of observance of regulatory compliance and, secondly, how sincere compliance can help to create a robust safety culture; thirdly, the impact of the need for a profit-orientation by shipping companies that might compromise safety in the operation of shipping; fourthly, the effect of all these three elements on safety management; and fifthly the influence of safety management on accident prevention. A high priority for reducing costs to increase profits can lead to the overlooking of unsafe practices and partial or non-compliance towards safety standards, which can be instrumental in leading to accidents at sea.

The concept of regulatory compliance here is based on the ISM and MLC codes. Safety culture is more abstract, but includes the sincere and consistent espousing of safety values by a particular, shipping company, commitment to safe working practices through safety management and focus on accident prevention and reduction. Profit orientation can be seen in terms of pressure on achieving financial results in a context of reduced margins and rising costs. These five main elements are interwoven and have been identified as significant in influencing the cause of accidents. This study has attempted to create a model to predict the existence of a higher level of safety in a specific maritime context.

The methodology employed in this research included analysis of a wide range of maritime accidents which have occurred before and after the implementation of ISM (1998), to consider the impact of an increased requirement of regulatory practice. Through the application of action research and using quantitative research method the researcher has surveyed 165 multinational seafarers (including safety managers) and analyzed the findings using structural equation modelling (SEM).

Keywords: accidents at sea, action research, ISM/MLC, merchant shipping, regulation compliance, safety at sea, safety culture

1. Introduction

1.1. Importance of Merchant Shipping in World Trade

Merchant shipping provides a large volume (90%) of world trade of merchandise goods transportation (IMO,

2017) to the world at the cheapest cost using a very little manpower. UNCTAD (2016), reported an estimation of seaborne trade surpassed 10 Billion tons of weight transportation in the year 2015. This figure shows how important merchant shipping is in today´s Global Economy. It has been an important player in the economy, and without it, economic development in many parts of the world would not have been possible. An example of such knowledge is, shipping made it possible for Hong Kong to evolve from an isolated tiny fishing village to become an active member of international trade community (Lai, Lun, Wong, & Cheng, 2011). Similar examples are the developments in Jebel Ali, Fujairah ports. A few decades back, these areas were just parts of a desert with little population but are now transformed in to shipping hub ports, serving hundreds of ships annually. Millions of US dollars shipping business deals are made in these ports.

It is the backbone of the global trade and global economy (On World Day, UN spotlights role of maritime transport as backbone of global economy, 2016). It thus requires sophisticated ships, skilled, certified, experienced, and trained workforce as well as a high standard of safety. Haapasaari, Helle, Lehikoinen, Lappalainen, and Kuikka (2015) stress on a proactive approach to safety by adopting policies in anticipation of future events of disasters and their possible prevention. The high standard of safety can be achieved by genuinely complying the safety regulation and developing a good safety culture.

In the year 1998, International Maritime Organization (IMO) enforced ISM code for safety regulations. Safety regulation compliance may seem to be similar to Safety Culture, but according to ISM code for safety regulations they are found to be different. ISM code can be considered as establishment of safety culture (Trafford, 2009). According to ISM regulation a platform of Safety Management System (SMS) needs to be created in every shipping company. The goal of SMS is to create a good Safety Culture by complying safety regulations. Therefore, it can be interpreted that, over the safety management system platform, if safety regulation is genuinely complied it can develop a good safety culture. Through the safety management the accidents can be reduced. However, this situation may get disturbed if profit is valued and prioritized by the stakeholders to compromise safety regulation compliance which in turn negatively affect safety culture and reduces the size of safety management platform, and this has been shown in the research conceptual model.

1.2. Accidents Occurring in Merchant Shipping

Accidents and catastrophes have high potential for occurrence in the maritime industry due to the nature of the working environment on board ship (Bergheim, Nielsen, Mearns, & Eid, 2015). The industry is often affected by frequent major accidents of ship sinking, example Titanic, Derbyshire, Prestige, Costa Concordia, El Faro, Sewol, Steller Daisy, Emerald Star, ultra large containership Maersk Honam, and very recently on 8 Jan 19, Aulac Fortune an oil tanker that exploded in Hong Kong, at Lamna anchorage. Other examples are MARPOL claim for environment damage (Exxon Valdez), collisions in major shipping choke points like English channel, Singapore strait, Turkish strait and Gibraltar strait. The industry has witnessed on an average, total loss of 113 ships every year in last ten years, 2008 - 2018 (Allianz, 2018). If average cost is of ship is considered to be 10 million USD then 1.13 billion USD has been buried every year under the seas (Fig-2).

Other regions like South China sea, Indochina, Indonesia and Philippines maritime regions have been identified as “new Bermuda Triangle” by a leading media person, because of ships´ sinking and disappearance (Allianz, 2018). Shipping in coastal areas are in a more vulnerable state of safety hazards than in international water, example eastern part of Mediterranean sea, Black Sea, and Arabian gulf region. The accidents, such as those mentioned above at the end always cause financial loss to the stakeholders and prevent the aspiring shipping entrepreneurs to enter in to shipping business.

1.3. The Wider Picture - the Context of Maritime Safety Study

In industries like aviation, atomic, surface transport, mining and chemical, deep safety culture researches have been conducted and corrective actions have been implemented and are found to be effective. In shipping, we still lack the same high level of in depth safety culture research, based on empirical and in the field of insider practitioner role as a researcher. Accidents are higher in shipping than airlines (fig-1). A comparative analysis of fatal accidents, has been made in fig - 1, and fig - 2 to show the number of accidents. EMSA (2017) has reported in its annual overview of maritime casualties and incidents 2017, that between period from 2011 to 2016, there have been 16539 casualties involving 18655 ships, loss of 253 ships, 5607 persons injured, and 600 fatalities. In 2016 itself, there were 106 fatalities, 957 persons were injured, 26 ships were lost. These figures do not take in to account of unreported accidents and incidents. Introducing a great deal of safety regulations in shipping industry does not necessarily mean, the industry has a high level of safety.

Additionally, seafaring is considered, to be a dangerous occupation with respect to work related fatalities and there are several causes of deaths that occur at sea, example death due to accidents, illness and natural causes, homicide, missing, drowning, disasters like ship sinking, and suicides (Nielsen,1999; Roberts, Nielsen, Kotlowski, & Jaremin, 2014). This issue has even been stated by IMO in its website (IMO, 2019). A study conducted between 1960 and 2009 (Iversen, 2012) to investigate the number and causes of seafarers' death indicated that 17026 deaths occurred during this period, of which 1011 deaths were due to suicides, 4487 deaths were due to illness and the remaining ones were due to other causes. These tragic incidents have not only made the organization pay for compensation to the victims' next of kin but also lose the worker, as Leigh, Markowitz, Fahs, Shin, and Landrigan (2000) mention there are direct and indirect costs involved with every injury and fatality. Iversen (2012), further states seafarers' rights to mental health care is needed for the safety reason and he identifies several dimensions that need to be considered, namely loneliness, separation from spouse and families, work related stress, fatigue, lack of going ashore due to non-permission, short duration of ship's stay in port, job security, cultural problems, abuse, criminalization, and piracy.

At present, there are regulations from four major maritime conventions that govern the global merchant shipping, and these are SOLAS 1974, MARPOL (1973 /1978), MLC -2006, and STCW 1995/2010 as amended. SOLAS means Safety of life at Sea, MARPOL means Marine Pollution, STCW means Standard Training Certification and Watch-keeping, and MLC means a code for Marine Labour Convention regulations. In the appendix section the definition and purpose of these regulations have been provided. The years in which these conventions were held have been suffixed. International Maritime Organization (IMO) which is a United Nation agency is the regulatory body for adopting the safety regulations for merchant shipping. The members states of IMO are the nations who have shipping business interest. They ratify the regulations as adopted in conventions and subsequently the regulations are enforced and implemented by the IMO member states. These member states are also called as flag-states, and they register the ship´s nationality following which ship is required to fly their flags to show the nation they belong to, the certificate of registry can be considered as ship´s passport. ISM code for the safety regulations was created on 4 Nov 1993 to bring them all on a common compliance platform. ISM code is supposed to have given strength to the merchant shipping safety regulations. Once the regulations are globally implemented, their functioning is checked through random inspections by respective member states´ government agency called Port State Control (PSC). Sometimes, several regional maritime nations sign memorandum of understanding (MOU) joint ship inspections and form an organization, example Paris MOU, Tokyo MOU. Such organizations not only inspect their own national ships but also the visiting ships in their ports from other nations.

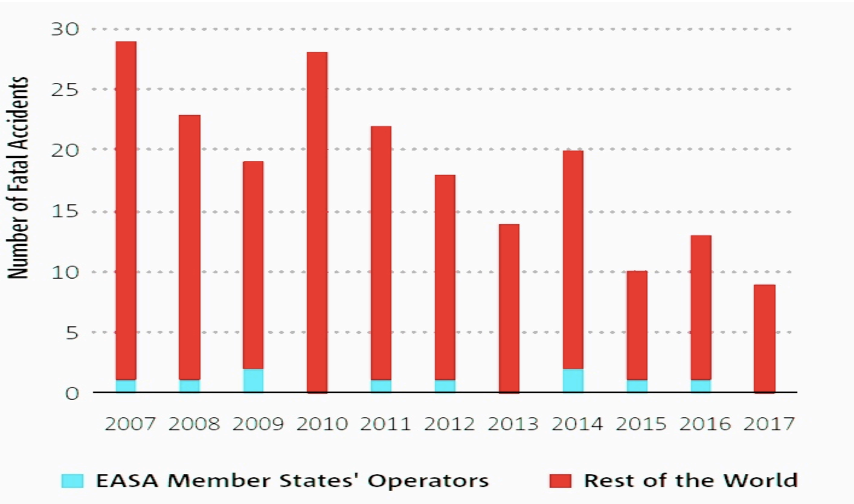

Figure 1: Fatal Airliner accidents per year 2007-2017,
Courtesy: European Aviation Safety Agency (2018)
Source: https://cdn.aviation-safety.net/airlinesafety/industry/reports/EASA-Annual-safety-review-2018.pdf accessed 28 Mar 19

Accidents ¨after¨ ISM code of safety regulation was implemented in 1998

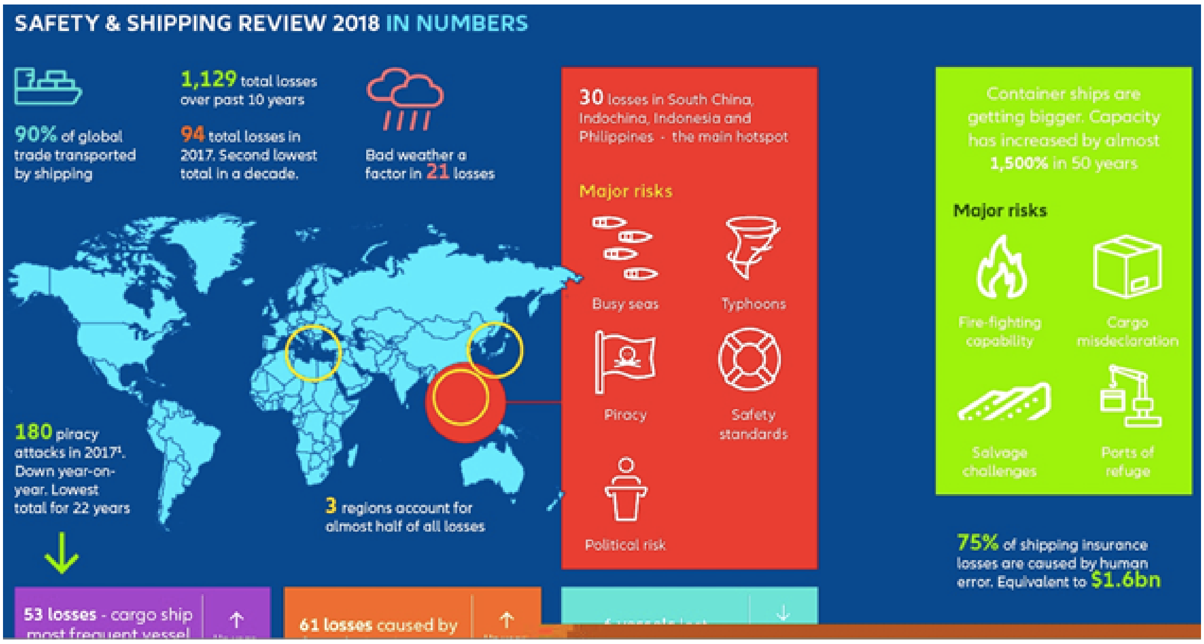

Figure 2: Marine Casualty Statistics (2008 - 2018): Total Loss of Ships after ISM regulation
Source:https://www.agcs.allianz.com/content/dam/onemarketing/agcs/agcs/reports/AGCS-Safety-Shipping-Review-2018.pdf, accessed 30 Jan 19).

1.4. Research Gap and Intended Contribution

The researcher´s search in the existing literature indicates there have been four gaps in the available research studies. First, it has been observed, only a few studies have been made in the shipping industry to investigate the influence of regulatory compliance on safety culture. Havold and Nesset (2009, p-307), stated very little research has been done in shipping on safety culture / safety climate. Second, the researcher has also not found any research that has been done to find out how organization´s profit orientation moderates the relation between regulatory compliance, safety culture and safety management at sea. Third, so far, no insider practitioner like this one of the researcher, who works on a ship as Captain, has done any action research over the present dilemma. However, it has been found in the existing literature, that most of the articles related to accidents have a broad explanation of the various causes of accidents, and the ones which are due to human factor have been emphasized more. Hetherington, Flin, and Mearns (2006, p. 410) claim in shipping, safety is influenced by human factor. The researcher argues, that cause of all accidents are not due to human factor only, example, sometimes accidents can also occur due to sudden equipment and mechanical failure, hidden material fatigue of ship structure, and unpredictable impact natural disasters (example, dangerous sea storms). Fourth, the existing articles related to shipping safety lack recommendation for organization´s various members to undertake responsibilities and accountability according to hierarchy, to act on, and to reach at the core of the problem to avoid accidents. Example of such articles are the ones which have been authored by 1/ Fenstad, Dahl, and Kongsvik (2016), 2/ Nielsen (1999), 3/ De Weerd, Tierney, Van Duuren-Stuurman, and Bertranou (2014), 4/ Flin, Mearns, O´Connor, and Bryden (2000), 5/ Beus, Payne, Bergman, and Arthur (2010), 6/ Hetherington et al. (2006). An article, authored by Blanch (2013) discusses on regulatory compliance and safety culture in nuclear industry. This article has been studied by the researcher to acquire the knowledge of relationship between regulatory compliance and safety culture, and to find how these are related to each other. Another article by Lefranc, Guarnieri, Rallo, Garbolino, and Textoris (2012) have discussed the effect of regulatory compliance and occupational risk on safety culture. Similarly, Blanch (2013) and Lefranc et al. (2012), have not mentioned recommendation for the organizations where accidents have taken place.

1.5. Research Limitation

This research has two limitations, first limitation is, the research is only limited to the perspective of ship owners´ safety regulation compliance and how it is influenced by profit orientation that eventually affects shipping companies´ safety culture and safety management. The five elements of other stakeholders like Port authorities, Charterers, Insurance agencies, Pilot association, Commercial operators have not been included in this study. The research sample area is only a small portion (ship-owners) of huge merchant shipping world. Therefore, how the other stakeholders function and play their roles in shipping have not been included, even though they influence the ship board operation to great extent and hold a major portion of shipping organization. Thus, unit of analysis will only be the ship owners (shipping companies), and will not include the shipping educational institutes or the organizations of pre-sea training students. Thus, the survey sample area is small 165 multinational seafarers compared to thousands of seafarers around the world.

The second limitation was, the supporting mechanism used, was an action research, more particularly insider practitioner action research as mentioned in details under paragraph ¨Formation of Research Group¨. This was because, in this study the researcher restricted himself to a practitioner´s role in ship owning and ship operating sector by working on board ship. Because of the nature of action research, he has formed a research group and took helps and advice from this group for his study. Thus, the research outcome has become a cogeneration of knowledge from group of shipping professionals.

2. Literature Review

2.1. Safety Culture

The contributing factors for majority of the merchant shipping casualties and incidents mostly relate to lack of organization´s safety culture. Several factors have been identified as, lack of follow up and compliance of safe procedures, inadequate procedures and checklists, lack of knowledge, lack of co-ordination of tasks, inadequate work method, training ignored, unavailability of right tools and equipment. Attitude of saving money and time, to increase profit and not investing in safety can give rise to all these elements which eventually cause accidents. Investing in safety culture may be considered to be non-productive expenditure by some stakeholders, but it actually improves profitability. Cooper (2001, p.2) has given an example that 2.5% of direct labour cost in construction industry if invested in safety program it can make a net saving of 4%. This is because multiple costs associated with accidents can be avoided by preventing accidents, which can be achieved by investing in safety culture. The multiple costs can be lost time injury, insurance claim, medical treatments, legal expenses, incapacitation.

2.2. Safety Management

Most shipping accident investigation reports reflect that poor organizational safety causes the accidents, avoiding any mention of cost issues. This has been recently confirmed on 12 Dec 17, by National Transport and Safety Board (NTSB) USA, after it carried out a two year´s investigation of tragic sinking of an American ship, “El Faro” in Oct 2015. The NTSB investigation board stated that the shipowner`s poor safety culture and inadequate safe work procedures in the safety management system caused the accident that claimed the lives of all 33 people on board (Dearen, 2017). This may be true – but this research study needed to find answer, was this the reason behind these inadequate safety management procedures?

The need for a robust safety management have long been recognised in the shipping industry. After the well-known sinking of a ferry ship “Herald of Free Enterprise” in 1987, which caused the death of 193 people, the merchant shipping regulatory body the IMO realized that there was need for all shipowners to adopt a robust safety culture and safety management, and that this must be made compulsory. Subsequently, in 1998, the IMO made it mandatory for all shipping companies to adopt a safety culture, by introducing the ISM code for safety regulations (resolution, A741-18). Fifteen years later, on 4 Dec 2013, the IMO adopted another resolution (A28/Res1075) which created a model for investigating accidents in merchant shipping. Using the concept of this model, the European Maritime Safety Agency (EMSA, 2017) has created another model called EMCIP model. This EMCIP (European Maritime Casualty Investigation Program) model is used by EMSA for marine casualty and accident investigations. These investigations often reflect the scope for improvement of safety management.

EMSA publishes an annual marine casualty and incidents report, which suggests that the contributing factors in the majority of the merchant shipping casualties and incidents mostly relate to lack of ship owners´ safety culture and safety management. These factors have been identified as a lack of follow up and compliance of procedures; inadequate procedures and checklists; lack of knowledge of safety needs; lack of co-ordination of tasks; inadequate work methods; a lack of safety training; and the lack of availability of safety-related tools and equipment. It can be argued that an attitude of saving money and time, to increase profits by not investing in safety, could give rise to all of these elements which eventually cause accidents. Investing in a robust safety culture might be considered to be non-productive expenditure by some stakeholders, especially shipowners, particularly those looking at reducing short-term operating expenses.

2.3. Profit Orientation

The ship owners are major actors of global trade and take opportunity of making business profit. Their investment in buying ships cost huge amount of money and thus it is important for the ship owners to maximize profit for business sustainability but it is also equally important to balance between, being profitable and being safe, as focusing purely on profits may be a short-term thinking and losses can be incurred from accidents due to non-compliance of safety regulation. High profit orientation in terms of monetary units may provide short time benefits by avoiding cost for safety. At same time, it may also cause negative long-term effect in performance and reputation, if an accident occurs due to lack of regulation compliance, specially when the accident causes monetary loss which in other words may be stated that the money is buried at seabed under the water. Such profit orientation can be interpreted as irrational profit orientation, as suggested by researcher´s action research team. Irrational profits are not ¨good profit¨ for an organization, it is not good for the employees and the people whom the organization serves. Good profit does not mean high margin or high return on investment or lots of profits by any means (Koch, 2016). The researcher and his action research team concluded that shipping companies´ rational profit (good profit) orientation can keep the ship, seafarers, environment, and shipboard cargoes safe. The survey questionnaire has been set on rational profit orientation. Example, ¨I think, efficiency expectation more than ability, does not lead to profit, therefore efficiency should be considered within the limit of safety management system ¨. The researcher and his action research team also concluded that pressure on the shipping industry increases to make irrational profit by compromising the safety standards when ship operating margins are squeezed. This long-term effect of accidents may be further aggravated in legal complications by lawyers' and maritime union's demand for higher compensation for the injured people, and the corruptions therein during the period resolving the issues, and it may turn the compensation to bigger amounts. It is important to know that occupational safety and health (OSH) economy revolves around both, causes and consequences and its factors in the aetiology of workplace ill-health and unsafe performance of ship staff. If unsafe culture of work practices is the cause then the consequence is the accident. This has, an effect on economic prospects for human resource in an organization and its business and finally world as a whole. In other words, this study can raise a rational question, how can better working condition be made profitable for a business? (Dorman, 2000).

Each accident has a negative effect on economy of an individual and his society. Economics is a social science and it considers the society as a whole (Dorman, 2000), example, the uninterrupted life of workers and their families due to no accidents as well the business community, and because of this calculus of cost benefit (CBA) analysis of investment in safety to avoid risks is important, but then market competition to maximize profit forces the stakeholders to ignore CBA and puts the seafarers and their ships at potential safety threats. Profitability increases by taking actions to lower the organization's operating expenses (Burja, 2011), but then due diligence needs to be exercised by adopting appropriate strategic thinking after analysis of better profitability management and thus not to compromise organization's safety issues which originate from its safety culture. If these issues are overlooked then accidents can happen leading to severe consequences of revenue and reputational loss. Fraher (2014), has found short-term profit maximization in airline industry negatively affect the long-term safety and government's failure to stop them. Similar situation but higher accident number prevails in shipping and some of the national governments and FOCs need to be proactive to stop dichotomous work process as discussed below to disregard profit orientation that compromises on safety.

2.4. Regulation Compliance

IMO (International Maritime Organization) being an agency of United Nation´s maritime domain, introduces safety regulations at sea. The SOLAS (Safety of Life at Sea) was such a type of convention that passed first major safety regulations in 1914 after RMS Titanic sank. Titanic was built for the purpose of transporting passengers and Royal mail between United Kingdom and North America. Titanic caused the loss of almost one thousand five hundred lives in Atlantic Ocean after it hit an iceberg. Sinking of RMS Titanic set the background of merchant shipping regulatory environment for safety of seafarers, passengers and their ship. The 1993 IMO resolution emphasized on developing a strong safety culture which was meant to focus on the safety demand of seafarers´ and their ships. In the said resolution, IMO concluded that the safety culture is the answer to reduce merchant shipping accidents. The said 1993 resolution, A.741(18) introduced ISM (International Safety Management) code for safety regulations. This research study explores the compliance (as defined in glossary) and effectiveness of ISM code for safety regulation with respect to organizational safety management system and developing of safety culture in shipping companies.

Regulation as defined by Dudley and Brito (2012) is a primary vehicle by which authoritative bodies implements laws and objectives. It tells us what are we allowed to do, and not do as applicable in every sphere of our professional and private life. The regulators who make regulations to enforce a safety system need to understand their ethical and moral responsibility to ensure people's safety according to their knowledge and the technology they are likely to use. These people's safety should be considered as their fundamental right and not dependent on the reputation of the organization in which they work (Mohan et al., 2002). Existing literatures have reported that regulators themselves lack of action and competence (Størkersen, 2015). But these two strengths, action and competence of the regulators are required for fundamental decision making, by balancing among profit orientation, efficiency , and protection with various constraints of the regulatees. However, the fundamental decision making is weakened by the regulators' limited resources and the political pressure for economic benefits. Weaker the fundamental decision is made, less effective will be the regulatees' concern to comply with regulation and consequently safety culture will be negatively affected by unethical practice, like workhours and rest hours compliance, untruthful acts which are all violation. This violation is difficult to be noted, unless it is pointed out to the regulative bodies by a whistleblower, who him/herself is also a victim but intends to engage in ethical practices. Ethical culture is not achieved only by transperency, but also by openness and a state when no whistle blower is necessary (ACCA 2014). ISM regulation was introduced to incorporate a philosophy of creating an environment of safety (Grech, Horberry, & Koester, 2008, p-132). This environment is the safety culture in shipping and its creation is from ISM code for safety regulation. Accidents, can be avoided if there is a good safety culture in an organization and the organization itself encourages its employees to engage on focusing ethical practices, and supported by authentic compliance of regulation. However, apparent regulatory compliance does not always improve safety levels as in the researchers experience, it is possible to appear to be compliant without having practical safety policies actively in place and following them sincerely. Thus, apart from making regulation, the regulation theory should also consider the feasibility of regulation compliance before the regulation enforcement in the applicable area.

2.5. Accident Prevention

The coverage for accident prevention at sea is a huge area of a complex network of multiple variables (Hanninen, Banda, & Pentti, 2014), these variables are all different elements of safety culture, namely safety information reporting and exchange, shipping companies' responsibilities and authorities, recruitment of a designated person in company's office who is considered to be one point contact in case there is a breach of safety on board ship, safety management documentation , emergency preparedness, Internal and external auditing system, feedback, maintenance of ship equipment, management commitments and reviews. A list of other elements are also essential, namely Captain's responsibilities and his overriding authority, no blame culture, personnel awareness and involvement, human resource, planning, and implementation of personnel's, safety and environmental protection policy. Such organizational references influence human actions and explain their roles in accident prevention (Kjellen and Albrechtsen, 2017). It thus indicates, if safety management is the cause then the effect is accident prevention. Therefore accident prevention has been considered to be the last endogenous variable in the conceptual model.

3. Hypotheses

H-1: A high level rational profit-orientation among ship's stakeholders (who do not believe in making and saving money as the primary consideration in all decision-making) can positively affect the safety culture.

H.2: A high level rational profit-orientation among ship's stakeholders (who do not believe in making and saving money as the primary consideration in all decision-making) can positively affect the safety management system.

H - 3: A high level of safety regulation compliance would be expected to positively influence a consistently-implemented safety culture.

H - 4: A high standard of safety culture on board ship would be expected to positively influence safety management.

H - 5: A consistently implemented safety management system that has well a defined safety policy and adequate necessary safe working procedures can positively influence to reduce the annual number of reported marine accidents/casualties worldwide.

4. Conceptual Model

Considering the above hypotheses, the conceptual model is as below, and it guided the study of this research as shown in the figure below. Regulation compliance and Stakeholders´ profit orientation are exogenous variables. Safety culture, Safety management, and Accident prevention are the endogenous variables.

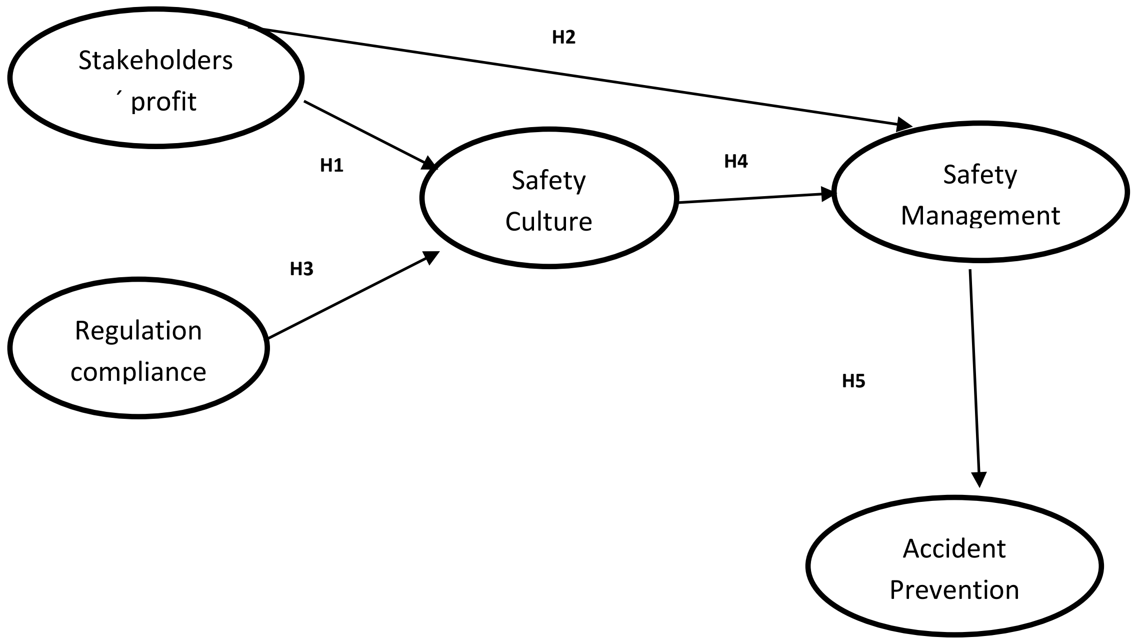

Figure 3: Conceptual Model, Showing the Latent Variables

5. Research Methodology

This research design has four stages as mentioned in the next few paragraphs. The first stage refers to the ¨Formation of Research Group¨, the second stage refers to ¨Operationalization of Conceptual model¨, the third stage refers to ¨Wider Data Collection area¨, and the fourth stage refers to ¨Data Analysis by Structural Equation Modelling (SEM)¨. The use of SEM has considered the influence of the existence of a rational profit orientation that may lead an organization and its people to compliance of regulations, policies and procedures.

5.1. Formation of Action Research Team

Formation of research group was based on action research principle. The idea of Action research was first conceived by Kurt Lewin in 1934 in USA (Adelman, 1993). Action research focuses on the objectives, such as social change or the production of a socially desirable outcomes compared to the other research methods where knowledge acquisition is emphasized (Blumberg et al. (2014, p.17). Action research focuses on empowering and change across contexts and cultures. Action researchers are the ¨doers¨ who intend to improve their practices creating innovation, change and development and this part can be interpreted as ¨action¨. The other part is ¨research¨ which refers to the rigour of academic research of thesis writing, publishing and defending in academia. According to Zuber-Skerritt and Fletcher (2007), action research depends upon environmental, situational, personal and organisational factors and multiple perspectives in which the ¨doers¨ reflect to improve their practice oriented significant issues by interlinking reflection and action. The research team consisted of thirteen numbers of multinational senior and junior seafarers (ship Captains, Ship chief engineers, and junior officers). The team also included two safety managers. The researcher and his team had sufficient work experience in shipping and they acted further to the three processes what Revans (1998) named alpha, beta, and gamma processes. Alpha relates to what prevents safety to improve and what were previously attempted? Beta relates to researcher and his research team´s action and reflection over rigorous exploration of various companies profit orientation, and how it differently controls various companies´ interrelation between regulation compliance and safety culture. The reflection is also to include the extent of importance laid towards developing safety culture in individual companies, and why the importance is different in one company to another. Finally, the gamma relates to the research team´s effective interaction that enables individual critical reflection and learning and create a shared meaning as to what improvements are necessary in shipping´s safety culture for accident avoidance.

5.2. Operationalization of the Conceptual Model

The second stage, is to operationalize the conceptual model as prepared after the literature review and factor table and survey questionnaire for all latent variables as shown in the conceptual model. This helped to collect data for quantitative methods and to measure the safety regulatory compliance, stakeholders' profit orientation, and organizational safety culture. Using these factors a structure was created, and their path analysis has been made. The researcher was then able to find out how the profit orientation and regulation compliance affects the safety culture, safety culture affects safety management, and finally safety management affects accident prevention.

5.3. Wider Data Collection Area

The third stage began after checking the result of pilot study over 24 people (seafarers and managers) was found to be similar or closer to what stated in the articles as reviewed in the literature review, and also if anything was found new was added to the questionnaire. The questionnaire consisted a total of 75 questions, and all had Likert scale ratings 1- 10. The questions for Stakeholders´ rational profit orientation (stop) reflect the rationality of profit orientation, example ¨ Cutting down on essential safety items, leads to non-compliance of safety regulation¨. The Stakeholders´ rational profit orientation (stpo) had 15 questions, Regulation compliance (rc) had 15 questions, Safety culture (sc) had 27 questions, Safety management (smrcsc) had 10 questions, and finally Accident prevention (ap) had 8 questions . After this stage the researcher began data collection from more number of shipping companies and from their employees, For the unit of surveys, there were safety managers and seafarers of different nationalities that made a total 165 units of surveys. The nationalities were British, Croatians, Filipinos, and Indians.

5.4. Data Analysis by Structural Equation Modelling (SEM)

The fourth stage was to analyse the collected data by the researcher using SEM, in consultation with his supervisors to test the hypothesis and find answers of research questions. It was done by comparing SEM path analysis diagram. Then the entire work was presented to researcher´s action research team (ART) for final evaluation and conclusion. Hereinafter this article was prepared. SEM is useful in social and behavioural sciences and when it runs using syntax the algebra knowledge is not required (Hoyle, 2012) . There was a good reason for selecting SEM, as he found, that it could be used for multiple regression analysis with little coverage of factor analysis. SEM method estimates multiple and interrelated dependence of variables in a single graphical analysis. The SEM model also displays very clearly the path diagrams of latent variables and causal effects between variables.

6. Data Presentation and Analysis

The researcher used STATA 15 for statistical calculation and data analysis. Five models, namely 1/ Safety culture (sc) , 2/ Safety management (smrcsc), 3/ Regulation compliance (rc) , 4/ Stakeholders´ rational profit (stpo), and 5/ Accident prevention (ap), were created according to conceptual model. The results are in the appendix section, however the SEM diagram has been shown hereunder followed by conclusion.

7. Hypotheses Verification

H-1: A high level rational profit-orientation among ship's stakeholders (who do not believe in making and saving money as the primary consideration in all decision-making) can positively affect the safety culture. *In SEM diagram rational profit orientation loads positively on safety culture (sc) by its value +0.046.*
H.2: A high level rational profit-orientation among ship's stakeholders (who do not believe in making and saving money as the primary consideration in all decision-making) can positively affect the safety management system. *In SEM diagram rational profit orientation loads positively on safety management (smrcsc) by its value +0.8.*

H - 3: A high level of safety regulation compliance would be expected to positively influence a consistently-implemented safety culture. *In SEM diagram safety regulation compliance (rc) loads positively on safety culture (sc) by its value +0.34*.

H-4: A high standard of safety culture on board ship would be expected to positively influence safety management. *In SEM diagram safety culture (sc) loads positively on safety management (smrcsc) by its value +0.11*

H-5: A consistently implemented safety management system that has well a defined safety policy and adequate necessary safe working procedures can positively influence to reduce the annual number of reported marine accidents/casualties worldwide. *In SEM diagram safety management (smrcsc) loads positively on accident prevention (ap) by its value +0.37*.

SEM Diagram

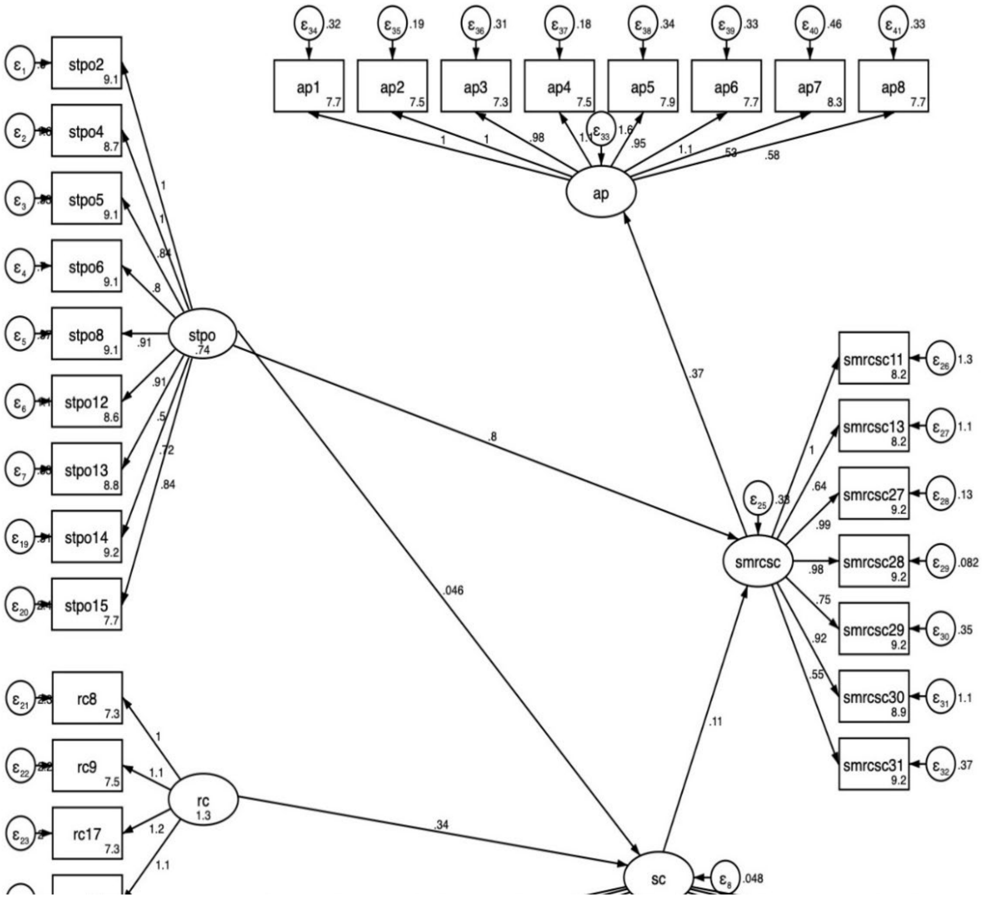

Figure 4: Structural equation Modelling, Showing Latent and Manifested Variables

8. Conclusion

This work has been a preparatory work for researcher´s DBA dissertation. The data collection through survey questionnaire is still in progress and the target has been set to 400, at present it is 165. More data collection will possibly create better SEM presentation as well as better model fit values. It is noted the knowledge of cause and effect of accident prevention not only includes the positive human behaviours but also rational (good) profit orientation that positively helps to create safety culture and safety management practices. Merely adopting good safety policies and not genuinely complying them in reality will not bring down the number of shipping accidents. The goal should be set that any preventive measure must prevent the injuries, damage to environment and property. The survey revealed the majority of seafarers prefer to have a safety culture and exercise safe management practices. It is not only the seafarers´ interests that can prevent accidents but also the top management ashore should have sincere equal interest, genuine efforts, an inspiration to seafarers. This joint ship-shore effort and its effectiveness will help the organization to achieve higher results of accident prevention. Without the joint efforts it will not be possible to achieve accident reduction results, despite hard works and use of safety policies by the front line workers. The SEM model as shown in the fig-4, has indicated rational profit orientation helps to create safety culture and safety management both are important to reduce accidents. Regulation compliance helps to improve safety culture and safety management. Therefore if there is a model in a shipping company, as shown in above SEM diagram where, there exists rational profit orientation and regulation compliance, the shipping company will have an improved safety culture model over safety management platform and it will reduce accidents.

In future, such research studies should also be conducted over other stakeholders, namely Port authorities, Charterers, Insurance agencies, Pilot association, Commercial operators as these organization also influence the shipboard activities. This future study will help to find out how much these other stakeholders are interested to share the ship-owners´ and seafarers´ responsibilities in reducing the number of annually reported accidents.

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Online Integrated Optimization Model for Container Rehandling and Pickup Sequence in Container Terminals

Su-min Chen[1], *and Qing-cheng Zeng*[1]

[1] Department of Maritime Economics and Management, Dalian Maritime University, Dalian

Abstract

During containers retrieving process, the unproductive rehandling moves occur when containers stacked above the target container for retrieval, which decreases the efficiency of the terminal operation, increases the delay of external trucks, and decreases vessel operation efficiency. The container relocation problem (CRP) is a classic combinatorial optimisation problem, which is to retrieve all the containers (outbound or inbound) from a bay in the prescribed order while minimizing the number of rehandles. Different from the CRP of outbound containers, the exact retrieval sequence of inbound containers in a bay is unknown in advance due to the uncertainty of truck retrieval time. With the development of GPS (Global Positioning System) and IoT (Internet of things) and the implementation of truck appointment systems, truck arrival time can be revealed during the retrieval process. This paper introduces and investigates such online version of the problem with the real-time truck arrival information. We also study a class of flexible service policies, which allows adjustments to the container pickup sequence within each group to minimize the total number of rehandles. In summary, this problem is an online integrated problem to optimize the pickup sequence and the container rehandling strategy simultaneously.

Due to the problem class being NP-hard and time limit of online optimization, we decompose this problem into two sub-problems. One is offline Container relocation problem which is to get the set of optimal rehandling plans of all possible pickup sequences before retrieval operations begin. With the output of the previous problem and real-time truck arrival information, another is online integrated problem which is to choose the optimal pickup sequence and its corresponding rehandling plan. In order to address sub-problems, we propose rehandling model with time windows and online integrated optimization model respectively. Finally, we design an algorithm based on decision tree search algorithm and greedy strategy to solve the model and analyze the validity of our model and algorithm.

Numerical experiments indicate that the proposed algorithms can effectively solve the addressed problem. In most cases, optimizing the rehandling scheme and pickup sequence simultaneously can greatly reduce the number of rehandles, but may increase the average waiting time of external trucks. Moreover, our models control wait time of each external truck, thus contribute to the stability of the service level in container terminals. The proposed method provides an efficient tool for container terminals to reduce the number of rehandles and obtain relocation patterns in real time.

Keywords: Container terminals, Container rehandling, Pickup sequence, Online integrated optimization

1. Introduction

The container terminals are important nodes of the global transportation network. The continuing growth of throughput increases the number of containers in container terminals. In order to utilize the scarce resource of yard surface, containers are stacked vertically, thus at times resulting in the costly rehandling moves. A high proportion of unproductive operations resulting from container rehandling decreases yard efficiency, increases the delay of external trucks, and decreases vessel operation efficiency. Container rehandling is receiving considerable attention from terminal operators, but remains a difficult problem to be solved.

Generally, the number of rehandles is influenced by the relocation strategy and the pickup sequence. The relocation problem which is referred to as the container relocation (rehandling, reshuffling) problem (CRP) or the block relocation problem (BRP), is to determine suitable positions for the rehandled containers with the least number of reshuffling moves, which has been the focus of numerous studies (Caserta et al., 2012; Carlo et al., 2014; Lehnfeld and Knust, 2014; Zhen et al., 2013). Since the exact order of truck arrivals is not available in the case of uncertainty in the external truck arrival sequence, optimizing the relocation strategy alone cannot efficiently reduce the number of relocations and can only obtain an expected number of rehandles. Dictating the container pickup sequence is an efficient way to overcome the uncertainty of truck arrival sequence and thus reduce the number of rehandles. Therefore, we propose a method of simultaneously optimizing the pickup sequence and the container rehandling strategy in this paper.

An effective means of reducing the number of rehandles is to utilize the truck arrival information. With implementation of truck appointment systems, the hauliers send the time windows about the trucks arrival time to the terminal before they arrive at the terminal. According to their appointment periods, before retrieval operations begin, the external trucks are allocated to the corresponding time windows in which way they are divided into groups. With the development of GPS (Global Positioning System) and IoT (Internet of things), the real-time truck arrival information will become available at container terminals. Thus, this problem is the online version of CRP.

In terms of model solving, CRP has proven to be NP-hard (Caserta et al., 2012). Furthermore, online optimization requires to be completed in a short time. To solve the online integrated problem within limit time, we decompose it into two problems. One is offline Container relocation problem which is to get the set of optimal rehandling plans of all possible pickup sequences before retrieval operations begin. With the output of previous problem and real-time truck arrival information, another is online integrated problem which is to choose the optimal pickup sequence and its corresponding rehandling plan. In order to solve the model, an algorithm based on decision tree search algorithm and greedy strategy is designed.

The remainder of the paper is organized as follows. In Section 2, a review of previous work is presented. In Section 3, the problem description and model formulation are provided. The solution algorithms are designed in Section 4. Numerical experiments are reported in Section 5, and conclusions are given in Section 6.

2. Literature Review

The container relocation problem(CRP) is one of the most critical factors which influences the efficiency of yard operations. CRP is defined as follows: given a pickup order for containers stacked in a given bay layout,

choosing the suitable storage location of rehandled containers in the given order while minimizing the number of rehandles (Steenken et al., 2004). Most studies of the CRP have focused on outbound containers whose retrieval sequences (the ship-loading sequences) are known before the retrieval operations. Wan et al. (2010) formulated an integer programming model MRIP for relocation and designed a branch and bound method to determine the optimal drop location. On this basis, Ünlüyurt and Aydın (2012) propose an improved branch and bound method, which can solve larger instances. Since CRP is proved to be NP-hard (Caserta et al., 2012), several heuristic solution approaches are designed. Most of the heuristic approaches are based on branch and bound and apply different branching and exploring strategies (Caserta et al.,2011; Forster & Bortfeldt, 2012; Ünlüyurt & Aydin, 2012; Zhu, Qin, Lim, & Zhang, 2012) or search tree algorithms (Forster et al.,2012).

Compared with the CRP of outbound containers, issues related to the CRP of inbound containers have not been extensively studied. Due to the uncertainty of the retrieval time for inbound containers, Kim (1997) assumed that the pickup order is random and proposed a method for calculating the expected number of rehandles. To minimize the expected number of rehandles, Kim and Hong (2006) designed OH heuristic algorithm to optimize the storage location of blocking containers. In order to alleviate the imbalance of peaks and troughs of truck arrival times, Truck appointment system (TAS) has been implemented at many ports (Giuliano et al., 2007;Namboothiria et al.,2008;Zehendner et al.,2014). With the implementation of TAS, the time windows of truck arrival will be available at container terminals and the rehandling of inbound containers have received increasing attention. Ku et al. (2014) designed branch and bound method and heuristic algorithm to calculate the expected number of rehandles based on the time windows of truck arrival. In addition, Ku and Arthanari (2016) used stochastic dynamic programming to solve the optimization plan of relocation for import containers that have departure time windows obtained by the TAS. To reduce the number of rehandles with real-time arrival information of external trucks, some studies have focused on online version of CRP. Borgman et al. (2010); Dekker et al. (2006); Aspen et al. (2013) used simulation to compare the performance of different reshuffle strategies with storage space assignment. Zehendner et al. (2017) proposed an online algorithm based on real-time truck arrival information. Borjian et al. (2015) introduced the so-called CRP where the retrieval order of a subset of containers is known initially and the retrieval order of the remaining containers is revealed all at once at a later time. With the assumption of a probabilistic distribution on the unknown retrieval orders, they proposed a 2-stage approximate stochastic optimization algorithm extending the A$*$ algorithm.

For adjusting the pickup sequence to match the storage location also reduces rehandling work, the integrated problem to optimize pickup sequence and container rehandling strategy simultaneously begins to be paid attention. After pickup sequence dictation, although a greater reduction in rehandles can be achieved, longer time delay will be incurred to some trucks. For example, because of the service sequence change, the first truck to arrive might be the last one served. Therefore, to avoid causing excessive delays for the other trucks, pickup sequence dictation approach was applied only to the first group of trucks (Zhao and Goodchild (2010)). Borjian et al. (2015) and Galle et al. (2018) reduced the waiting time of the external trucks by controlling the number of containers out-of-order. All these papers dealt with the offline problem, which is optimizing the pickup sequence and the container rehandling strategy simultaneously before retrieval operations begin. Since the lack of exact truck arrival time, it is unable to calculate waiting time of external truck accurately. Thus, it is hard to use these methods to balance the number of rehandles and the waiting time of external trucks effectively.

The contributions of this paper are as follows. (i) We address a research problem that is important for container terminals to improve the efficiency of their yard operations, namely, the problem of how to reduce the number of container rehandles with the real-time truck arrival information. (ii) We develop a mathematical model which is distinctive to the literature in relative areas to simultaneously optimize the pickup sequence and the rehandling plan. This model can serve as an efficient tool for container terminals to reduce rehandling in real time. (iii) We design an algorithm to solve the model efficiently and effectively.

3. Model Formulation

3.1 Problem Description

In marine container terminals, inbound containers are unloaded to container yards for storage and then picked up by external trucks. Figure 1 is the illustration of inbound containers retrieving process. After entering the yard, the external truck will drive to the bay where the target container is stored, and wait for the gantry crane to put the target container on. "Blocking" occurs when a target container is stored beneath containers to be picked up later. The containers on top of the target container are "rehandled containers". As shown in Figure 1, numerical code on the container represents its pickup order. Since container 1 will be picked up before container 2, container 2 is the rehandled container for container 1. When blocking occurs, the rehandled containers must be relocated to other stacks. Such unproductive rehandling moves will decrease the efficiency of the terminal operation.

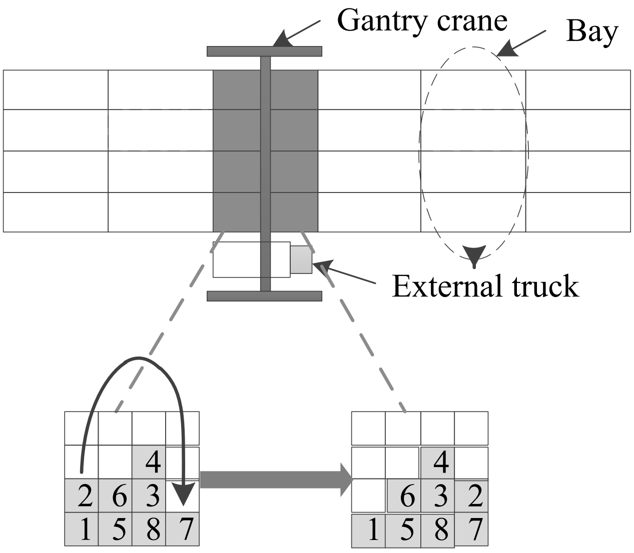

Figure 1: Illustration of Inbound Containers Retrieving Process
Source: Chen and Zeng of the original source (2019)

There are two ways to reduce rehandling work with truck arrival information. One is to carefully determine the storage location of rehandled containers to avoid future rehandling. The second is dictating the container pickup sequence for trucks so that it matches the container stacking sequence as closely as possible. In this paper, we consider both approaches. Since pickup sequence dictation will also increase the waiting time of some external trucks, we needs to utilize the arrival time of the outer card external trucks to balance the number of rehandles and the waiting time of external trucks.

Recently, several ports have implemented TASs (Truck appointment system). Before retrieval operations begin, TASs can provide time windows within which trucks will arrive to pick up containers. We consider a port with a TAS offering 30-minute time windows during which truck drivers who want to pick up a container can register to arrive at the port. As shown in the Figure 2, there are three time windows from 9:00 a.m. to 10:30 a.m. Trucks appointing the same time window are assigned to the same group. In this example, the first group of external trucks which arrive at the terminal from 9:00 a.m. to 9:30 a.m. is truck 1, truck 2 and truck 3. The second group of external trucks is truck 4 and truck 5. The third group of external trucks is truck 6 and truck 7. The exact arrival time of external trucks is revealed over time as trucks arrive at the terminal. Since adjusting pickup sequence of containers in different groups may cause too long waiting time of external trucks, the pickup sequence of containers within the same group is adjusted.

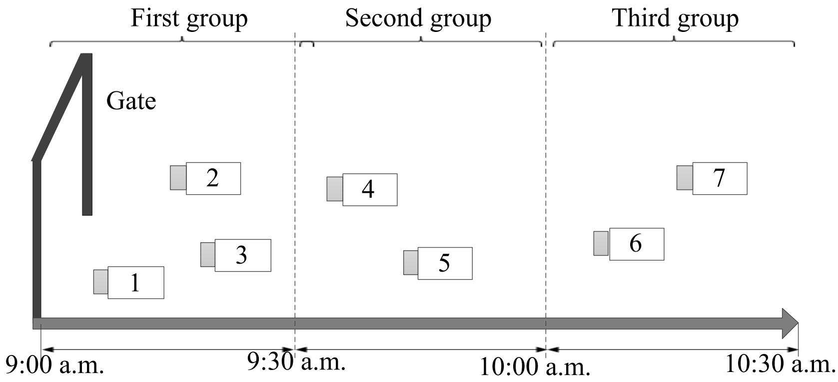

Figure 2: Illustration of Truck Arrival Information with the TAS
Source: Chen and Zeng of the original source (2019)

In this paper, an integrated problem to optimize pickup sequence and container rehandling strategy simultaneously is addressed. Before retrieval operations begin, we conduct the rehandling model with time windows to get the set of optimal rehandling plans of all possible pickup sequences. With this output and real-time truck arrival information, we can choose the optimal pickup sequence and its corresponding rehandling plan by online integrated optimization model.

3.2 Model Formulation

The following five assumptions that are generic to this variant of the CRP:

(1) The initial bay layout is known.

(2) Containers in the same bay have the same size and can be piled up in any order. This assumption is used from a practical point of view to decrease the solution space, in line with e.g., Kim and Hong (2006) and Caserta et al. (2011b). Note that this assumption might result in cutting away some optimal solutions. However, relocating non-blocking containers belongs to the pre-marshalling movements. The pre-marshalling movement in real time is another challenging problem waiting to be addressed, which is beyond the intent of this paper.

(3) No container is arriving in the stack during the retrieval process.

(4) Rehandled containers are only relocated to stacks in the same bay (Kim and Hong, 2006; Zhao W, Goodchild, 2010; Forster and Bortfeldt, 2012). This is a reasonable restriction since relocations between bays are very time consuming.

(5) Containers are reshuffled if and only if any container below them is to be retrieved. This assumption is used from a practical point of view to decrease the solution space. The container relocation problem has been proven to be NP-hard. Since adjusting the retrieving sequence results in a much larger solution space, the non-blocking containers are not relocated in this problem. Note that this assumption might result in cutting away some optimal solutions. However, relocating non-blocking containers belongs to the pre-marshalling movements. The pre-marshalling movement under the group arrival information is another challenging problem waiting to be addressed, which is beyond the intent of this research.

To include the parts of the truck arrival information, the following assumptions are also made in the model:

(6) The pickup sequence is adjusted only within the same group. To avoid excessive delay of the external trucks, the pickup sequence is adjusted only within the same group.

(7) The full arrival information of trucks in the group is reveal at the moment the retrieval of the group commences. Through GPS (Global Positioning System) and IoT (Internet of things) technology, the full arrival information of trucks in the group is revealed at the moment the pickup of the group starts.

(8) There is an equal chance for any pickup sequences to be chosen. This assumption is reasonable because containers within the same group can be retrieved in any order.

3.2.1. Rehandling Model with Time Windows

This model is a stochastic dynamic programming model, which is to get the set of optimal rehandling plans of all possible pickup sequences before retrieval operations begin. If the storage location of rehandled containers is not well planned, they may require further rehandling which will increase the number of rehandles and the waiting time of external trucks. Therefore, the purpose of this model is to minimize the expected number of rehandles.

Let $i \in \{1,...,N\}$ be the set of containers to be retrieved in a bay indexed by i where N represents the total number of containers to be retrieved in a bay. The number of groups of external trucks is denoted by W. For each group $w \in \{1,2,...,W\}$, let q_w be the number of external trucks in w. Since each external truck retrieves one container, the total number of containers equals the number of external trucks by definition $\sum_{w=1}^{W} q_w = N$.

Initially, the priority of containers whose corresponding trucks are in group w is denoted by ς_w, such that $\varsigma_w = 1 + \sum_{u=1}^{w-1} q_u$, where the sum is empty for $w = 1$. If a container is chosen to be the k^{th} container to be picked up, its priority reveals to k. The index of container to be the k^{th} container to be retrieved is denoted by c_k and the probability of container i to be the k^{th} container to be retrieved is denoted by $p_k(c_k = i)$. If the external truck of container i in group w, $p_k(c_k = i)$ is given by

$$p_k(c_k) = \begin{cases} \dfrac{1}{q_w}, w = \min\{\varsigma_w \geq k\} \\ 0 \end{cases} \tag{1}$$

Let Y_w be the state before the pickup sequence of containers in group w is chosen, and X_{ς_w} be the state after the choice of pickup sequence. If random pickup sequence denoted by $c_{\varsigma_w},...,c_{\varsigma_w+q_w-1}$ is chosen, we can write $Y_w \xrightarrow{c_{\varsigma_w},...,c_{\varsigma_w+q_w-1}} X_{\varsigma_w}$ which represents transforming Y_w to X_{ς_w}. After the pickup sequence of external trucks in group w has been chosen, actions to retrieve its corresponding containers must be made. Let a_k be the action to pick up the k^{th} container from the bay, we can write $X_k \xrightarrow{a_k} X_{k+1}$ which represents transforming X_k to X_{k+1} after the action a_k. After the retrieval of external trucks in group w, we need to choose the pickup sequence of external trucks in next group. Thus, we have $X_{\varsigma_w+q_w-1} \xrightarrow{a_{\varsigma_w+q_w-1}} Y_{w+1}$. When all containers in the bay have been retrieved, the state is denoted by Y_{W+1}. The number of rehandles that occur during action a_k given the state X_k is denoted by $r(a_k | X_k)$. Let the function $f(\cdot)$ be such that $f(X)$ is the minimum expected number of relocations required to pick up all containers from the state X. The following are calculation formulas of $f(X)$:

$$
\begin{aligned}
f(Y_w) &= \mathop{\mathrm{E}}_{c_{\varsigma_w},\dots,c_{\varsigma_w+q_w-1}} \left[f(X_k) \right] \\
&= \sum_{c_{\varsigma_w},\dots,c_{\varsigma_w+q_w-1}} \left[\prod_{k=\varsigma_w}^{\varsigma_w+q_w-1} p_k(c_k) f(X_k) \right], k = q_w
\end{aligned}
$$

$$f(Y_{W+1}) = 0 \tag{2}$$

$$f(X_k) = \begin{cases} r(a_k | X_k) + \min_{a_k} \{ f(X_{k+1}) \}, q_w > 1 \text{且} k \in \{\varsigma_w, \varsigma_w + q_w - 2\} \\ r(a_k | X_k) + \min_{a_k} \{ f(Y_{w+1}) \}, k = \varsigma_w + q_w - 1 \end{cases} \tag{3}$$

in short:

$$f(X_{\varsigma_w}) = \min_{a_{\varsigma_w},\dots,a_{\varsigma_w+q_w+q_w-1-1}} \left\{ \left(\sum_{k=\varsigma_w}^{\varsigma_w+q_w-1} r(a_k | X_k) \right) + f(Y_{w+1}) \right\} \tag{4}$$

Since the previous state and the action taken there are independent, the object function of the model $f(Y_1)$ is given by

$$
\begin{aligned}
f(Y_1) = &\sum_{c_{\varsigma_1},\dots,c_{\varsigma_1+q_1-1}} \min_{a_{\varsigma_1},\dots,a_{\varsigma_1+q_1-1}} \sum_{c_{\varsigma_2},\dots,c_{\varsigma_2+q_2-1}} \min_{a_{\varsigma_2},\dots,a_{\varsigma_2+q_2-1}} \dots \sum_{c_{\varsigma_W},\dots,c_{\varsigma_W+q_W-1}} \min_{a_{\varsigma_W},\dots,a_{\varsigma_W+q_W-1}} \\
&\times \left[\prod_{k=1}^{N} p_k(c_k) \sum_{k=1}^{N} r(a_k | X_k) \right]
\end{aligned} \tag{5}
$$

3.2.2. Online Integrated Optimization Model

Based on the solution of the previous model and real-time truck arrival information, this model is to find the optimal pickup sequence. Because the set of optimal rehandling plans of all possible pickup sequences is known, the rehandling plan of optimal pickup sequence can be determined at the same time. As aforementioned, adjusting pickup sequence usually increases the waiting time of external trucks. Therefore, this model limits the departure time of every external truck to avoid excessive delay.

Let $b \in \{\varsigma_w,\dots,\varsigma_w + q_w - 1\}$ be the set of external trucks in group w indexed by i. The time the retrieval of the group W commences is denoted by O_w and $O_1 = 0$. Let E_b be the latest departure time of external truck b. The time of one retrieval and rehandling operation are donated by h_1 and h_2 respectively. r_b^t represents the number of rehandles required when external truck b retrieves the container which is the t^{th} container to be retrieved in group w. The set of all possible pickup sequences of external trucks in group w is denoted by $t \in \{1,\dots,q_w\}$.

We introduce a binary decision variable Z_b^t, which denotes whether $Z_b^t = 1$ or not $Z_b^t = 0$ external truck is the t^{th} to pick up the container in group w .Furthermore, variable S_b identifies the time external truck b starting to pick up the container and D_b identifies external truck b finish the retrieval. The online integrated optimization model can be formulated as follows:

$$\min\{R(Z)\} \tag{6}$$

s.t.

$$\sum_{t=1}^{q_w} Z_b^t = 1,\ \forall b \in \{\varsigma_w,...,\varsigma_w + q_w - 1\} \tag{7}$$

$$\sum_{b=\varsigma_w}^{\varsigma_w+q_w-1} Z_b^t = 1,\ \forall t \in \{1,...,q_w\} \tag{8}$$

$$Z_b^1 \times (S_b - O_w) = 0 \tag{9}$$

$$Z_b^t \cdot \left(S_b - \sum_{l=\varsigma_w}^{\varsigma_w+q_w-1} \left(Z_l^{t-1} \times D_l \right) \right) = 0,\ \forall b \in \{\varsigma_w,...,\varsigma_w + q_w - 1\},\ \forall t \in \{2,...,q_w\} \tag{10}$$

$$Z_b^t \times \left(D_b - S_b - h_1 - h_2 \times r_b^t \right) = 0,\ \forall b \in \{\varsigma_w,...,\varsigma_w + q_w - 1\} \tag{11}$$

$$\sum_{t=1}^{q_w} \left(Z_b^t \times D_b \right) \le E_b,\ \forall b \in \{\varsigma_w,...,\varsigma_w + q_w - 1\} \tag{12}$$

$$O_{w+1} = \sum_{b=\varsigma_w}^{\varsigma_w+q_w-1} \left(Z_b^{q_w} \times D_b \right),\ \forall w \in \{1,...,W-1\} \tag{13}$$

The purpose of the objective function (6) is to minimize the expected number of rehandles. Note $R(Z)$ represents the minimum expected number of rehandles of the pickup sequence Z which can be achieved by solve the previous model. Constraint (7) ensures that each truck pick up a container. Constraint (8) ensures that only one truck can pick up the container at each stage. Constraints (9) and (10) determine the time that trucks in group w start to pick up containers. Constraints (11) determine the time that truck b completes its pickup task after retrieval and rehandling operation. Constraint (12) ensures that each truck should complete its pickup task within the acceptable time. Constraints (13) determine the time that all trucks in group w have completed pickup tasks.

4. Solution Algorithms

4.1 The Framework of the Algorithms

The container relocation problem has been proven to be NP-hard (Caserta et al., 2012). The problem in this paper is a variant of the CRP with more complexity and higher requirement of completion time. Therefore, to improve the computation efficiency and obtain relocation patterns for container terminals in real time, we design an algorithm based on decision tree search algorithm and greedy strategy. The framework of the algorithms is shown in Figure 3.

Like the model, the algorithm is divided into two parts: one is offline stage (before retrieval operations begin), the other is online stage (during retrieval process). At the offline stage, we divide the external trucks into groups based on arrival time windows and then use decision tree search algorithm calculate the set of optimal rehandling plans of all possible pickup sequences and its minimum expected number of rehandles. At the online stage, with real-time arrival information and the results of offline sage, we use greedy heuristic algorithm to choose the optimal pickup sequence.

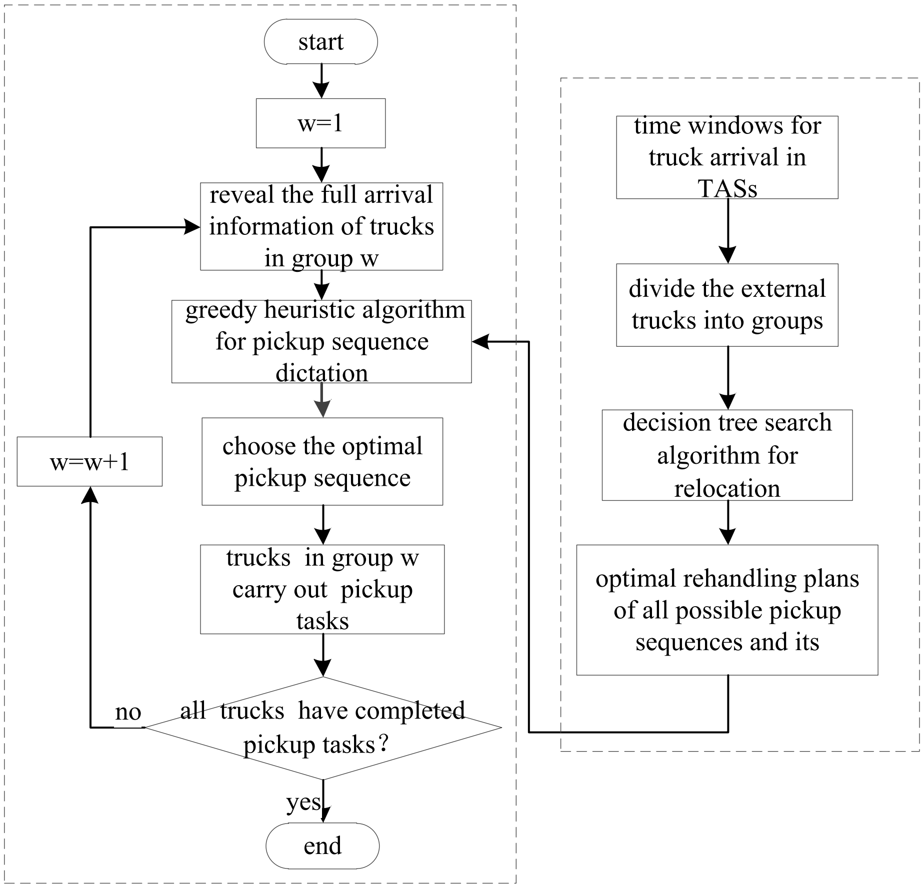

Figure 3: Framework of the Algorithms
Source: Chen and Zeng of the original source (2019)

4.2 Decision Tree Search Algorithm for Relocation

Rehandling model with time windows is a stochastic dynamic programming model, which can often be modeled as a tree search in a state space starting from some given initial state with rules describing how to transform one state into another. They will be applied over and over again to eventually achieve some goal condition. In this problem, the transfer of states represents an action of defining the next container to be retrieval or retrieving the container. Different from Ku and Arthanari (2016), from each state, successors are reachable by the arrival of next external trucks or the retrieval of a container.

As shown in Figure 4, we construct a decision tree. In the context of this problem, each node in the search tree corresponds to a bay configuration. The left side of Figure 4 is the tree structure expressed in bay configuration, where the numerical code on each container identifies its priority. The priority is group priority initially, and reveals to the retrieval order of the corresponding container after the choice of pickup sequence. The root node represents an initial state of the bay configuration and the leaf nodes the empty layout, i.e. the goal state. The decision tree of the stochastic dynamic programming model consists of chance nodes and decision nodes. A chance node embodies the stochasticity of the model, whereas a decision node models the possible choices of the algorithm. Thus, the left side of Figure 4 is the tree structure expressed in nodes, where chance nodes and decision nodes are denoted by circles and squares respectively, and the number of rehandles to pick up the target container represented by the line shape of arrows. A chance node is a bay configuration for which pickup sequence within the group is not known yet, which occurs only at the beginning of each group. A decision node is a bay configuration for which pickup sequence within the group is known. Therefore, chance nodes correspond to Y_w and decision nodes correspond to X_{ς_w}.

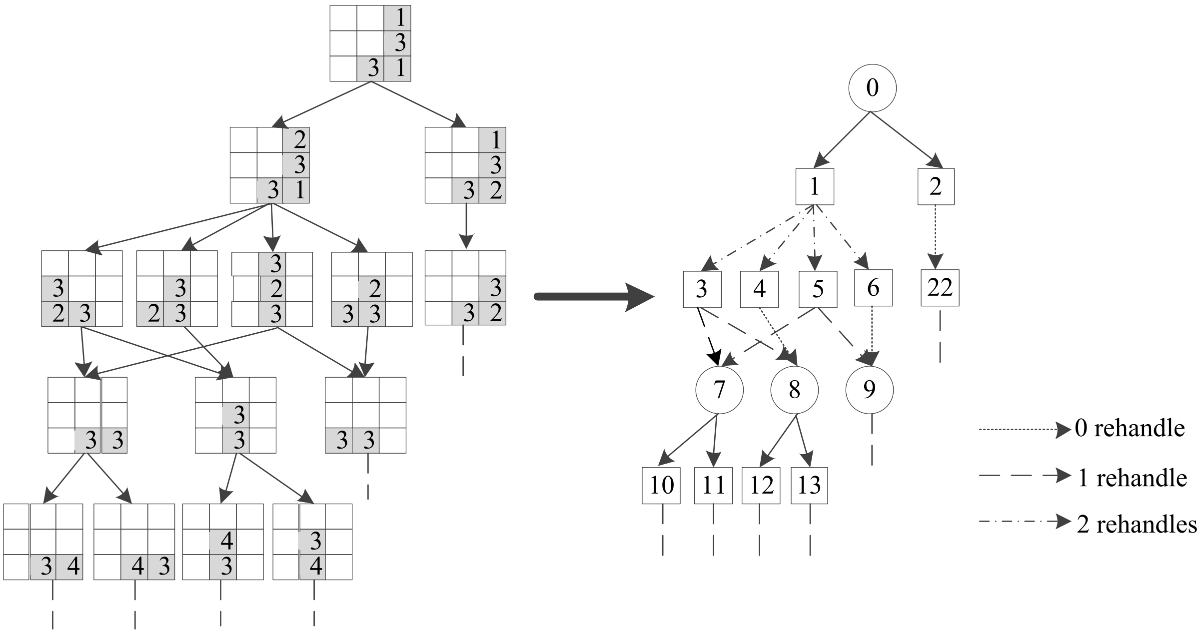

Figure 4: Illustration of Decision Tree

Source: Chen and Zeng of the original source (2019)

Let n be a node corresponding to a bay configuration in the decision tree. Each node in the decision tree has the cost function denoted $f(n)$, combines the path cost from the root node to node n and the estimated cost of the cheapest path from n to the goal. $f(n)$ is given by Eq. (14) where $f(n)$ is the sum of the number of reshuffles incurred thus far denoted $g(n)$, and the minimum expected number of future rehandles denoted $h(n)$.

$$f(n) = g(n) + h(n) \tag{14}$$

At any node n, getting $g(n)$ is trivial given the decision tree, but predicting $h(n)$ may be difficult in the remaining depth of the node n . Let $n_k\,(1,2,...,m)$ be successor from any node n where m be the total number of successors from the node n . If the node n is a decision node, $h(n)$ is calculated by Eq. (15); if the node n is a chance node, $h(n)$ is calculated by Eq. (16), assuming the equal chance of the node n being transformed into any node n_k .

$$h(n) = min\left[cost(n, n_k) + h(n_k)\right] \tag{15}$$

$$h(n) = \frac{1}{m}\sum_{k=1}^{m} h(n_k) \tag{16}$$

In order to reduce search space while ensuring optimality, before the searching the decision tree, we use the "Abstraction" technology proposed by Ku and Arthanari(2016) to reduce the number of nodes in the tree. For each node in the tree, the technology is implemented by two steps: (1) remove all empty columns from the stack; (2) reorder the columns in an ascending order of the pickup priorities from the bottom tier to the top tier. For instance, in Figure 5, after removing the empty column(s), the bay configuration in Figure 5a may be represented as [(1, 2, 0), (3, 0, 0), (4, 2, 4)] in a 2-D array. This array can be reordered to [(1， 2， 0)，(3， 0， 0)，(4， 2， 4)], the graphical representation of which is illustrated in Figure 5d. Likewise, bay configurations in Figure 5b and c can be projected into the same abstract bay configuration as of Figure 5d.

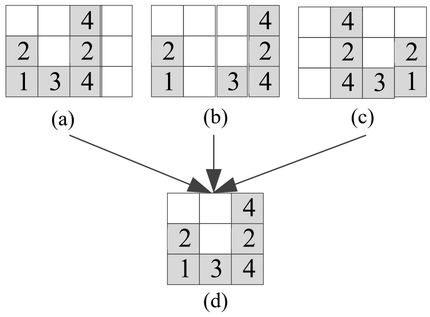

Figure 5: Illustration of"Abstraction" procedure
Source: Chen and Zeng of the original source (2019)

After decreasing the size of the tree, we use the depth-first search (DFS) with back tracking to search the decision tree. Since the exact method may do not show reasonable time performance in large instances, we use ERI heuristic algorithm for choosing the target column for each container above the target container to be reshuffled in. The main idea of ERI algorithm is to select the stack with the lowest as the location of the container being reshuffled to. ERI indicates the number of containers in the column that departs earlier than the container being reshuffled to the column. Let m be the number of the containers in the column where their priorities are the same as that of the container being reshuffled to. $p(k)$ represents the probability of having k number of earlier departing containers below the container being reshuffled to. ERI is calculated by Eq. (17).

$$ERI = \sum_{k=1}^{m}\left(k \times p(k)\right) = \sum_{k=1}^{m}\frac{k}{m+1} = \frac{1}{m+1}\frac{m(m+1)}{2} = \frac{m}{2} \tag{17}$$

4.3 Greedy Heuristic Algorithm for Pickup Sequence Dictation

The main idea of greedy heuristic algorithm for pickup sequence dictation is to select the pickup sequence of the minimize expected number of rehandles for external trucks in group w, while ensuring that each truck should complete its pickup task within the acceptable time. The procedures for this algorithm are as follows:

Step1: $MinR$ represents the minimum expected number of rehandles. A very large constant is denoted by M. Let $MinR = \mathrm{M}$.

Step2: Generate the set of all possible pickup sequences of external trucks in group w, denoted by $s = \{s_1, ..., s_{q_w!}\}$.

Step3: Take a pickup sequence from the aforementioned set, denoted by s， and calculate the departure time of external trucks in group w with this pickup sequence.

Step4: If there is an external truck in group w departing the yard after the latest departure time, go to Step3. Otherwise, go to Step5.

Step5: R_s represents the minimum expected number of rehandles of pickup sequences s. If $R_s < MinR$, update $MinR = R_s$, and let s be the optimal pickup sequence for external trucks in group w and the optimal rehandling plan of s be the optimal rehandling plan.

Step6: If all possible pickup sequences of external trucks in group w have been search, go to Step7. Otherwise, go to Step3。

Step7：If there is an optimal pickup sequence, end. Otherwise, and the optimal pickup sequence is the arrival order of external trucks in group w and end.

5. Computational Experiments

Numerical experiments have been performed to evaluate the performance of the proposed model and algorithms. For a typical block served by rubber tire gantry cranes, each bay normally consists of 6 stacks and in each stack, the containers may be up to 3 or 5 tiers high (Tang et al., 2015). Thus, 18 scales of bay configurations consisting of 5-10 stacks and 3-5 tiers were considered in numerical experiments. The average time of one retrieval and rehandling operation are 2min/TEU and 1min/TEU respectively. The current appointment system implemented in HIT is a straightforward quota system in which the number of appointments is allocated in every 30-minute time slot (Murty et al. (2005b)). The number of external trucks in each 30-minute time window is 3-7. Truck arrival time is following a uniform distribution within the time windows of the external truck. Each external truck must finish its retrieval within 30 minutes. For each scenario, 50 instances with different initial storage states (configurations) were randomly generated. For each storage state, 100 different truck arrival times were randomly generated. All experiments are performed on a 64-bit Windows 7 OS PC with 2.60 GHz Intel i5-4210 processor and 8.00 GB of RAM, and the programming language is MATLAB 2014a.
To evaluate the performance of integrated optimization of rehandling plan and pickup sequence, we compare results of four kinds of retrieval strategies. S represents using the sequencing method, while NS represents using the no-sequencing method(FCFS). R represents optimizing rehandling plans, while NR represents not optimizing rehandling plans which is relocating the blocking container to the lowest stack. NR is the most common rehandling method in the yard. Thus, the simplest strategy is NS&NR. The method of this paper is denoted by S&R. The other two strategies are NS&R and S&NR. The algorithm of NS&R replaces section 5.3 with the method where pickup sequence is the arrival order of external trucks. The algorithm of S&NR removes the offline phase and change the meaning of R_s in section 4.3 into the number of renhandles caused by pickup sequence s. The calculation results of the four suitcases are shown in Table 1.

Table 1: Comparison of four kinds of Retrieval Strategies

Scenario	Rehandles rate (%)				Avg truck waiting times (min)			
	S&R	NS&R	S&NR	NS&NR	S&R	NS&R	S&NR	NS&NR
5-3	13.4	34.1	14.1	46.1	3.5	1.9	5.1	2.5
5-4	20.3	39.2	23.0	52.6	3.5	2.0	5.4	2.7
5-5	36.7	56.7	36.2	71.3	4.3	2.3	4.8	3.4
6-3	15.7	32.5	13.9	41.2	3.1	2.1	5.1	2.3
6-4	22.5	39.9	31.9	62.8	3.8	2.0	4.9	3.0
6-5	34.4	53.4	37.1	67.5	3.7	2.4	5.2	3.2
7-3	17.9	30.9	12.3	36.8	2.9	2.1	4.6	2.1
7-4	22.3	39.2	28.2	48.8	3.3	2.1	5.3	2.6
7-5	28.9	42.9	37.3	61.7	3.6	2.2	5.6	3.0
8-3	19.4	34.5	24.7	45.6	3.0	2.2	4.7	2.4
8-4	28.1	39.1	28.3	55.3	3.5	2.2	5.8	2.7
8-5	29.7	43.1	41.6	63.7	3.5	2.2	4.9	3.1
9-3	16.3	27.2	17.2	32.8	2.4	2.0	5.1	2.0
9-4	32.1	42.4	31.2	47.3	2.9	2.2	5.0	2.5
9-5	35.8	48.2	44.7	62.2	3.4	2.5	5.5	3.0
10-3	12.7	22.6	21.5	32.9	3.8	1.7	5.9	2.0
10-4	24.8	33.6	31.5	44.5	5.4	2.1	6.0	2.4
10-5	32.7	45.9	43.0	59.0	7.0	2.2	7.2	3.0

Source: Chen and Zeng of the original source (2019)

For the rehandles rate, it can be seen in Table 1 that the results are S&R<S&NR< NS&R<NS&NR. Because optimizing the rehandling plan can reduce the number of rehandles, S&R has a lower rehandles rate than S&NR. Similarly, rehandles rate of NS&R is lower than NS&NR. S&R has a lower rehandles rate than NS&R, due to adjusting pickup sequence can further reduces the number of rehandles. Similarly, rehandles rate of S&NR rate is lower than NS&NR. S&NR has a lower rehandles rate than NS&R, because pickup sequence dictation can avoid rehandle directly, while optimization of the storage location of rehandled containers only reduces future rehandles. Therefore, optimization of pickup sequence or the storage location of rehandled containers alone can reduce the rehandles, while the effect of pickup sequence dictation is more remarkable. However, optimizing the rehandling plan and pickup sequence simultaneously can achieve the minimum number of rehandles.

When it comes to truck waiting times, the average truck waiting time of all strategies is within 8 minutes in Table 1. S&R results in longer waiting time than NS&R strategy, because optimizing the rehandling plan can reduce rahandling time. Similarly, compared with NS&NR, the truck waiting time of S&NR is longer. Since

adjusting pickup sequence may cause delay of the external trucks, the average truck waiting time of S&R is higher than that of NS&R. Similarly, compared with S&NR, the truck waiting time of NS&NR is longer. So we can conclude that Optimizing the rehandling plan and pickup sequence simultaneously greatly reduces the number of rehandles, while increases the average waiting time of external trucks.
To evaluate the performance of the online algorithm in this paper, we compare results of solving the integrated problem online and offline. The offline algorithm removes the online phase, and changes the chance nodes of the decision tree in section 4.2 into the decision node. Since the exact arrival information of trucks is unknown before the retrieval, the offline algorithm cannot consider the truck waiting time and just consider the number of handles. The results are presented in Table 2.

Table 2: Comparison between Online Algorithm and Offline Algorithm

Scenario	Rehandles rate (%)		Avg truck waiting times (min)	
	offline	online	offline	online
5-3	12.6	13.4	4.3	3.5
5-4	18.0	20.3	4.8	3.5
5-5	35.8	36.7	4.3	4.3
6-3	15.3	15.7	3.8	3.1
6-4	21.4	22.5	4.2	3.8
6-5	33.2	34.4	3.7	3.7
7-3	16.8	17.9	3.0	2.9
7-4	21.8	22.3	3.5	3.3
7-5	28.5	28.9	3.8	3.6
8-3	18.9	19.4	3.1	3.0
8-4	27.8	28.1	3.6	3.5
8-5	28.9	29.7	3.5	3.5
9-3	15.8	16.3	2.5	2.4
9-4	31.5	32.1	3.1	2.9
9-5	33.6	35.8	3.6	3.4
10-3	11.9	12.7	3.9	3.8
10-4	23.9	24.8	5.7	5.4
10-5	31.5	32.7	7.8	7.0

Source: Chen and Zeng of the original source (2019)

As shown in Table 2, the offline algorithm results in lower rehandles rate because the only goal is to reduce number of rehandles. Lower rehandles rate means lower rehandling time. So the truck waiting time of offline

optimization is lower too. In summary, we can conclude that the online algorithm increases the number of rehandles and the average waiting time of external trucks slightly.
To show the truck waiting time of the online algorithm and the offline algorithm clearly, we draw the contrast probability density curve in Figure 6. The dotted line represents offline optimization, which is more dispersive. Since the online algorithm controls wait time of each external truck, excessive delay of the external trucks is avoided. Therefore, through the online algorithm, container terminals can limit the waiting time of each external truck in a reasonable range.

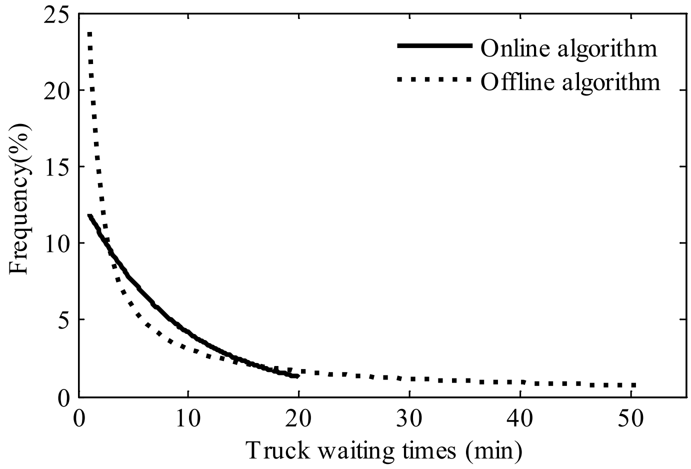

Figure 6: Contrast Curve of Truck Waiting Time

Source: Chen and Zeng of the original source (2019)

6. Conclusion

In this paper, issues related to reducing the number of rehandles performed with real-time arrival information of external trucks are addressed. To solve the online integrated problem considering adjustments to the container pickup sequence within each group, we decompose it into two sub-problems. A rehandling model with time windows and an online integrated optimization model are developed to address sub-problems respectively and minimize the total number of rehandles. The relocation of the rehandled containers and the container pickup sequence are optimized simultaneously. An algorithm based on decision tree search algorithm and greedy strategy is proposed to solve the model.
Salient points from the computational experiments are as follows: First, among the four kinds of retrieval strategies discussed in this paper, optimizing the rehandling plan and pickup sequence simultaneously can greatly reduce the number of rehandles, while may increase the average waiting time of external trucks. Second, after comparison between the online algorithm and the offline algorithm, the online algorithm we proposed controls wait time of each external truck, thus can contribute to the stability of the service level in container terminals.
For future research, this paper considers only the storage location of rehandled containers and the container pickup sequence. Actually, The Yard Crane Scheduling also affects the retrieval process. Although the problem falls into a difficult category, how to solve integrated problem of the Yard Crane Scheduling and the Container Relocation with real-time arrival information will be an interesting topic for future studies.

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The Outlook of Deep-water Container Terminal at the Port of Kaohsiung

Ting-Yi Tsai[1], *Hui-Huang Tai*[2]

[1] PhD student, Department of Shipping and Transportation Management, National Kaohsiung University of Science and Technology, Taiwan. Chairman of Taiwan International Ports Logistics Corporation.
[2] Professor, Department of Shipping and Transportation Management, National Kaohsiung University of Science and Technology, Taiwan
Email: [1]p04685@gmail.com

Abstract

The Port of Kaohsiung has been encountered impacts from the internal and external environment. The impact has been substantially reflected in the recent declining of the transshipment routes and container volume and even endangers its status as a regional hub port. This paper demonstrates the development of the deep-water Container Terminal at the Port of Kaohsiung. Upon the terminal's completion, it is not only expected to allow the Port of Kaohsiung to be capable to accommodate mega containerships, but also reintegrate the new and old terminals and readjust the capacity distribution and terminal function. The reallocation of the terminal capacity and function readjustment of the port area would also make the transformation of the old port area to a waterfront recreation wonderland. In order to sustain its competitive advantages and status as a regional hub port, this study suggests that the Port of Kaohsiung should intensify its container transshipment function and quality service for carriers.

Keywords: Intercontinental hub port, Deep-water container terminal

1. Introduction

The Port of Kaohsiung is located in the southwest part of Taiwan, and the intersection of East-West and North-South shipping routes of Asia-Pacific. The Port has an advantageous geographical location and has been the largest container port in Taiwan since the early years. Moreover, it's also an important transshipment hub for shipping route of Asia-Europe, Asia-America and Southeast Asia. The Port of Kaohsiung is handling more than 70% of Taiwan's import and export containers. Around half of the total container volumes were transshipment containers (MOTC, 2016a). The Port of Kaohsiung has been listed the top 3 in the world's container ports in 1999 and plays major intercontinental transshipment hub for both Mainland China and Southeast Asia. However, the need for transshipment has been significantly reducing due to the economic rise of China over the past twenty years, particularly its rapid development of industry and trade, the growth of import and export containers, and the massive investment in the construction of ports alongside the coast to provide the direct access service for containers. On the other hand, the traditional industries in Taiwan have moved to Mainland China and Southeast Asia because of the high cost of land and labor and the limitation of resources. The economies of Southeast Asian countries have also grown annually and some of them, such as Thailand and Vietnam have also solicited foreign capital to build deep-water ports and reduce their dependence on transshipment. In addition, the rapid changes in the recent maritime and shipping management environment, ship upsizing, and the business situation of shipping carriers (closure, acquisition, or alliance restructuring), all of which have severely affected the transshipment routes and the volume. The Port of Kaohsiung has been facing challenges from both internal and external environment. While the overall operation volumes of the Port is experiencing mild growth with a growth rate of only about 3-5 % between 2008 and 2018 (TIPC's website, 2018), the proportion of the transshipment is decreasing, and the Port's ranking of world container ports has gradually slid and eventually the status of an intercontinental transshipment hub port has been down grading to a regional hub port.

Most of the container terminals at the Port of Kaohsiung are leased to shipping carriers for years. This operation model has brought a great volume of transshipment to the Port. However, due to the dispersed location leased by different shipping carriers and their various container capacity and capability to canvass cargo, it's hard to truly bring it to the terminals' fullest function. The Port of Kaohsiung has lost its advantage to become an intercontinental hub port for not being able to accommodate containerships over 15,000 TEU because of the lack of deep-water terminals and channels to properly serve the mega containerships. At the Port of Kaohsiung, the number of Fareast-Europe (herein after as FE/Europe) route has been greatly reduced but trans-Pacific (herein after as T/P) routes are still using the port as a transport hub for most Southeast Asian countries and South China due to its advantageous geographical location, high operation efficiency and the lower operation costs compared to the neighboring ports. Currently, the expansion project of the deep-water wharfs at the Container Terminal No. 7 is under progressive planning to increase the competitiveness of the Port of Kaohsiung and further become the regional transport hub. During the process of the expansion it is possible to modify the old terminals and implement terminals reallocation and re-designating of port areas. The current tenant carriers will be given an opportunity to exchange their leasing wharfs for a more appropriate location, and the stevedoring operation and transportation between terminals can be properly integrated and adjusted to reduce unnecessary cargo transferring in the port area and substantially improve the capacity and operation scale of the terminals. Upon the completeness of the terminal reintegration, the old port area which is close to the urban area with insufficient water depth may be transformed to the waterfront recreation and commercial tourism area.

The objective of this study is to examine the internal and external environment of the Port of Kaohsiung and the outlook of developing deep-water container terminal at the Port of Kaohsiung.

2. The Current Environment and Operation Status of Container Terminals at the Port of Kaohsiung

2.1. Analysis of Internal Environment

2.1.1. Changes in Industrial Structure

Traditional industries in Taiwan have gradually moved to Mainland China or Southeast Asian in recent years for cost reduction and thus the industrial structure in Taiwan has shifted from the traditional manufacturing to service industry. According to the report of Ministry of Economic (2018), the output value of service-oriented industries in Taiwan accounted for 64.14% of GDP, whereas the industrial sector was 34.54% and other economic areas (agriculture, fishery, and animal husbandry) accounted for less than 2%. The shifting of the industrial structure has also acted to limit the growth of import and export container volumes and even cause its stagnation. However, due to the high cost of maritime transport, instead of manufacturing or processing in countries with low labor and land costs and transports the products to the consumption market, the operation pattern at present tends to manufacture or process right where the consumption market is, and therefore, demand for long-haul or multiple transports is declining among which, the demand for maritime shipping is inevitably affected (MOTC, 2016b).

2.1.2. Terminals Being Leased in Disperse

There are six container terminals in the Port of Kaohsiung, mainly adopting a landlord port model and being leased to Evergreen, OOCL, APL, Wan Hai, Yang Ming, and Hyundai (As shown in Figure 1) which operating with the Port of Kaohsiung as their transshipment center for ocean or near-sea shipping. Because the container terminals were built in different stages and dispersed across the port, some tenant carriers have to lease piers in two different terminals (such as Evergreen, YML and HMM) or two different carriers leased piers in the same terminal and causing the containers of the same carrier are in need to be transported inter-terminals and thus result in higher transshipment cost. Moreover, the terminal conditions and berths arrangements of each carrier differed considerably, causing excessive congestion at some terminals while others remain idle. The port's overall capacity therefore cannot be fully utilized or furthermore increased (MOTC, 2016a; MOTC, 2017).

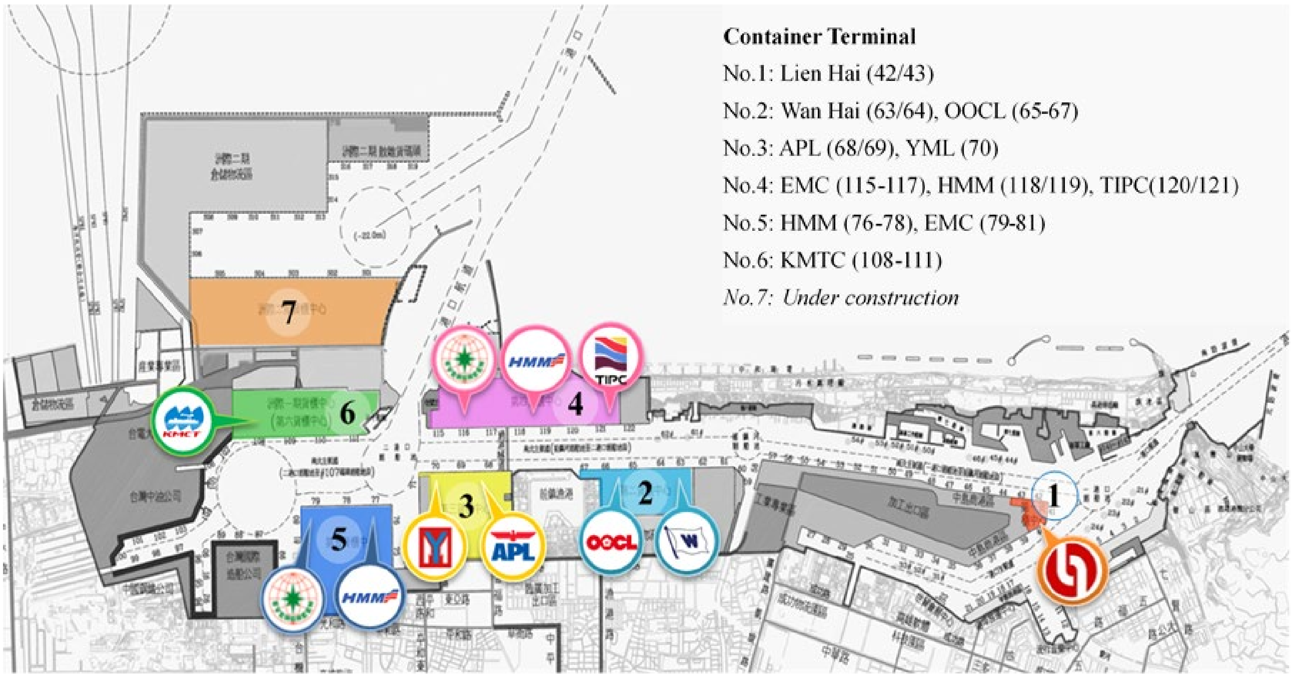

Figure 2: Location of Container Terminals at the Port of Kaohsiung

2.1.3. The Slow Progress of Terminal Expansion

The expansion of the terminals and channels at the Port of Kaohsiung has been in slow progress over the past 20 years, and certainly not sufficient to catch up with the speed of containerships upsizing. Currently, only Container Terminal No.4 leased by Evergreen and Container Terminal No.6 leased by Kao Ming are equipped with berths with depth of 16 meters to accommodate large containerships with draft up to 15 meters (approximately a 14,000 TEU containership). Underneath the main channel of the Port of Kaohsiung, there is a Cross-Harbor Tunnel that renders berths to its north unavailable for ships with a draft of more than 14 meters. However, berths located south to the tunnel can only accommodate containerships more than 14,000 TEU under certain condition (e.g., load, draft, weather, and tugboats) because of the limited width of the turning basin and channel.

2.1.4. The Tenant Carriers Withdrew from the Port of Kaohsiung

Taiwan traditional industries have been moved abroad since the late 1990s, and the local import and export sources have also been significantly reducing, besides, Mainland China and the neighboring countries have aggressively expanded their ports to strive for the transshipment container sources. As a result, MAERSK line which leased Pier 75-77 at Container Terminal No. 5 withdrew from the Port of Kaohsiung in 2010 and turned to invest container terminals at Xiamen Port due to the limited source of import and export goods and decreased transshipment cargo in Taiwan. Moreover, NYK terminated its leasing of Pier 121 in 2015.

2.2. Analysis of External Environment

2.2.1. The Impact of Ship Upsizing

According to statistics of Alphaliner (2019) (as shown in Figure 2), ships with a capacity of more than 18,000TEU accounted for only 1.5% of global ship capacity in 2014 and those with 10,000 TEU to 17,999TEU accounted for 17.24%. In 2016, ships with 10,000TEU to 23,000TEU capacity accounted for more than 25%. In 2018, the ships with 10,000TEU to 17,999TEU capacity significantly accounted for 24.79% and those with capacity over 18,000 TEU accounted for 8.1% and is expectable to further increase to 11.26% in 2020. Besides, according to the report of UNCTAD (2018), two-third of new build ships in the future will be mega ships over 14,000 TEU in capacity and will be operated by large shipping carriers. Therefore, it's quite clear that if a port fails to keep pace with this upsizing trend, shipping carriers will most likely deploy their shipping routes and dock their ships elsewhere. Figure 3 shows the number of incoming large vessels at the port of Kaohsiung has been increasing annually since 2012, and there were 351 container ships with a capacity of 13,000 TEU and 99 container ships with a capacity of 10,000-12,999 TEU berthed at the Port of Kaohsiung in 2018. Regretfully, Mega containerships with a capacity of more than 15,000 TEU are unable to call at the port because of the limitation of channel depth and the turning basin width. Moreover, most of the mega ships are mainly deployed at the FE/Europe routes which result in the Port of Kaohsiung's gradual loss of its transshipment cargo at these routes.

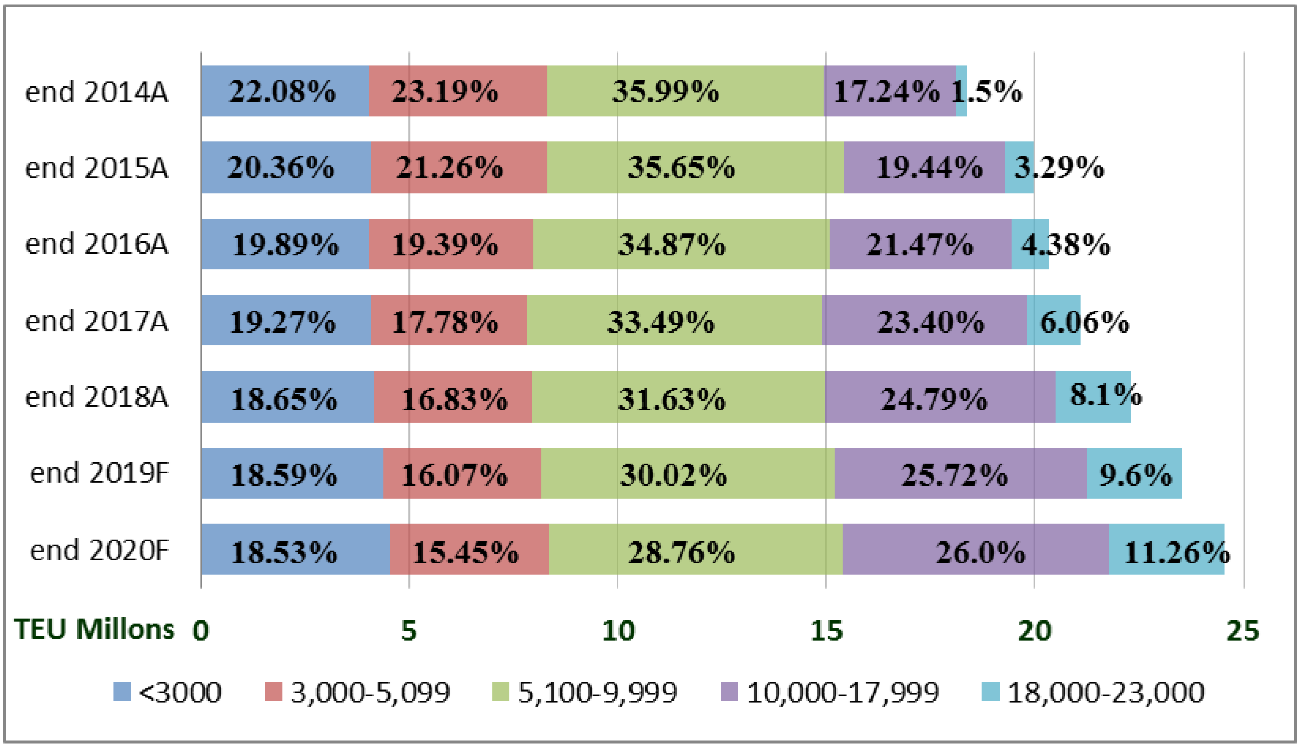

Figure 3: The Percentages and Size of the Containerships
Source: Alphaliner (2019)

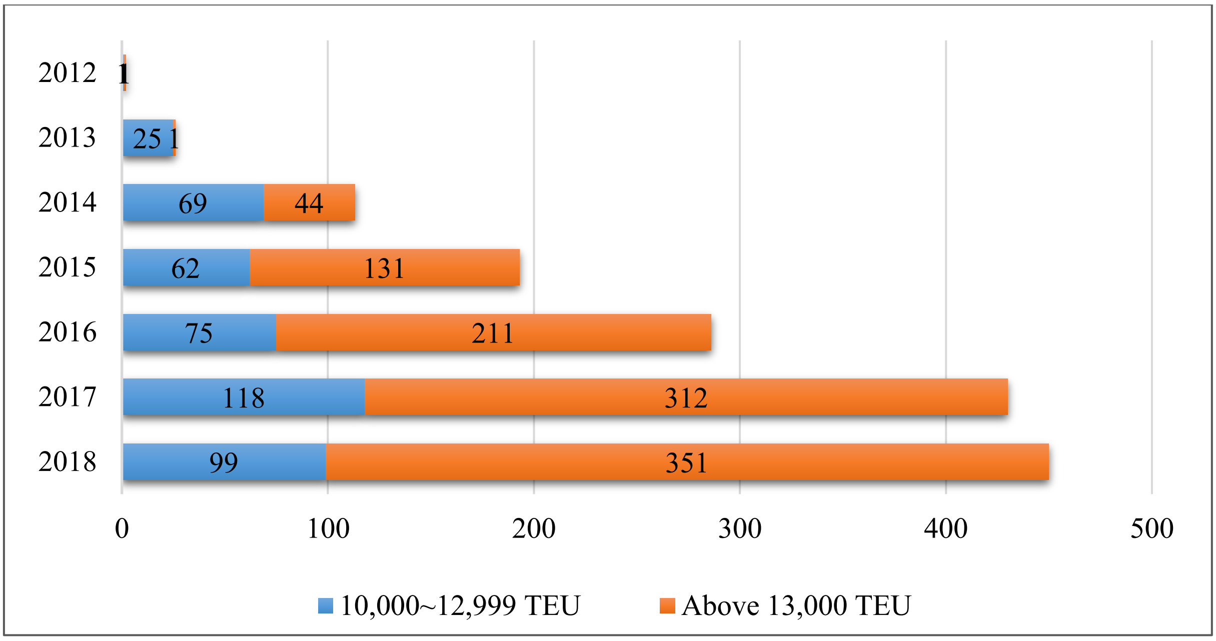

Figure 4: Number of Incoming Vessels over 10,000TEU at the Port of Kaohsiung
Source: TIPC's website (2019)

2.2.2. Acquisition and Alliance Restructuring of Shipping Liners

As the result of the ship-upsizing, the unit cost of the maritime transportation has been reduced, yet the problem of surplus of vessel tonnage far exceeding actual shipping demands has also surfaced, which in turn has caused a dramatic drop in freight rate in the global shipping markets. Combining the result with substantial fuel price rising and ongoing increases in operating costs, there's no surprised that most shipping carriers have suffered from consecutive losses, and some may even be forced to be closed, merged or integrated with other companies. For instance, the CMA CGM group acquired Neptune Orient Lines (APL) of Singapore in 2015, Hanjin declared bankruptcy in 2016, and three Japanese shipping companies merged in October of the same year, while COSCO acquired OOCL in 2017. The above mentioned APL, Hanjin and OOCL all operated terminals at the Port of Kaohsiung, thus these closure and acquisitions have directly influenced the port's overall container volume. Many carriers have begun to strategically withdraw themselves from price competition and adopted approaches of shipping space sharing or joint venture with strategic alliance (Hirata, 2017), in which carriers cooperate on different shipping routes to continuously expand their market (Yap and Zahraei, 2018). This situation has been getting even intensified in 2016. Figure 4 shows the acquisition, consolidation, and alliance restructuring of global shipping carriers over the past few years. In April 2017, the carriers experiencing mergers have restructured the original four shipping alliances (2M, O3, G6 and CKYHE) into three (2M, Ocean, and THE Alliance) and readjusted their trunk routes and ports of call, thus causing a dramatic change in the global shipping market and inevitably affecting the Port of Kaohsiung significantly (MOTC, 2017).

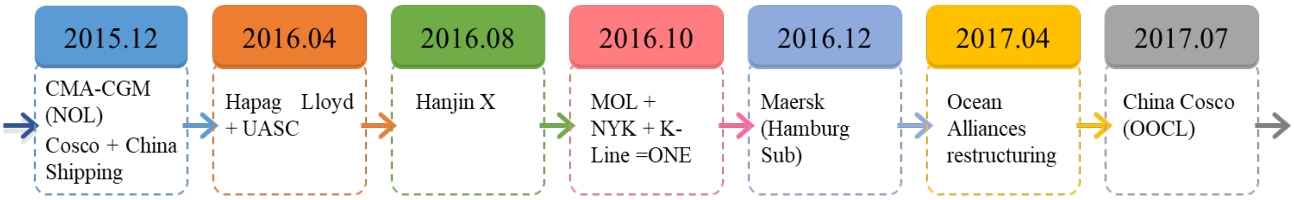

Figure 5: Acquisition, Consolidation and Alliance Restructuring of Global Shipping Carriers between 2015 and 2017

After the restructuring, the shipping alliances not only hold increased bargaining power to the port, but their choice of calling port is greatly relevant to determine the prosperity or decline of a port (UNCTAD 2018). The new alliances have a stronger relationship between members, which produces a greater binding effect. Shipping companies are constrained by other carriers in the alliance while deciding primary hub port and the binding effect has a great impact on hub ports in the Southeast Asia, particularly the Port of Kaohsiung. According to Alphaliner (2018), the combined capacity of the three new shipping alliances represents 80.3% of global capacity. In the past, for example, a carrier needed to ship containers from a Southeast Asian port to the Port of Kaohsiung and then transship them to North America. However, if an alliance member deploys a mother ship to transport containers from a main port in Southeast Asia to North America, then other members of the alliance are required to use the mother ship to transfer their containers with the same origin and destination ports.

After the restructuring of the new shipping alliances, the Port of Kaohsiung experienced a drastic decline in its container handling volume during the second quarter of 2017, as shown in Figure5. This study analyzed the main causes of this decline as follows: Firstly, THE Alliance added port connections to Kobe, Nagoya, Shimizu, Tokyo, and other Japanese ports on the FE/Europe route and in consequence, containers from these ports no longer required transshipment at the Port of Kaohsiung. Secondly, trunk routes have been developed in Southeast Asia, while Cai Mep and Jakarta incorporated direct shipping lines to the US west coast instead of transshipping at the Port of Kaohsiung. Furthermore, following the acquisition of APL by CMA CGM, containers formerly transshipped at the Port of Kaohsiung are now handled in Singapore. Hence, the Port of Kaohsiung has been overwhelmed by changes in the new shipping management environment, ship upsizing and the business situation of shipping carriers (closure, acquisition, or alliance restructuring), all of which have severely affected the volume of containers transshipped here. As shown in Figure 5, the transshipment container volume has decreased by about 20% after April of 2017 which jeopardized the port's hub status.

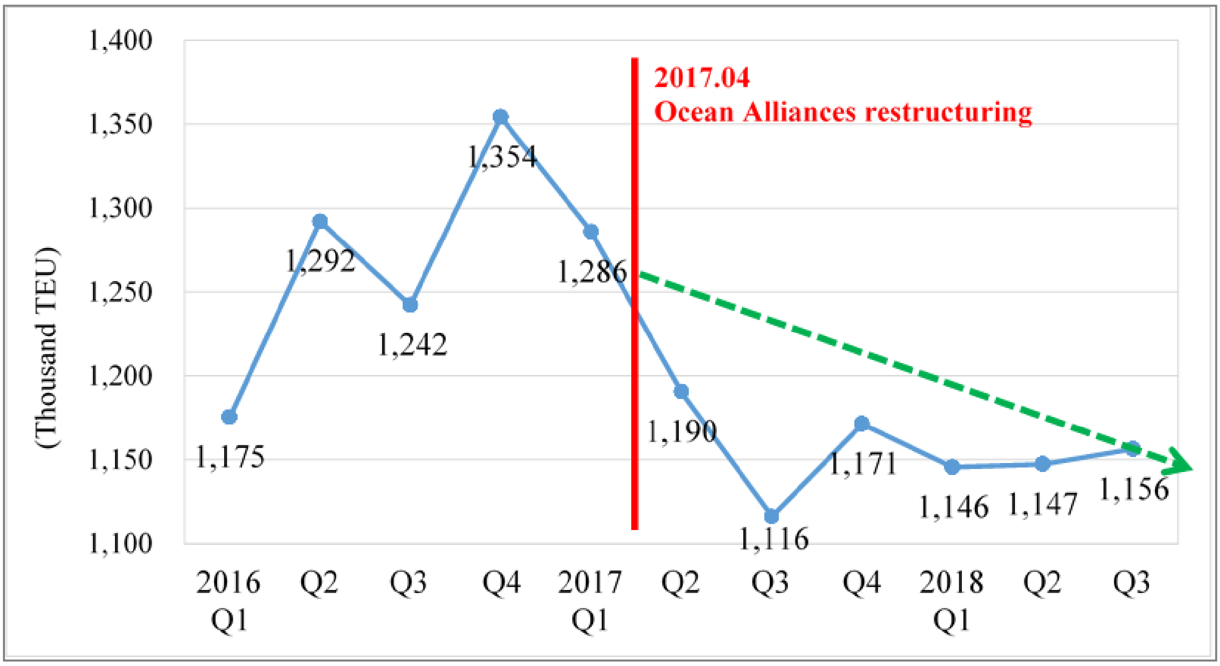

Figure 6: Volume Decline of Transshipment Container at the Port of Kaohsiung following Shipping Alliance Restructuring (Q2, 2017)
Source: TIPC's website (2018)

Table 2: The Top 20 Container Ports in the World (in Thousand TEU)

Rank	Port	Economy	Throughput 2017	Throughput 2016
1	Shanghai	China	40,230	37,133
2	Singapore	Singapore	33,670	30,904
3	Shenzhen	China	25,210	23,979
4	Ningbo-Zhoushan	China	24,610	21,560
5	Busan	Republic of Korea	21,400	19,850
6	Hong Kong	Hong Kong SAR	20,760	19,813
7	Guangzhou (Nansha)	China	20,370	18,858
8	Qingdao	China	18,260	18,010
9	Dubai	United Arab Emirates	15,440	14,772
10	Tianjin	China	15,210	14,490
11	Rotterdam	Netherlands	13,600	12,385
12	Port Klang	Malaysia	12,060	13,170
13	Antwerp	Belgium	10,450	10,037
14	Xiamen	China	10,380	9,614
15	Kaohsiung	Taiwan	10,240	10,465
16	Dalian	China	9,710	9,614
17	Los Angeles	United States	9,340	8,857
18	Hamburg	Germany	9,600	8,910
19	Tanjung Pelepas	Malaysia	8,330	8,281
20	Laem Chabang	Thailand	7,760	7,227

Source: UNCTAD (2018)

2.2.3. The Competition from the Neighboring Ports

The world's major ports have been facing the dramatic changes of ship upsizing, alliance restructuring, redeployment of Asia/America/Europe trunk routes and the increasing bargaining power of alliance. There will be an average of extra container volume of 300,000 TEU per year for a port with a new Asian-European weekly route; the figure can even reach 450,000 TEU per year with a 20,000 TEU mega ship (UNCTAD, 2018). According to UNCTAD's (2018) statistics, China and Asian ports accounted for a total of 15 among the world's top 20 container ports (as shown in Table 1), and the placement of the Port of Kaohsiung has dropped to No. 15 in the ranking (see in Figure 6). Moreover, while other ports had a significant growth, there're only Port Klang and the Port of Kaohsiung suffered from declining after the alliance restructuring of 2017. There're several strategies adopted by the neighboring ports to strive for the source of transshipment which originally handled in the Port of Kaohsiung. For example, PSA (Singapore) and CMA CGM chose to joint venture (JV) in a deep-water terminal. CMA CGM was required to move its transshipment from the neighboring ports to Singapore under its guaranteed container volume scheme. The Port of Busan also implemented incentive programs and JV with Hyundai for the terminal operation to ensure the source of the transshipment from Hyundai. Xiamen Port is also actively attracting the shipping carriers by JV model with a guaranteed container volumes strategy, free charge for phase-in/phase-out vessels, and the exercise of favorable berth designation and pricing. The terminal operators in Hong Kong provides considerable discounts to shipping carriers to maintain its market share while facing the competition from neighboring ports such as Shenzhen and Yantian.

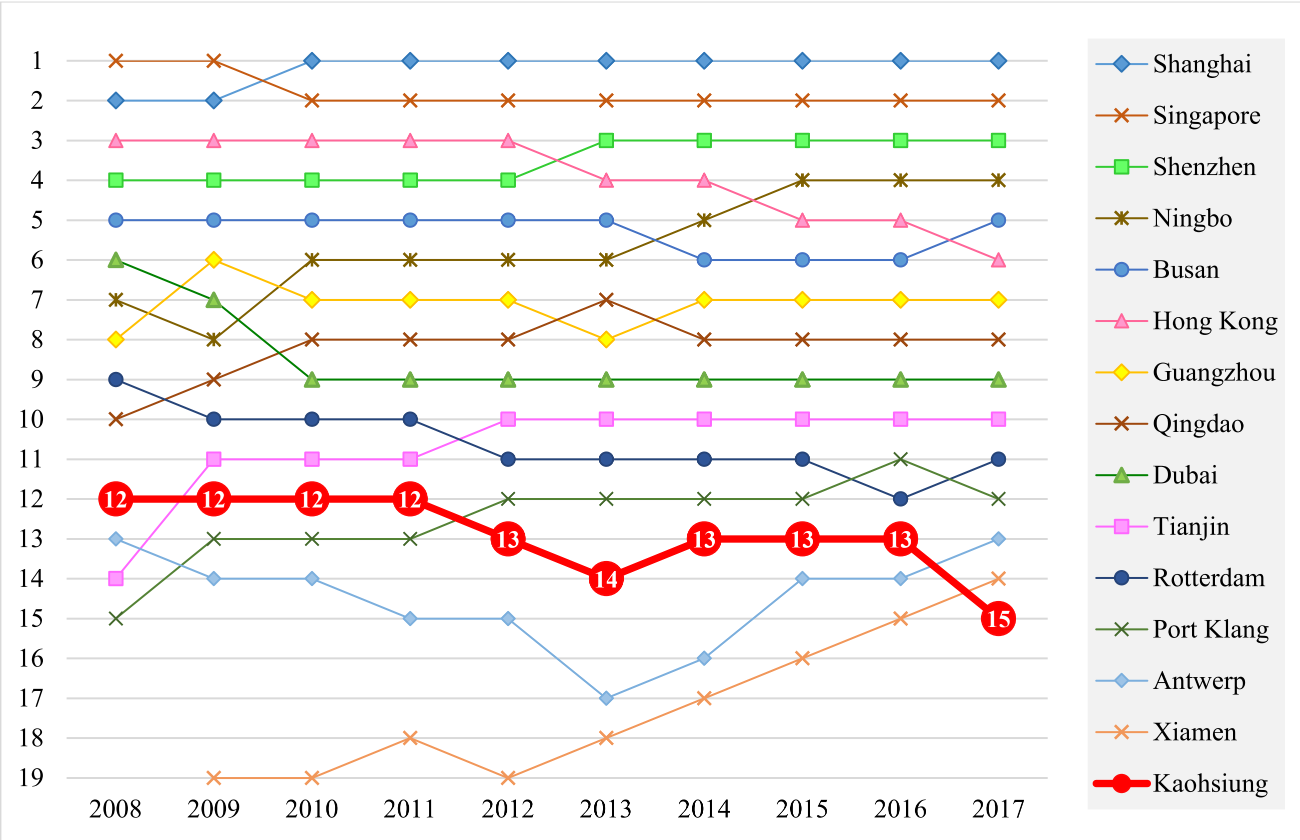

Figure 7: Ranking of the World's Container Ports in 2008-2017
Source: UNCTAD (2018) with TIPC's website (2018)

Table 3: The Top 20 Container Ports in the World (in Thousand TEU)

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20	Laem Chabang	Thailand	7,760	7,227

Source: UNCTAD (2018)

3. The Current Status and Obstacles of the Port of Kaohsiung

3.1. The Change of the Container Volume of the Port of Kaohsiung

The growth of total container volume in the Port of Kaohsiung has been stagnated due to change and threats from the external and internal environment as mentioned earlier. As shown in Figure 7, the container volume of the Port of Kaohsiung decreased by 1.85% in 2017. Port of Kaohsiung and Klang Port were only two ports with negative growth rate among the top 20 container ports in the world. In 2018, the total container volume of the Port of Kaohsiung slightly increased by 1.7% contributed by the continuous growth of the imports and exports. As shown in Table 2, the volume of transshipment containers in 2017 declined by 4.15% comparing with 2016 (from 5.06 million TEU decreased to 4.76 million TEU), and the share of the transshipment decreased from 48.38% to 46.38%. In 2018, the transshipment volume further dropped by 3.79% to 4.66 million TEU and the share fell to 44.62%.

Table 4: Changes in Container Volume Handled at the Port of Kaohsiung in the Past 10 Years (in thousand TEU)

Year	Total Volume	Volume of Import and Export Containers				Volume of Transshipment Containers	
		Import	Export	Total	Percentage	Transshipment	Percentage
2008	9,676.55	2,535.93	2,695.01	5,230.94	54.06%	4,445.61	45.94%
2009	8,581.27	2,226.42	2,314.22	4,540.63	52.91%	4,040.64	47.09%
2010	9,181.21	2,380.71	2,515.20	4,895.91	53.33%	4,285.30	46.67%
2011	9,636.29	2,491.44	2,640.77	5,132.21	53.26%	4,504.08	46.74%
2012	9,781.22	2,457.66	2,651.31	5,108.97	52.23%	4,672.25	47.77%
2013	9,937.72	2,583.66	2,606.78	5,190.44	52.23%	4,747.28	47.77%
2014	10,593.34	2,780.77	2,799.15	5,579.93	52.67%	5,013.41	47.33%
2015	10,264.42	2,723.01	2,720.96	5,443.97	53.04%	4,820.45	46.96%
2016	10,464.86	2,695.26	2,705.81	5,401.08	51.61%	5,063.78	48.39%
2017	10,271.02	2,752.96	2,754.13	5,507.09	53.62%	4,763.93	46.38%
2018	10,445.73	2,898.43	2,886.19	5,784.62	55.38%	4,661.11	44.62%

Source: TIPC's website (2018)

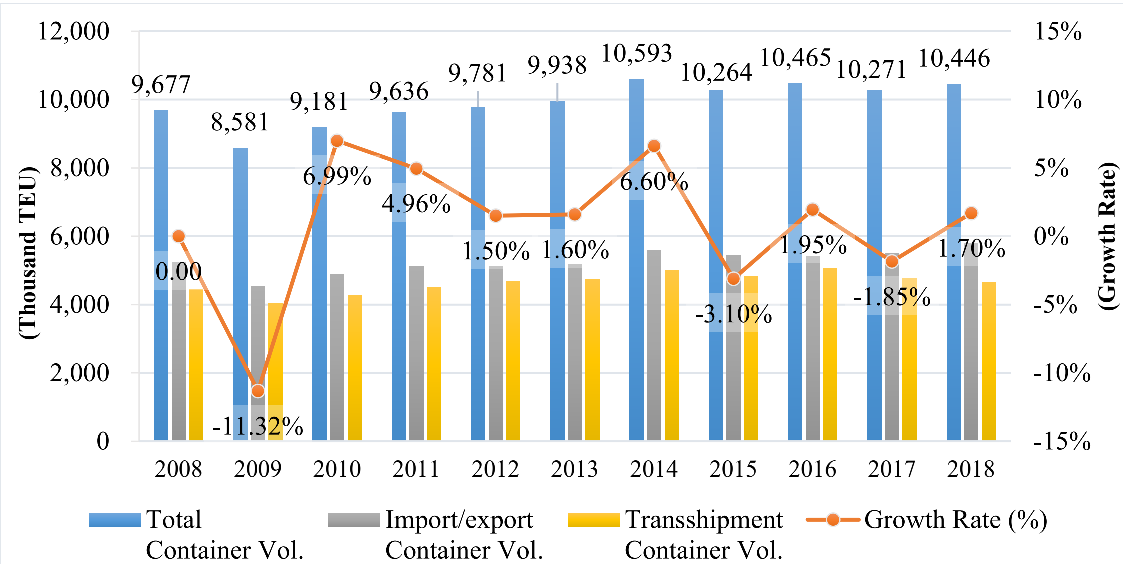

Figure 8: Changes in Container Volume Handled at the Port of Kaohsiung between 2008 and 2018
Source: TIPC's website (2018)

3.2. The Analysis of the Transshipment Route and Container Volume at the Port of Kaohsiung

As indicated in Table 3 and Figure 8, Southeast Asia (37.11%), Northeast Asia (30.77%) and North America (17.89%) accounted for about 85% of transshipment market at the port of Kaohsiung. As shown in Figure 9, the main countries of transshipment market, including China, the United States, Japan, Europe, Philippine, Vietnam and Indonesia, accounted for 75% of the transshipment volume at Port of Kaohsiung. However, Table 4 indicates the transshipment container volumes from the above countries have been declining.

Table 5: The Transshipment Container Volume at Port of Kaohsiung by Region between 2008 and 2017

Unit: 1,000 TEU

Year	Northeast Asia	Southeast Asia	Other Asia	North America	Europe	Others (Central /South America, Africa, Oceania)
2008	975.99	1,485.99	93.30	971.32	152.33	155.03
2009	1,135.23	1,325.63	188.81	797.93	203.16	168.13
2010	1,217.59	1,452.94	226.32	790.58	191.33	166.55
2011	1,260.56	1,586.69	238.35	779.33	183.80	189.57
2012	1,349.13	1,662.12	217.72	790.02	165.87	222.00
2013	1,484.79	1,688.77	229.18	752.82	158.81	255.17
2014	1,640.89	1,819.09	229.69	753.58	195.64	287.12
2015	1,523.66	1,714.59	189.30	750.76	208.40	290.85
2016	1,532.51	1,866.97	190.04	831.62	253.75	302.07
2017	1,496.81	1,816.75	190.86	700.45	242.74	308.25

Source: TIPC's website (2018)

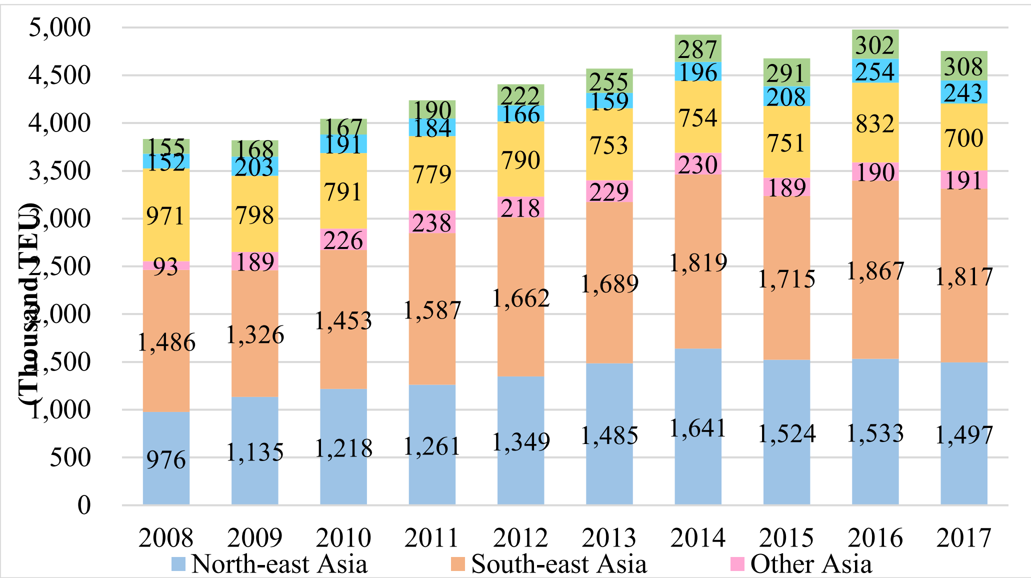

Figure 9: The Transshipment Container Volume at Port of Kaohsiung by Region between 2008 and 2017

Source: TIPC's website (2018)

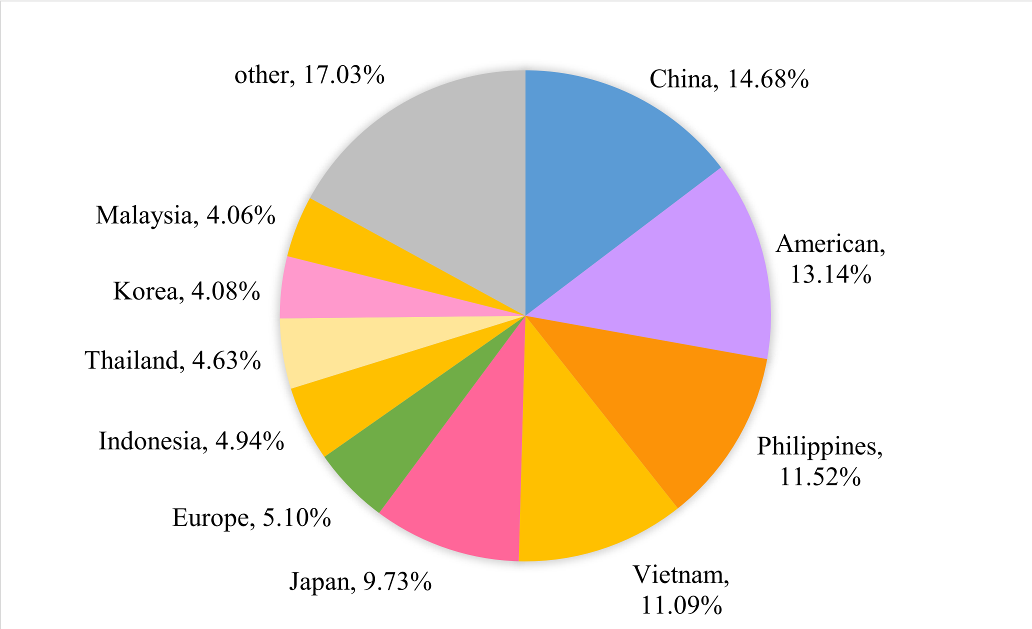

Figure 10: The Proportion Chart of the Main Countries Contributing Transshipment Containers in 2017
Source: TIPC's website (2018)

Table 6: The Main Countries Contributing Transshipment Containers to the Port of Kaohsiung between 2008 and 2017

Unit: 1,000 TEU

Year	China	USA	Philippine	Vietnam	Japan	Europe	Indonesia	Thailand	Korea	Malaysia
2008	364.52	893.44	420.73	375.39	365.61	152.33	167.59	208.61	142.44	160.01
2009	485.08	732.32	389.05	333.53	407.21	203.16	153.09	178.14	162.52	139.45
2010	526.66	722.85	449.62	327.62	461.10	191.33	165.87	187.13	154.00	161.94
2011	549.01	703.11	500.67	366.98	472.85	183.80	187.97	193.61	163.28	165.18
2012	628.45	697.40	541.65	359.13	457.95	165.87	219.01	165.95	155.05	173.18
2013	717.75	644.10	509.38	387.86	487.34	158.81	240.10	162.71	155.80	171.40
2014	797.96	681.20	566.08	424.16	525.76	195.64	228.40	173.73	171.55	178.44
2015	756.56	684.45	554.94	380.81	532.54	208.40	227.57	192.74	152.37	181.88
2016	741.90	757.01	574.58	505.91	519.71	253.75	236.20	200.33	170.19	189.51
2017	697.98	625.10	548.07	527.37	462.66	242.74	234.92	220.13	193.85	192.97
Growth rate in 2017	-5.92%	-17.43%	-4.61%	4.24%	-10.98%	-4.34%	-0.54%	9.89%	13.90%	1.83%

Source: TIPC's website (2018)

3.3. The Change of the T/P Route and FE/Europe Route at the Port of Kaohsiung

In order to secure its status as a regional transshipment hub, the main strategy for Port of Kaohsiung would be attracting transshipment from the T/ P route and FE/Europe route. Table 5 and Figure 10 indicate a declining in numbers of T/P route calling at the Port of Kaohsiung, while there were 22 routes in 2013 and only 19 in 2017. Specifically, the average and the maximum ship-size calling at the Port of Kaohsiung have been both increasing annually which in 2017, the average ship size has reached 7,469 TEU and the maximum size of containership was 10,010 TEU. For the FE/Europe route Kaohsiung Port had 5-6 routes during 2013-2016, and 7 in 2017 under the influence of the restructured alliance. The maximum ship size is also upsizing from 9000 TEU to 14000 TEU. While tenant shipping carriers have deployed ships over 15,000 TEU to FE/Europe routes and cannot call at the Port of Kaohsiung, it will greatly affect the role of the Port of Kaohsiung as a hub port in FE/Europe or in Asian.

Table 7: The Change of Route Number and Ship-size of the T/P and FE/Europe Route

Route / Year	T/P			FE/Europe		
	Number of routes	Ave. Vessel Tonnage	Max. Vessel Tonnage	Number of routes	Ave. Vessel Tonnage	Max. Vessel Tonnage
2013	22	5,955	8,888	6	8,614	10,062
2014	21	6,649	10,062	6	9,434	13,808
2015	21	7,233	10,700	5	10,925	14,080
2016	19	7,229	10,070	5	10,763	14,080
2017	19	7,469	10,010	7	12,886	14,424

Source: TIPC's website (2018)

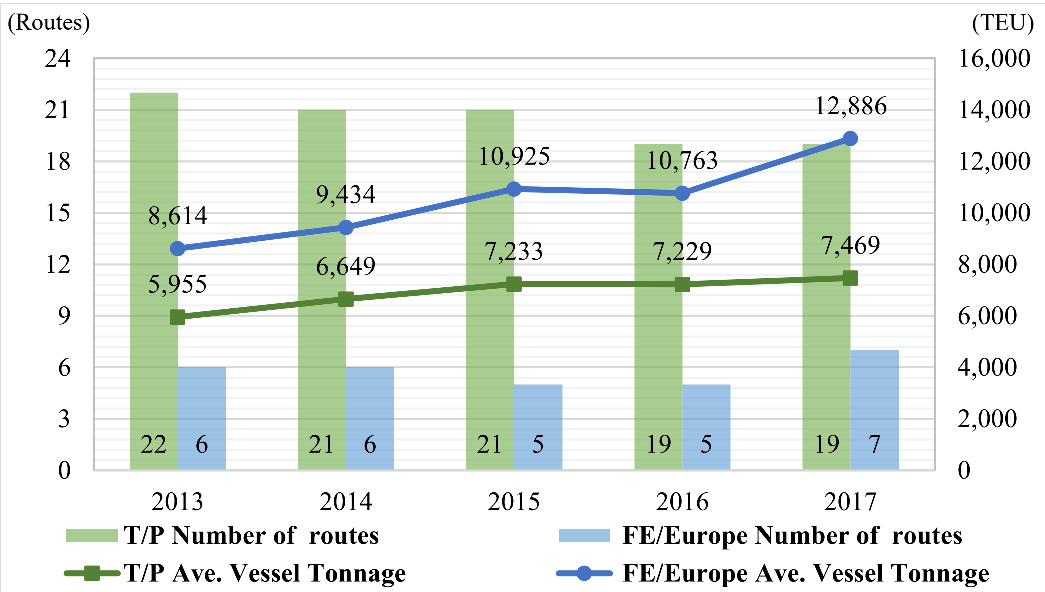

Figure 11: The Change of Route Number and Ship-size of the T/P and FE/Europe Routes
Source: TIPC's website (2018)

The transshipment container volume from the T/P route accounted for 25% of total transshipment containers at Port of Kaohsiung. Figure 11 displays most containers come from the T/P Western America route (69.9%), followed by the T/P Eastern America route (15.7%), and Latin America route (14.5%) in 2017.

Table 6 and Figure 12 indicate that the highest transshipment container volume of T/P route was in 2014 at 1.35 million TEU, and gradually declined to 0.95 million TEU in 2017. The number of vessels calling at the Port of Kaohsiung also declined from 1,423 in 2013 to 1,345 in 2017. The average container loading per ship in 2013-2016 was 2,165 TEU. However, it dropped to 1,909 TEU in 2017 with a declining rate of 11.85%. The transshipment container volume per ship in T/P route was 884 TEU during 2013-2016, and decreased to 706 TEU in 2017.

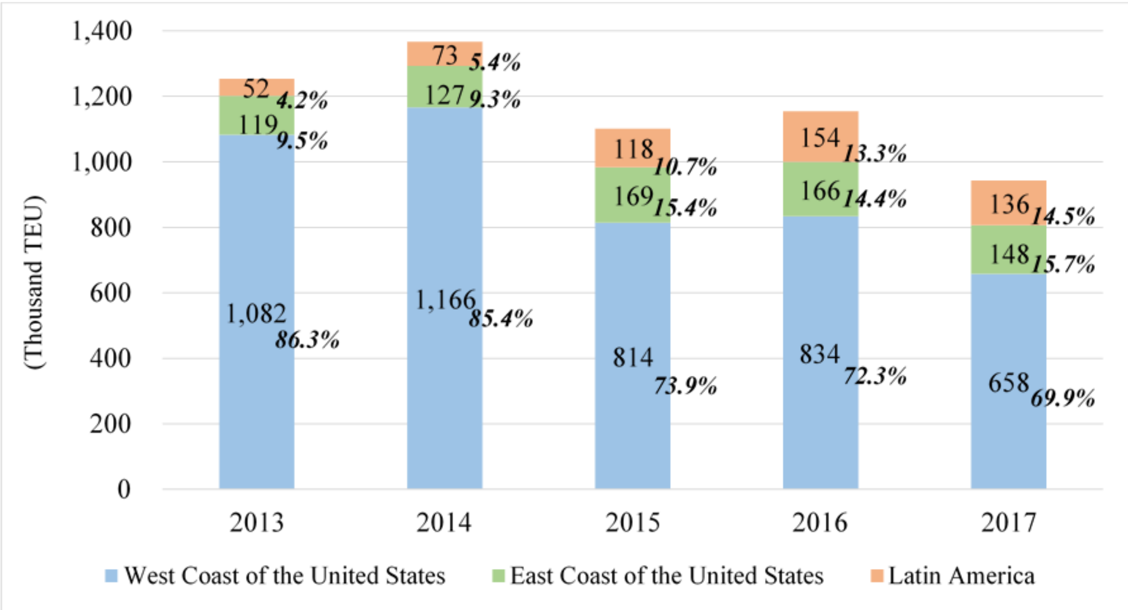

Figure 12: The Container Volume by Proportion of Regions in T/P Route between 2013 and 2017
Source: TIPC's website (2018)

Table 8: The Number of Vessels and Container Volume of T/P Route

Route / Year	T/P route						
	Total Vessel number	Total Container vol. (1,000 TEU)	Ave. container volume/ship	Transshipment Container Vol. (1,000 TEU)	Ave. container volume/ship	Import/export Container Vol. (1,000 TEU)	Ave. container volume/ship
2013	1423	2,981.87	2,095	1,256.56	883	1,725.31	1,212
2014	1364	3,274.88	2,401	1,357.67	995	1,917.20	1,406
2015	1387	2,883.48	2,079	1,111.99	802	1,771.59	1,277
2016	1356	2,831.31	2,088	1,162.58	857	1,668.73	1,231
2017	1345	2,568.20	1,909	949.23	706	1,618.97	1,204

Source: TIPC's website (2018)

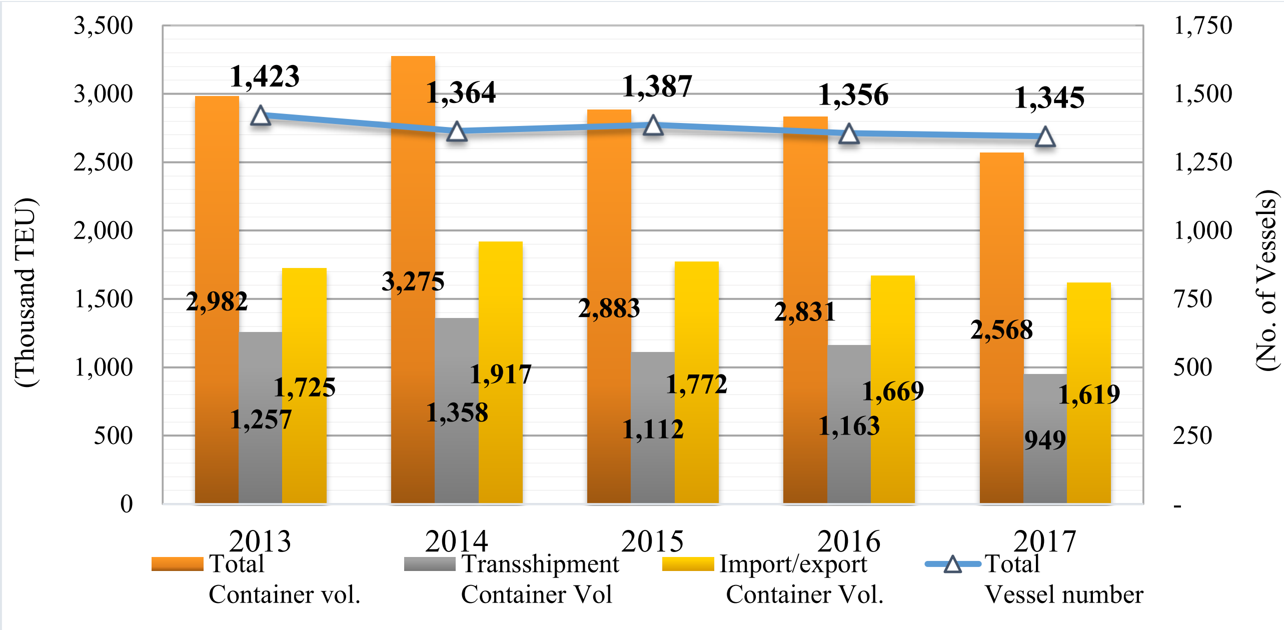

Figure 13: The Change of Container Volume of T/P Route
Source: TIPC's website (2018)

The transshipment container volume from the FE/Europe route accounted for only about 5.10% of the Port of Kaohsiung's total transshipment containers in 2017 (see Figure 9). Figure 13 shows that the North Europe route accounted for 60.87% and the Mediterranean route accounted for 39.13%.

As shown in Table 7 and Figure 14, the transshipment container volume in 2013-2016 had a steady growth and the volume reached 0.36 million TEU in 2016 with a high growth rate of 25%. However, it has started to decrease in 2017 with a rate of about 1.76% and further dropped by 0.43 million TEU in 2018 with a declining rate of 12.15%. The average container loading per ship during 2014-2016 was 3,150 TEU, which dropped to 2,643 TEU in 2017. The transshipment container volume per ship in FE/Europe route was 1,182 TEU in 2016, however it declined to 959 TEU in 2017.

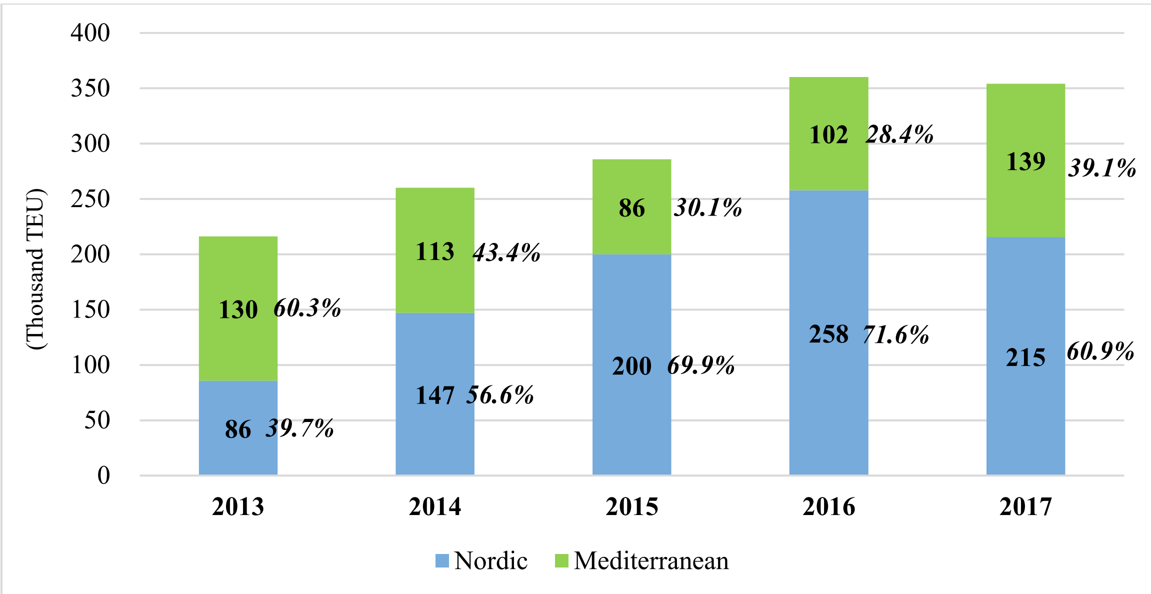

Figure 14: The Container Volume by Proportion of Regions of FE/Europe
Source: TIPC's website (2018)

Table 9: The Number of Vessels and Container Volume of FE/Europe Route

Route / Year	FE/Europe route						
	Total Vessel number	Total Container vol. (1,000 TEU)	Ave. container volume/ship	Transshipment Container Vol. (1,000 TEU)	Ave. container volume/ship	Import/export Container Vol. (1,000 TEU)	Ave. container volume/ship
2013	279	661.80	2,372	218.83	784	442.97	1,588
2014	244	785.05	3,217	260.00	1,066	525.05	2,152
2015	261	838.25	3,212	287.70	1,102	550.56	2,109
2016	305	922.80	3,026	360.38	1,182	562.42	1,844
2017	369	975.10	2,643	354.02	959	621.08	1,683

Source: TIPC's website (2018)

In terms of the world container volume of major shipping routes in 2017, there were 27.6 million TEU in T/P route, 24.8 million TEU in Asia to FE/Europe route and 8.1 million TEU in Trans-Atlantic route (UNCTAD,2018). Port of Kaohsiung had 2.568 million TEU in T/P route, which accounted for about 9% of the world volume; 0.97 million TEU in FE/Europe route which accounted for only 4%. This reflected that the Port of Kaohsiung is facing being marginalized in the FE/Europe route.

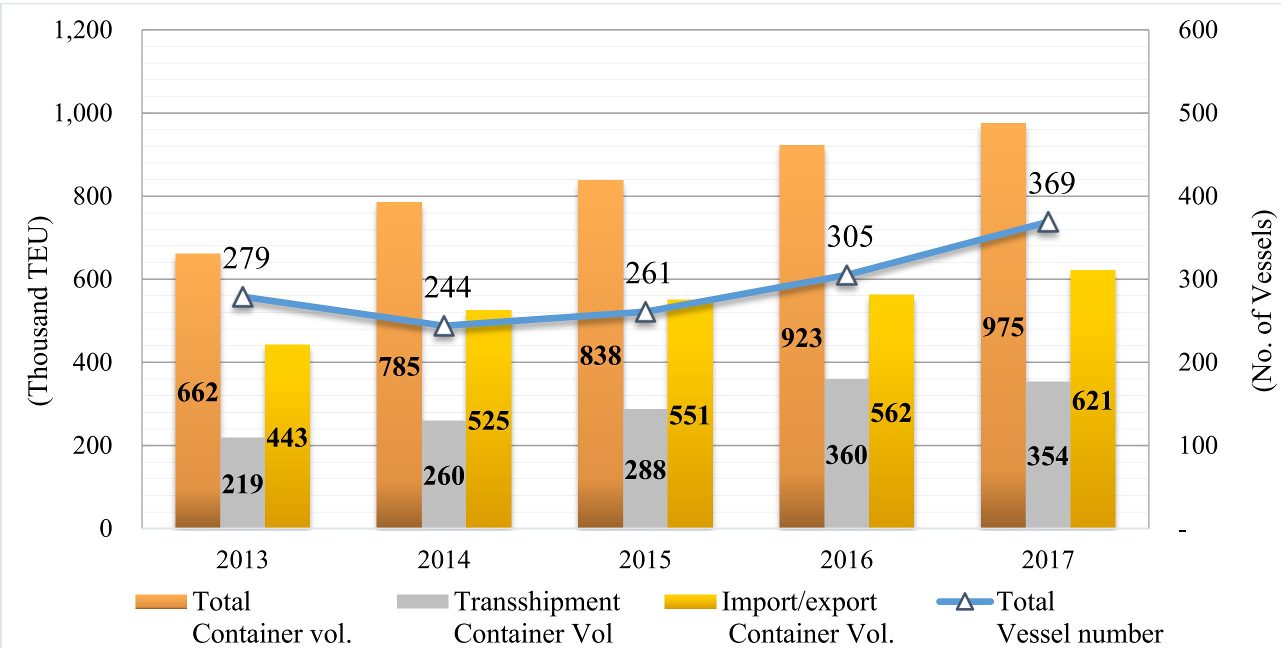

Figure 15: The Change of Container Volume of FE/Europe Route
Source: TIPC's website (2018)

4. Outlook of the Port of Kaohsiung

While Port of Kaohsiung is facing the challenges of the slight growth of import and export market, the declining of transshipment and the development of large vessels, several strategies are proposed as follows:

4.1. Providing Incentives and Expanding Deep-water Terminals for Carriers

There are 6 major shipping carriers leasing terminals at the Port of Kaohsiung. Three Taiwanese carriers, Evergreen, YML and Wan Hai, are all based at the Port of Kaohsiung. Wan Hai focuses on the regional Asian route and does not join alliances. Evergreen and YML are global carriers and are joining Ocean and THE alliance respectively. The other three ocean carriers including APL (acquired by CMA), OOCL (acquired by COSCO) are joining Ocean Alliance, while HMM cooperates with 2M. A member within an alliance deploys its vessels on a specific trunk route will consider geographical location, supreme facility, low operation cost, high efficiency and selection of dedicated terminal. When facing a fierce competition from nearby ports, Port of Kaohsiung needs to reclaim its status as a regional transshipment hub. The relevant strategies include lowering the rent and the operational cost, raising the incentive and allowing the carriers to invest the terminal in JV to share profit and exchange for the guaranteed volume with carriers. Yet more importantly, Port of Kaohsiung must expand the deep-water terminal and channel so the mega containerships could be accommodated efficiently and safely.

4.2. Developing the Container Terminal NO.7

The Container Terminal NO.7 is under construction and recruiting investment which is located outside the second port entrance with a total pier length of 2,415 meters and depth of up to 18 meters. It will be allowed to accommodate 5 mega ships with 20,000 TEU capacity and the annual capacity will be increased to 5 million TEU (as shown in Figure 15). The completion of the Container Terminal NO.7 will resolve the previously mentioned problems of the Port of Kaohsiung not being able to accommodate mega containerships over 15,000 TEU in the T/P route or FE/Europe route. Upon completion of the new terminal, the Port of Kaohsiung will attract new routes and mega ships to call if it continues to implement the strategy of lowering the cost and improving the efficiency.

Evergreen has agreed to lease and invest the Container Terminal No.7 under the condition that it will release its current leasing terminals to other tenant carriers. This will solve the problem of transporting containers between different berths at different terminals and the shortage of terminal capacity. For example, Wan Hai currently renting pier no. 63 and 64 and suffering from insufficient capacity will have the opportunity to lease other adjacent piers. OOCL who has been renting pier no.65 and 66 located at the north of the Cross-Harbor Tunnel, which is not available to accommodate large vessels, will have the chance to exchange to the southern part of the tunnel. Container Terminal No.4 and No.5 leased by HMM might be able to be reallocated and combined to one terminal to enhance its operation efficiency. YML and APL may also have the opportunity to integrate their operations in Container Terminal No.3. By reallocating the current terminals, the carriers will be able to expand their operation capacity, increase new shipping routes, and deploy mega containerships to call at the Port of Kaohsiung. In addition, the piers with insufficient water depth or disadvantage location, such as the Container Terminal No.1 and No.4, will be allocated for bulk cargo operations and the old warehouses will be developed for waterfront recreation.

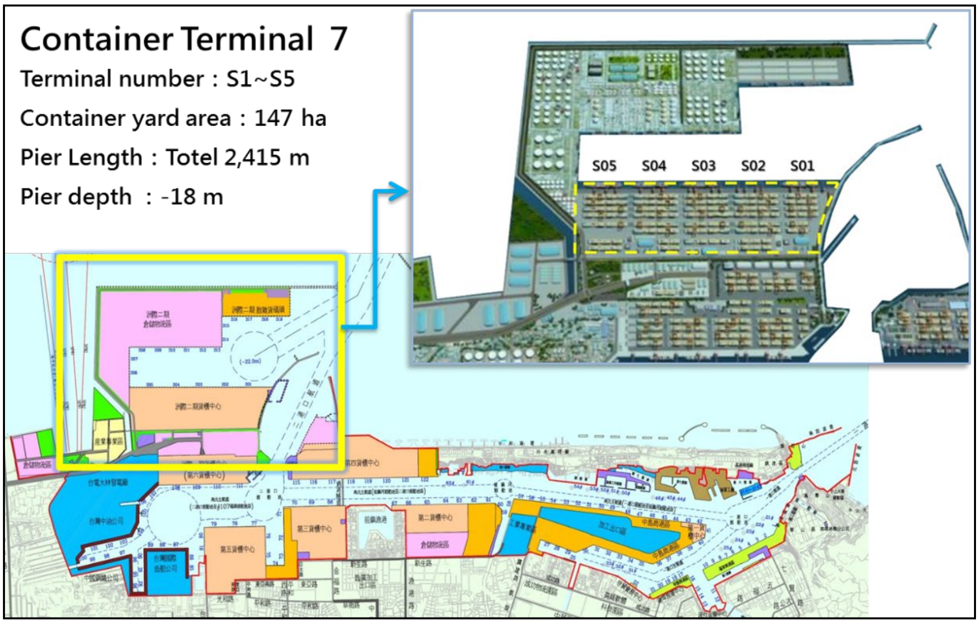

Figure 16: Locations and Operating Conditions of the Container Terminal No.7
Source: TIPC's website (2018)

5. Conclusion Remarks

The global container shipping market has been undergoing a rapid change in the recent years, including the upsizing of the ships and the restructured alliance. In order to increase competitive advantage, a container port should develop a deep-water terminal to meet the requirement of mega containerships. The development of the deep-water Container Terminal No.7 at the Port of Kaohsiung will sustain its status as a regional hub port and increase its container throughput.

This study explored the environmental factors and their impacts on the development of the Port of Kaohsiung. While the Port of Kaohsiung is currently facing a bottleneck of its development, to develop the deep-water Container Terminal No.7 and JV with container carriers are crucial strategies to increase the services and optimal utilization of container terminals. Furthermore, TIPC expects to enhance the port operation system from a landlord port to conducting joint venture investment with the carriers to retain the Taiwanese carriers and attract foreign carriers to secure the status as a regional hub port. Through the reallocation of the terminal capacity and function adjustment, the Port of Kaohsiung will intensify its container transshipment function and quality service for carriers.

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Industry Choice for Airport Economic Zone by Multi-Objective Optimization

Dan Wang[1]*, Zhongzhen Yang*[2,*]*, and Lixin Shen*[1]

[1]College of Transportation Engineering, Dalian Maritime University, Dalian, 116026, China
[2]Faculty of Maritime and Transportation, Ningbo University, Ningbo, 315211, China

[*]Corresponding Author

Abstract

In order to make full use of the advantages and resources of air transport and raise land efficiency and industrial economic benefits in the Airport Economic Zones, firstly, based on industrial input-output model, the industries closely relating to airport and air transport industries are identified, and the method of determining a set of industry alternatives, which may be located in the Airport Economic Zones, is proposed. Then, for the Airport Economic Zone, the industry selection issue is transformed into an unbounded knapsack problem. Targeting the maximum number of employees, the largest GDP, the highest degree of aviation correlation, the fullest utilization of basic resources and the greatest policy support, a multi-objective combinatorial optimization model is constructed subject to the constraint of land size of the Airport Economic Zone. NSGA-II is used to solve the model, and the most suitable industries and the being needed land in the Airport Economic Zone are determined from the industry alternative set of the Airport Economic Zone. Our research provides a new quantitative method for the industry selection and land use planning for Airport Economic Zone, which may contribute to the healthy development of the industrial cluster in the Airport Economic Zone.

Keywords: Airport Economic Zone; Industry Selection; Multi-objective Optimization; Unbounded Knapsack Problem

1. Introduction

As the growth of economic globalization and the improvement of global air transport system, airports are increasingly replacing seaports, railways or highways hubs, to become a new engine of economic and industrial development. Moreover, the Airport Economic Zones (AEZ) having developed on the basis of mega airports has become an important growth pole of regional economic development.

In 1959, Shannon Free Zone was established around Shannon Airport in Ireland as the first AEZ all over the world. In the following 50 years, the areas of many hub airports were developed into important AEZs, such as Frankfurt am Main Airport, Amsterdam Airport Schiphol, Memphis International Airport and so on. In 2004, China implemented the airport localization reform, and then the wave of development and construction of AEZ emerged in China. By the end of 2014, China had planned or built 63 AEZs.

AEZ is an important carrier for the integration and mutual promotion of airport and regional economy. Capital, technology and labor force are gathered around the airport, and various industries are derived in the airport area, such as high-air transport-oriented industry and non-air transport-oriented industries supporting production and life. Supported by air cargo flow and business flow, these industries have formed a unique economic development model, which is dominated by air transport-oriented industry and organically related to various industries. In theory, we can construct an ideal cluster system of airport industries by analysing the relationship between industries, and form a large and comprehensive AEZ.

Although the current development of the AEZs in China is good, the functions, scale and benefits of the existing AEZs are still insufficient. For example, the industries in AEZs have a low utilization rate of air transport, and the directivity of aviation is not obvious. The correlation between industries is not strong, the collaboration level of industry chain is low, and the scale agglomeration effect of the airport industry cannot be realized. Small scale of land use and population, low intensity of land use and poor economic benefits are also existing.

According to the resource endowment of the airport and the region, the construction of the airport industry cluster system with obvious aviation characteristics and competitiveness, and obtaining the maximum economic benefits with limited land resources has become a theoretical and practical issue that has attracted much attention in the field of airport economy.

2. Literature Review

The development of foreign AEZ started earlier. The relevant researches are mostly the summary of current experience and the elaboration of conceptual theory. In 1965, Conway first proposed the Airport Complex, which integrates air transportation, logistics, shopping, leisure, industrial development and other functions with the airport as the core.

In 1993, the Cambridge Systems Institute conducted a survey of more than 20 airports in Europe, North America and Japan, summarizing the types of industries that are most likely to be concentrated near the airport, and based on the concentration of different commercial activities within 6 km of the airport. The airport industries are divided into four categories, namely, extremely concentrated industries, highly concentrated industries, medium-concentrated industries, and increasingly concentrated industries. In addition, they established economic impact prediction and land development planning model system for airport areas, and explained the impact and planning framework of new or expanded airports on regional development.

Kasarda (2000, 2001, 2006) predicted that globalization and the development of the aviation industry will shape a new urban form—the Aerotropolis, a city that is centred on the airport and attracts relevant business activities and recreational activities from the aviation industry. His research found that the major airport industries in the development of large-scale airports in the world are mainly modern service industry, aerospace industry, headquarters economy, scientific research institutions, biomedicine, automobile industry and traditional manufacturing.

Huber (2009) pointed out that the industry oriented by air transport (human flow, logistics) has the agglomeration effect of self-enhancement mechanism, forming a manufacturing cluster and various industrial clusters related to air transport around the airport. Through expert interviews, Wang (2015) summarized 30 key factors and 7 trends in the development of airport cities, and proposed industrial categories for the development of Taoyuan Airport area using industrial matrix analysis and verb coding.

Domestic research on the airport economy is still in its infancy, mainly to learn from and apply foreign theoretical and construction experience to guide the development of the AEZ. In 1997, Li first proposed to expand the business scope of the airport. He believed that the airport could operate commercial, tourism, trade, real estate and other industries in addition to air transportation.

Xia (2006) and others classified the airport industries into basic industries, leading industries and auxiliary industries according to the aviation directivity, and take Beijing Shunyi Airport Economic Zone as an example to analyse the industrial relevance and determine the leading industries in the region. Cao (2009) divided the airport industries into core industry, air-related industry and air-inducing industry with the directionality of the airspace as the standard. Wei (2010) and others are in the perspective of industrial choice. The industries that can be selected in the AEZ include the following categories: common industries (that is, industries with any directional orientation that can be developed in any AEZ), individual industries (ie, local industries), the new eco-environmental industry and related supporting industries that can be brought about by the unique location and resources.

In order to solve or avoid the problem of poor industrial agglomeration faced by the airport economic zone, Tong (2013) and others believe that the principle should be adhered to the principle of location, industry, development potential, investment environment, technological progress, social benefits and dynamic development. Industry types, focusing on the development of industries directly related to the air transport industry and aviation preference industries. Zhang (2014) and others studied examples of industrial research in the airport area, and proposed to grasp the direction of industrial development from the three dimensions of the industry development trend of the airport area, the industrial development trend of the airport area and relevant policy requirements. Guan (2010) et al. proposed that the development of the AEZ should fully consider the size of the airport and the regional economic level, and select the industries that are prioritized for development.

Zhao (2013) believed that three industrial clusters are suitable for key development under the background of industrial transfer, namely: air transport industry cluster, airport high-tech industrial cluster and airport modern service industry cluster. She theoretically analysed the inter-industry relationship and development timing. Zhou (2015) summarized 66 advantageous industries in the cities with 51 large airports in China, and classified them into 32 industrial categories. The industry selection was based on density, value-added, easy-loading, time-based and scientific and technological indicators.

In summary, it can be found that most of the domestic and international research on the industry of the AEZ is based on empirical summary and theoretical analysis. Among them, there are few studies on the industrial selection of the AEZ, and most of them are qualitative analysis. The existing research only theoretically explores the principles and methods of industrial selection in the AEZ, and lacks accurate quantitative analysis and optimization model of industrial land planning. In practice, the planning reports for the AEZs that have been issued in China almost do not use quantitative methods to determine the type of airport industry and the scale of land use.

In order to make full use of the advantages and resources of air transport and raise land efficiency and industrial economic benefits in the Airport Economic Zones, firstly, based on industrial input-output model, the industries closely relating to airport and air transport industries are identified, and the method of determining a set of industry alternatives, which may be located in the Airport Economic Zones, is proposed. Then, for the Airport Economic Zone, the industry selection issue is transformed into an unbounded knapsack problem. Targeting the maximum number of employees, the largest GDP, the highest degree of aviation correlation, the fullest utilization of basic resources and the greatest policy support, a multi-objective combinatorial optimization model is constructed subject to the constraint of land size of the Airport Economic Zone. NSGA-II is used to solve the model, and the most suitable industries and the being needed land in the Airport Economic Zone are determined from the industry alternative set of the Airport Economic Zone. Our research provides a new quantitative method for the industry selection and land use planning for Airport Economic Zone, which may contribute to the healthy development of the industrial cluster in the Airport Economic Zone.

3. Problem Description

3.1 Airport Economy Zone Alternative Industry Collection

The airport industry refers to those industries whose own development is closely related to airport and air transportation. Industries directly or indirectly related to air transport gather in the AEZ and extend and expand around the airport, eventually forming a large-scale airport industry cluster. In order to select the industry category suitable for the development of the AEZ, it is first necessary to select the industries closely related to airport and air transportation based on the technical and economic links between the air transportation industry and other industries, and form an industrial alternative set of the AEZ.

The input-output analysis method can quantitatively analyse the direct and indirect technical and economic links between various industrial sectors of the national economy in a certain period of time. This technical and economic linkage can be quantified through industrial relevance, while the industrial relevance is generally expressed by direct consumption coefficient, complete consumption coefficient, direct distribution coefficient,

complete distribution coefficient, etc.. The larger the correlation coefficient, the greater the degree of correlation between industries, which can identify the airport industry closely related to the air transport industry.
Based on the industrial relevance analysis model, the interdependence and interaction between the air transport industry and other industries can be described from the perspective of backward linkage and forward linkage, as shown in Figure 1.

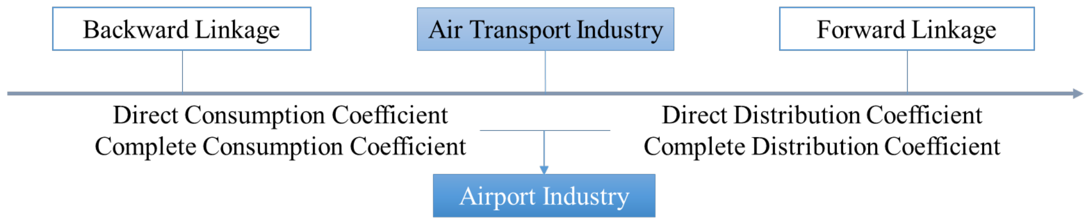

Figure 1: Schematic Diagram of the Industrial Relationship of the Air Transport Industry

Backward linkage refers to the impact of the air transport industry on those industries that provide production factors to them, and reflects the strength of the air transport industry for other industries or sectors. It can be expressed by the direct consumption coefficient and the complete consumption coefficient. The direct consumption coefficient (a_{ij}) indicates that the value of the product of each unit of production in the *j* department needs to directly consume the value of the product of the *i* department, and the calculation method is as shown in formula (1).

$$a_{ij} = \frac{x_{ij}}{X_j} \left(i,\ j = 1, 2, \cdots, n\right) \tag{1}$$

Among them, x_{ij} represents the value of the *i* department product in the production process of the *j* department, and X_j represents the total output value of the j department. The a_{ij} of each industrial sector is arranged to form a direct consumption coefficient matrix *A*.

The complete consumption coefficient (b_{ij}) indicates the amount of value of the *i* department product that is directly and indirectly consumed (ie, completely consumed) by the amount of value per unit of product produced by the *j* department. Based on the direct consumption coefficient matrix *A*, the complete consumption coefficient matrix B composed of b_{ij} can be calculated by equation (2), where *I* is an identity matrix.

$$B = \left(I - A\right)^{-1} - I \tag{2}$$

Forward linkage refers to the impact of the air transport industry on industries that use the products or services provided by the air transport industry as their own production factors, reflecting the supporting role of the air transport industry to other industries or departments, requiring direct distribution coefficients and completeness. The distribution coefficient is expressed. The direct allocation coefficient (h_{ij}) indicates the value of the total output of the *i* department directly allocated to the *j* department, and the calculation method is as shown in equation (3).

$$h_{ij} = \frac{x_{ij}}{X_i} \tag{3}$$

Among them, X_i represents the total output value of the *i* department. *H* is a matrix of direct partition coefficients composed of h_{ij}.

The full distribution coefficient (w_i) represents the value of the direct allocation of total output of the i department unit and the total indirect distribution (ie, full allocation) to the j department. Based on the direct distribution coefficient matrix H, the complete distribution coefficient matrix W composed of w_{ij} can be calculated by the equation (4).

$$W = (I - H)^{-1} - I \tag{4}$$

After using the input-output table to calculate the above four correlation coefficients, they are summed and z-score standardized. and then the industries whose standardized value is greater than zero (that is, the total correlation is higher than the average) will be regarded as the airport industries, and then they will form an industrial alternative set of the AEZ.

3.2. Industrial Selection Model of Airport Economic Zone

Assuming that there are K industries in the industrial alternative set of the airport economy zone, and each industry has five eigenvalues, the attributes of the candidate industry set can be represented by the matrix Q.

$$Q = \begin{bmatrix} q_{11} & q_{12} & \cdots & q_{15} \\ q_{21} & q_{22} & \cdots & q_{25} \\ \vdots & \vdots & \ddots & \vdots \\ q_{k1} & q_{k2} & \cdots & q_{k5} \end{bmatrix} (k = 1, 2, \cdots, K) \tag{5}$$

An important condition for the AEZ is that there are a large number of enterprises around the airport that can provide taxation and employment opportunities. Therefore, when choosing the airport industry, it is first necessary to pay attention to the number of jobs and the economic output value that the selected industries can provide. Here, the industrial characteristic value q_{k1} is defined as the number of employees employed in the k industry of the unit land, and is used to represent the ability of the industry to create employment; the industrial characteristic value qk_2 is defined as the total production produced by the k industry of the unit land, representing the economic benefits of the industry k.

In order to comply with the development law of the AEZ relying on the formation of airports, the industries in the AEZ are closely related to the airport and air transport industry. In this paper, the industrial characteristic value q_{k3} is defined as the comprehensive correlation degree between the kth industry and the air transport industry. q_{k3} is equal to the sum of the direct consumption coefficient, the complete consumption coefficient, the direct distribution coefficient and the complete distribution coefficient of the air transport industry.
The regional economic development level and industrial structure affect the industrial composition of the AEZ. Due to the different positioning and development modes of each airport, the characteristics of each region are not the same. Therefore, it is necessary to plan the airport industry according to the actual situation of the airport and the region The industrial base of the region is an important pillar to support the initial development of the AEZ. The resource base (ie, the level of development) of the region where the industry is located is also the influencing factor of the choice of the airport industry. The location quotient indicators commonly used in industrial economics research measure the level of industry development in the region [30]. In this paper, the industrial characteristic value q_{k4} is defined as the location quotient of the kth industry. The larger the value, the higher the level of specialization of the industry, which is used to indicate the resource base of the industry k in the airport area.

In addition, government leadership is an important driving force for the development of the AEZ. Therefore, it is necessary to plan the development of the industry in the AEZ in conjunction with relevant national policies on the region. Here, the industrial characteristic value q_{k5} is defined as the policy support of the k industry, and

is expressed by the number of times the *k* industry is mentioned in the national, regional, local and other policy documents, and represents the government's emphasis on the *k* industry.
The total planned area of the AEZ is *S*, and the planned area of the industry *k* is S_k. In order to make full use of the advantages of air transportation and resource endowment in the AEZ, and improve the land use efficiency and the economic benefits of the site selection industry, we stand at the perspective of government planning, with the largest number of employees, the largest GDP, and the highest aviation correlation. The resource utilization is the most fully utilized and the policy-oriented is the strongest, and the multi-objective airport economic zone industry selection model is constructed with the planning area as the constraint:

$$Object\,1\;\; max: \sum_{k=1,2,\cdots,K} q_{k1} \times S_k \tag{6}$$

$$Object\,2\;\; max: \sum_{k=1,2,\cdots,K} q_{k2} \times S_k \tag{7}$$

$$Object\,3\;\; max: \sum_{k=1,2,\cdots,K} q_{k3} \times \frac{S_k}{S} \tag{8}$$

$$Object\,4\;\; max: \sum_{k=1,2,\cdots,K} q_{k4} \times \frac{S_k}{S} \tag{9}$$

$$Object\,5\;\; max: \sum_{k=1,2,\cdots,K} q_{k5} \times \frac{S_k}{S} \tag{10}$$

$$\mathrm{S}.T.:\; 0 \le \sum_{k=1,2,\cdots,K} S_k \le S \tag{11}$$

The problem of industrial selection belongs to the problem of combinatorial optimization. The industry selection model of the AEZ constructed in this paper is essentially a backpack problem. It regards the AEZ as a backpack, the airport industry as an item, and the land area as a backpack weight limit. The characteristic value of the selected industry is regarded as the value of the item, thus transforming the industrial selection model of the AEZ into a multi-objective full backpack problem. Then, the multi-objective combination optimization method can be used to solve the problem, and the most suitable development type of the AEZ can be selected from the industrial candidate set of the AEZ, and the scale of the industrial land can be calculated.

4. Case Study

The case study is carried out by taking Zhengzhou Airport Economic Comprehensive Experimental Zone (ZZAEZ) as an example. The AEZ is an aviation economy and an aviation metropolitan area with Xinzheng International Airport as its core, with a planned area of 415 square kilometres. As China's first state-level AEZ, ZZAEZ has gradually developed into a modern industrial base led by aviation economy. The existing industry data can support our research and analysis. Therefore, an example analysis is carried out here for the ZZAEZ. The details are as follows.

First, based on the 2012 National Industrial Input-Output Table (139 Departments), calculate the direct consumption coefficient, complete consumption coefficient, direct distribution coefficient, and complete distribution coefficient of the air transport industry for other industries. There are 33 industries with standardized scores greater than zero. Here they are used as alternative industries suitable for site selection in the AEZ, and then according to the "China 2012 Input-Output Table Sector Classification and Code" and industrial cluster theory, they were reclassified into eight industrial clusters (Table 1).

Table 1: Alternative Industrial Clusters in the AEZ

Number	Industry Cluster	Items
1	Petrochemical industry	Refined petroleum and nuclear fuel processing products, oil and gas exploration products, plastic products, special chemical products and explosives, pyrotechnics, fireworks products, basic chemical raw materials, coal mining products
2	Modern service	Business services, monetary and other financial services, professional technical services, software and information technology services
3	Transportation service	Handling and transportation agents, road transport, warehousing
4	High-tech industry	Electronic components, computers, communication equipment, pharmaceutical products
5	Advanced manufacturing	Other transportation equipment, other general equipment, other special equipment, auto parts and accessories, automobile vehicles, steel rolling products, metal products, non-ferrous metals and their alloys and castings
6	Real estate construction	House construction, real estate, civil engineering construction
7	Wholesale and retail trade	Wholesale and retail, beverages and refined tea processed products
8	Supporting basic industry	Public administration and social organization, education, electricity, heat production and supply

Secondly, based on the 2012 Zhengzhou City Industry Input-Output Table, Zhengzhou City Statistical Yearbook, Urban Land Classification and Planning Construction Land Standard (GB50137-2011), and Zhengzhou Airport Economic Comprehensive Experimental Zone Development Plan (2013-2025) The “13th Five-Year Development Plan of Zhengzhou Airport Economic Comprehensive Experimental Zone”, etc., calculates the attribute matrix of the candidate industry set (Table 2).

Table 2: Attribute Matrix of Alternative Industrial Clusters in the AEZ

Number	Industry Cluster	Unit land area employment (10,000 people / square kilometers)	Unit area of land output value (100 million square kilometers)	Aviation Correlation	Location Quotient	Policy Support
1	Petrochemical industry	0.1012	2.0035	1.1346	0.6273	9

(Continued) Table 2: Attribute Matrix of Alternative Industrial Clusters in the AEZ

2	Modern service	0.3848	2.5047	0.7072	1.2585	54
3	Transportation service	0.1367	1.9384	0.2644	1.1935	67
4	High-tech industry	0.1286	3.9736	0.4974	1.4173	83
5	Advanced manufacturing	0.1364	2.4774	0.8251	0.8035	76
6	Real estate construction	0.1205	1.7236	0.2975	1.1245	11
7	Wholesale and retail trade	0.2054	2.1674	0.3201	1.3934	25
8	Supporting basic industry	0.1468	1.6158	0.8113	1.0724	34

The NSGA-II algorithm (the genetic algorithm with non-dominated sorting with elite strategy) solves the industrial selection model of the AEZ composed of formula (5)-formula (11), and obtains the optimized industrial scale and planned land use. Table 3 shows.

Table 3: Industrial Scale and Planned Land Area of ZZAEZ Based on Model Optimization

Number	Industry Cluster	Planned area (square kilometers)	Production value (100 million yuan)	Number of employees (10,000 people)
1	Petrochemical industry	23.96	48.00	2.42
2	Modern service	50.47	126.41	19.42
3	Transportation service	34.12	66.14	4.66
4	High-tech industry	41.39	164.47	5.32
5	Advanced manufacturing	106.23	263.17	14.49
6	Real estate construction	64.60	111.34	7.78
7	Wholesale and retail trade	31.10	67.41	6.39
8	Supporting basic industry	63.13	102.01	9.27
	Total	415	948.95	69.76

It can be seen from Table 3 that the advanced manufacturing industry has the largest land area of 106.23 square kilometres, accounting for 26% of the total planned area. Therefore, it is important to develop advanced manufacturing industries in the airport area; the advanced manufacturing industry also has the largest economic contribution, and its production The total value reached 26.317 billion yuan, accounting for 27% of the total output value of the region, but it provided jobs below the modern service industry, with 144,900 people, accounting for 21% of the total employment. The scale of land use in the modern service industry is 50.47 square kilometres, accounting for 12% of the total. As it is a labour-intensive industry, it provides employment of 191,400 jobs, accounting for up to 28%. The high-tech industry is also an industry category that should be developed intensively. As a capital-intensive and technology-intensive industry, although the scale of high-tech land use is only 10%, the number of jobs provided is only 8% of the total, but the output value is as high as 164.47. Ten thousand yuan, accounting for as much as 17%, second only to advanced manufacturing.

Although the petrochemical industry has the highest correlation with the air transport industry, the contribution rate of output value and employment is the lowest, less than 5%. The contribution rate of the transportation service industry is also very low, only 7%, but the transportation service industry is the basic airport industry that encourages the development of policies (the third is policy support), and its scale accounts for 8%. The real estate construction industry and the supporting basic industries account for 31% of the land use, but the output value contribution rate is only 24%, and the proportion of providing jobs is only 26%. It can be seen that our industry selection model can comprehensively consider the attribute characteristics of each industry when determining the scale of industrial land use, and obtain the results under multi-objective optimization.

Under the optimized industrial system, Zhengzhou Airport Port can achieve a total production value of 94.495 billion yuan, 24.48 billion yuan more than the actual amount in 2017; the number of jobs provided is 697,600, which is 2,100,000 more than in 2017. The optimized total production and number of jobs increased by 35.55% and 43.21% respectively. It can be seen that based on the industry selection optimization model, the industrial clusters of the airport area can be more scientifically and rationally allocated, and the land benefits of the airport area can be greatly improved.

From the calculation and analysis results of Zhengzhou Airport as an example, it can be seen that the AEZ should focus on the development of high-end industries with direct orientation and relevance, taking advanced manufacturing and high-tech industries as the leading industries, and manufacturing and maintenance of aviation equipment. Focusing on electronic information and biomedicine, we will build a production base for precision machinery products and promote the development of automobiles, electronics and other industries in the surrounding areas. At the same time, vigorously develop modern service industries such as information services, financial insurance, etc., improve the high-end business service functions in the airport economic zone, and build the airport economic zone into an industrial innovation centre and a productive service centre. It is also necessary to rely on the airport passenger and cargo network to further develop the transportation service industry such as logistics warehousing and transportation agency services, and improve the supporting industries such as real estate construction, education and scientific research, living and living, and ensure the rapid and healthy development of the airport economic zone.

5. Conclusions

At present, the development of China's airport economy is still in its infancy, lacking the theory and experience of planning and construction. The problems of unreasonable industrial planning and construction and prominent industrial structure conflicts in the AEZ have occurred from time to time, seriously affecting the AEZ. The development of the relationship between the airport and the local economy.
Based on the industry correlation analysis model, this paper identifies industries closely related to the airport and air transport industry, and forms an industrial alternative set for the AEZ. Based on the multi-objective combination optimization, the industry selection model of the AEZ is constructed, and the types of industries that can fully utilize the advantages of air transportation and regional resource endowments and improve economic benefits are selected. Taking the Zhengzhou Airport Economic Zone as an example, the calculation shows that the optimized industrial structure system is in line with the national and regional development

strategies, and can fully utilize the advantages of production factors in the AEZ, improve the economic benefits of land, increase employment opportunities, and promote the economy development of AEZ.

The choice of industry in the AEZ is two-way between the government and the enterprise. In order to avoid the situation that the development zone is planned but not developed in the AEZ, in addition to planning a scientific and rational industrial system, the government must formulate corresponding preferential policies and regulations to create a good investment and operating environment. Raise funds to attract domestic and foreign investment. Only in this way can the government-planned industry truly gather in the AEZ to achieve the expected economic development goals.

In addition, as the AEZ is far away from the urban area, it faces the problem of imperfect infrastructure and low quality of life. It is unable to attract and retain employees in the initial stage of development. Therefore, the AEZ should aim at the integration of production and city, build and improve the social service system, and actively develop the supporting services such as real estate, leisure and entertainment, culture and education, and form production, residence and life on the basis of industrial production. A multi-functional composite industrial city will enhance the attractiveness of the AEZ to practitioners.

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Comparative Analysis of Competitiveness of Sino-Euro Railway Express and Liner Shipping in the context of Sulphur Emission Control Convention

Jiaru Jin[1], *Feng Lian* [2], *and Zhongzhen Yang*[2]

[1] College of Transportation Engineering, Dalian Maritime University, Dalian, 116026, China
[2] Faculty of Maritime and Transportation, Ningbo University, Ningbo, 315211, China
Email: [1]jinjiaru@dlmu.edu.cn

Abstract

Comparing with ocean shipping system, which has mature market environment, large capacity and cheap unit cost, Sino-Euro Railway Express is short of competitiveness and has been facing the problems of weak profitability and being not able to operate without governmental subsidy. The convention of sulphur emission control on marine fuels in ocean area, which will be implemented by 2020, may weaken the competitiveness of traditional shipping and bring positive impacts on the operate profit of Sino-Euro Railway Express. Because to meet the requirements of the Convention, shipping companies either use clean fuels or choose to bypass, both of them will increase shipping cost. To maintain their profits, shipping companies may transfer this extra cost to shippers. While on the other hand, due to the governmental initiatives, the transport time by Sino-Euro Railway Express will decrease continually. The utilities' decrease and increase respectively of the two kinds of transports will inevitably leads to the changes in shippers' mode choices.

In order to clarify the impacts of the sulfur emission control convention on the competitiveness of Sino-Euro Railway Express, this paper first analyzes the behavior of shippers, shipping companies and the operators of the railway express by taking the value of goods, freight rates and total transport time of the products between China and Europe as the factors influencing the mode choice. For this, the total transport time is divided into on route time and waiting time. And then based on modal split model, the trade volume between China and Europe, the transport utility functions of nine types of trade goods between China and Europe are calibrated, and the influences of the proportion by which shipping companies transferring the added costs (hereinafter as transfer ratio) and the total transport time of Sino-Euro Railway Express on the competitiveness of the two modes in the transport markets of nine products and on the profits of shipping companies are studied.

The calculation results show that reducing total transport time of Sino-Euro Railway Express can greatly enhance its attractiveness to chemical raw materials and chemical products, metal smelting and processing products, equipment manufacturing products. The transfer ratio has a great influence on textile products, wood processing, papermaking and paper products, non-metallic mineral products. For different types of products, the changing pattern of shipping company's profit is different. Therefore, shipping companies need to make different decisions on different types products and choose an appropriate transfer ratio.

Keywords: Sulfur Emission Control Convention, Sino-Euro Railway Express, mode-choice model, transport time, transfer tatio

1. Introduction

At the 70th conference of the Maritime Environment Protection Committee of the International Maritime Organization (MEPC70), considering the air pollution caused by ships and restricting the sulfur oxides discharged by ships, adopted a resolution on the implementation of the sulfur content of marine fuel should not exceed 0.5%m/m in the global sea area from January 1, 2020. At the 71st conference of MEPC, it was confirmed that the implementation date of the 0.5% m/m fuel content standard in the global sea area was unchanged, and that the 0.1% m/m fuel sulfur content standard was still implemented in the emission control zones (Baltic Sea, North Sea, North America and Caribbean Sea). There is no doubt that the sulfur limitation convention will come into force on time.

Since 2020, global ship operators will comply with the new sulfur emission conventions. Compared with the previous, the new one requires lower sulfur emissions, and ship operators have to increase their fuel costs. Maersk estimates that once the new sulfur emission convention comes into force, the company will spend an additional $2 billion a year (Maersk Shipping). In 2017, the operation revenue of Maersk Shipping was US$24.299 billion and its net profit was US$541 million (Maersk's financial statements for the whole year 2017). Comparing Maersk's net profit in 2017 with the increased cost due to the sulfur emission convention, this additional cost is far beyond the current profit level of ship operators, so it is unrealistic for ship operators to bear the full cost of sulfur emission. In fact, on September 17, 2018, Maersk announced that it would implement a new fuel surcharge from January 1, 2019 in response to the 2020 sulfur emission convention. On September 24, 2017, CMA CGM and MSC followed closely, announcing that fuel surcharges will be adjusted from 2019.

In order to fully implement the strategic plan for promoting the construction of the “The Belt and Road”, the Chinese government has provided a large amount of funds and policy support for the development of the Sino-Euro Railway Express. In recent years, the number and routes of the Sino-Euro Railway Express have increased explosively, and its radiation range has expanded rapidly. The number of shifts increased from 7 in 2011 to 3673 in 2017 (Lu, 2018). According to the “Sino-Euro Railway Express Construction and Development Plan (2016-2020)”, by 2020, the number of Sino-Euro Railway Express will increase to 5000(National Development and Reform Commission, 2016). Up to 2017, there are 38 origin cities in China, reaching 36 cities in 13 European countries, with 61 lines operating. The on route time of Sino-Euro Railway Express is about 30% shorter than that of the initial stage, and the total transport time is gradually shortened from 20 days to 12-14 days. The price of the whole journey is about 40% lower than that of the initial stage (Lu, 2018).

For long-distance transportation between China and Europe, due to the huge difference in total transport time and freight rate, there is almost no intersection between ocean and air transport markets, so it is not necessary to study the competitiveness between sea and air transport. However, there are advantages and disadvantages in terms of total transport time and freight rate between Sino-Euro Railway Express and ocean shipping system, and there is little difference in transport utility between the two modes, which is comparable.That is to say, Sino-Euro Railway Express have certain competitiveness for maritime transport. On the one hand, the implementation of the new sulphur emission convention in 2020 has brought tremendous pressure on ship operators, and ship operators cannot bear this part of the cost alone. The increased cost will be transmitted to the downstream in the form of fuel surcharge, that is, the shippers will pay the bill; On the other hand, in order to promote the construction of "The Belt and Road", the on route time of Sino-Euro Railway Express decreased and the service frequency increased (the waiting time of the shippers decreased). The implementation of the sulphur emission convention and the development of Sino-Euro Railway Express have led to the weakening of the competitiveness of maritime transport relative to Sino-Euro Railway Express. Shippers may change their choice of transport modes and choose the Sino-Euro Railway Express as a substitute for maritime transport.

The utility of shippers' choice of transport mode is affected by the total transport time, freight rate and the attribute characteristics of trade goods. In view of this situation, it is necessary to study the impact of the proportion of additional fuel costs transferred by ship operators and total transport time changes on the competitiveness of the two transport modes in nine cargo transport markets, as well as the changes in the profits of ship operators, in view of the implementation of the sulphur emission convention, the development of the Sino-Euro Railway Express and the attribute characteristics of the trade goods between China and Europe.

2. Literature Review

In view of sulfur emission limitation, many experts and scholars have studied it from different aspects, which can be roughly divided into the following two aspects: the impact of the setting of emission control area (ECA) on ship speed, route and mode of transport; and the countermeasures of ship operators facing sulfur emission conventions.

The setting of ECA changes the fuel cost. Ship speed is the key factor to determine the fuel cost. Because of the difference of sulfur emission limitation standards inside and outside ECA, the ship operators use different marine fuel inside and outside ECA, and the two regions need to make different decisions on the speed.

Fagerholt (2015), Psarafties (2014), Doudnikoff (2014) and Psaraft (2013) proposed that ship operators choose to slow down in the ECA to reduce fuel costs, and choose to increase speed outside the ECA to compensate for the increased sailing time. Total fuel consumption and carbon dioxide emissions will increase. Cheng and Zhang (2017) set up the cost model of liner routes under emission control zones and carbon emission reduction. They compared the economic benefits of ship operators under the same and different speeds inside and outside ECA, and found that it is more appropriate to choose different speeds inside and outside ECA.

In addition, the effects of emission control area distance and carbon tax rate on liner transport cost are also studied. Lv and Mao (2017) take ship size selection, the number of ship and speed as decision variables, and establish a non-linear programming model to minimize the sum of total transport cost and carbon emission cost of container liner fleet. Fagerholt et al. (2015) proposed that the setting of ECA may affect the ship's route. Ship operators choose to go around without passing through the emission control area when they sail for a long distance. This choice of ship operators may lead to an increase in sulphur emissions by setting ECA in some rare cases. This effect is determined by the price difference between MGO and HFO. If the price difference between MGO and HFO is enlarged, the effect will become stronger.

Some scholars have studied the influence of sulphur emission conventions on the choice of transport modes. Kontovas et al. (2016) studied the potential impact of sulfur emission conventions on the market share of land-sea combined transport and road transport, and found that the implementation of sulfur limitation conventions increased the market share of road transport. Holmgren et al. (2014) studied the impact of the implementation of the sulphur emission Convention on the route choice of relatively high-value goods from Eastern Lithuania to Western Britain. The results show that it is unlikely to change the mode of transportation from sea transportation to road transportation.

Other studies have explored the countermeasures of ship operators in the face of sulfur emission conventions. Lindstad et al. (2015) studied the influencing factors of the optimal scheme for dealing with sulfur emission limitation, and pointed out that the best emission reduction scheme was related to engine size, annual fuel consumption in ECA and predicted future fuel price. Jiang et al. (2014) compared the economy of installing sulfur scrubber and using light diesel oil (MGO) as emission reduction measures. It was found that the price difference between light diesel oil (MGO) and heavy fuel oil (HFO) was the decisive factor in choosing emission reduction measures. Yang et al. (2012) used analytic hierarchy process to evaluate all emission reduction measures, and proposed that fuel switching is the best measure. In the future, it may be more appropriate to choose to install scrubbers under stricter sulfur emission restrictions. Brynolf et al. (2014) proposed three alternatives that meet ECA's sulfur and nitrogen limitations and compared them with life cycle assessment. Compared with heavy fuel oil (HFO), none of the three alternatives can significantly reduce the impact on climate change. However, all alternatives will reduce the impact on particulate matter, photochemical ozone formation, acidification and terrestrial eutrophication potential. Schinas et al. (2014) proposed a multi-standard method based on Analytical Network Process (ANP) to help ship operators choose the necessary technology alternatives in a better way, and to reveal the preferences and relationships among standards, so as to promote the improvement of decision-making tools. Abadie et al. (2017) discussed how the existing fleet of shipping industry adapted to the new emission regulations through economic evaluation of the two main technologies (a) fuel conversion and (b) scrubber installation under uncertain conditions. In the economic evaluation of these two technologies, the fuel price (spot and futures), the installation cost of scrubbers, the sailing time of ships in the emission control zone (ECA) and the remaining service life of ships are taken into account. Antturi et al. (2016) carried out a cost-benefit analysis of sulfur emission reduction policies in the Baltic Sea sulfur emission control area (SECA). This paper considers the optimal decision-making when choosing low sulfur fuel and installing scrubber to calculate emission reduction cost, and simulates its benefits by considering the formation and diffusion of emissions in high resolution impact path analysis. The calculation results show that the latest sulfur regulations are not cost-effective for the Baltic Sea alone. Wang (2018) expounded the advantages and disadvantages of three measures to deal with the sulfur emission Convention (selecting low-sulfur fuel, waste gas desulfurization device, LNG and other clean energy sources). He (2017) and Yue (2017) also elaborated on the measures to deal with the sulfur emission convention.

In summary, it can be found that most of the existing studies only focus on the impact of the setting of emission control zones (ECA) on ship speed, route and mode of transport. Ship operators face the sulfur emission convention measures as the research object, and do not combine the sulfur emission convention with the Sino-Euro Railway Express. In fact, the implementation of the new sulphur emission convention in 2020 has increased the fuel costs of ship operators, increased the transport costs of shippers, and consequently reduced the competitiveness of ocean shipping. Due to the strong support of the Chinese government, the total transportation time of Sino-Euro Railway Express has decreased. In this case, as an alternative to ocean shipping, the competitiveness of the Sino-Euro Railway Express may increase significantly. This paper deals with the impact of sulfur emission conventions and the development of shift schedules in Sino-Euro Railway Express on shippers' share of different transport modes. The proposed method is a non-aggregate model to predict the share of different transport modes. Arencibia (2015), Yang (2014), Chen (2013), Chen (2012), Liu (2017) and other scholars have done relevant research using Logit model. Combining the utility theory and the characteristics of different modes of transport, the paper gives the specific variables that should be selected when using Logit model to predict the freight sharing rate in the corridor.

3. Model Building

3.1. Modeling Conception and Framework

IMO has put forward stricter limits on sulfur content in marine fuels, requiring that the fuel sulfur content standards of 0.5% m/m and 0.1% m/m be observed in global sea areas and emission control areas respectively since 2020. From the perspective of ship operators, the new sulfur emission convention will lead to an increase in fuel expenditure, which makes it difficult for ship operators to bear the huge expenditure alone. In order to cope with this situation, ship operators will consider transferring part of the cost to shippers, which is embodied in the imposition of fuel surcharge on shippers, resulting in an increase in ocean freight rates. The advantage of ocean shipping over the Sino-Euro Railway Express lies in the low freight cost, which will be weakened by the implementation of the new sulfur emission convention.

The Chinese government has provided a large amount of capital and policy support to the Sino-Euro Railway Express as an important starting point to promote the " The Belt and Road " construction, such as increasing the number and line of Sino-Euro Railway, shortening the on route time, and subsidized freight to shippers. The traveling time of the Sino-Euro Railway Express is decreasing year by year, and the service frequency is increasing year by year (the waiting time of the shipper is decreasing). Compared with ocean shipping, the advantages of Sino-Euro Railway lie in less total transport time, less backlog of shippers' liquidity, and favorable impact on inventory and supply chain.

The implementation of the sulphur emission convention and the government's support to the Sino-Euro Railway Express have increased the freight of ocean shipping, while the total transport time of the Sino-Euro Railway Express has decreased. On the basis of comparing the freight rates and total transport time of the two transport modes, shippers may choose to replace ocean shippers by Sino-Euro Railway Express, thereby reducing the profits of ship operators and enhancing the competitiveness of the Sino-Euro Railway Express.

Therefore, in order to analyze the effect of the implementation of the sulphur emission convention and the government's support on the profits of ship operators and the competitiveness of Sino-Euro Railway Express, the attributes of the generalized transport cost function of Sino-EU trade goods are divided into two categories: total transport time and freight rate, and total transport time is divided into on route time and waiting time. Secondly, based on the generalized transport cost of the two modes and the market share status of the various modes of transport, the transport mode partition model is calibrated. Finally, according to the proportion of ship operators passing on additional fuel cost and the total transport time change of the Sino-Euro Railway Express, the changes of market share and profit of ship operators in Sino-Euro Railway Express are analyzed.

3.2. Modeling Method

Based on stochastic utility theory, this paper analyses the effect of the implementation of sulphur emission convention and the government's support on the profits of ship operators and the competitiveness of the Sino-Euro Railway Express. To this end, the following assumptions are made: (1) the selected capacity of ocean shipping is 18,000 TEU; (2) the capacity of a Sino-Euro Railway Express is 84 TEU; (3) the speed of container ships is fixed at 20 knots; (4) all freight demand between China and Europe need to be met.

According to the stochastic utility theory, the shippers will choose the transport mode according to the utility, and the greater the utility, the greater the probability that the transport mode will be chosen (Psaraftis, 2010). Logit model can be used to calculate the following (Kontovas, 2016):

$$P_i^k = Exp\left(\lambda_i U_i^k\right) / \sum_{k \in K} Exp\left(\lambda_i U_i^k\right) \tag{1}$$

Modal split of various transport modes can be calculated by Eq. (1). P_i^k represents the probability of choosing the transport mode *k* for product *i*, U_i^k represents the utility of choosing the transport mode *k* for product *i*, λ_i represents the parameter to be calibrated, ***K*** represents the set of optional transport modes between China and Europe, *k=0* represents for the chosen transport mode is Sino-Euro Railway Express, *k=1* represents for the chosen transport mode is ocean shipping..

The direct utility is determined by the transport impedance and can be set to

$$U_i^k = -C_i^k, k \in K \tag{2}$$

$$C_i^k = F_i^k + VT_i^k \tag{3}$$

$$V_i = M_i r/(24 \times 365) \tag{4}$$

Here, C_i^k represents the generalized transportation cost of choosing the transport mode *k* for product *i*. F_i^k represents the freight cost of choosing the transport mode *k* for product *i* (USD/TEU). T_i^k represents the total transport time of choosing the transport mode *k* for product *i* (h). V_i is the normal number proportional to the value of products. M_i represents the value of product *i* (USD/TEU), and *r* is the capital opportunity cost of investors..

$$T_i^k = TT_i^k + WT_i^k \tag{5}$$

$$WT_i^k = 168/f_i^k/2 \tag{6}$$

Here, TT_i^k represents the on route time of choosing the transport mode *k* for product *i* (h). WT_i^k represents the service frequency of choosing the transport mode *k* for product *i*. Because the unit of service frequency is shift/week, for 168 hours a week, the interval between adjacent Sino-Euro Railway Express is $168/f_i^k/2$ (Zhao, 2018).

$$TT_i^1 = T_i^{1,ECA} + T_i^{1,out} \tag{7}$$

$$T_i^{1,ECA} = \frac{d_i^{1,ECA}}{v_i^1} \tag{8}$$

$$T_i^{1,out} = \frac{d_i^1 - d_i^{1,ECA}}{v_i^1} \tag{9}$$

Eq. (7) represents the on route time of choosing the transport mode ocean shipping for product *i* (h). $T_i^{1,ECA}$ and $T_i^{1,out}$ represents the sailing time inside and outside ECA for transport product *i* respectively (h). $d_i^{1,ECA}$ represents the distance in ECA for transport product *i* (n miles). d_i^1 represents the total distance of choosing the transport mode ocean shipping for product i (n miles). v_i^1 represents the ship speed for transport product *i* (knots).

$$M_i^{1,ECA} = F_i^H \left(v_i^1 / v_i^d\right)^3 \frac{T_i^{1,ECA}}{24} \tag{10}$$

$$M_i^{1,out} = F_i^H \left(v_i^1 / v_i^d\right)^3 \frac{T_i^{1,out}}{24} \tag{11}$$

Eq. (10) and Eq. (11) are respectively fuel consumption inside and outside ECA when transporting products *i* by ocean shipping (Doudnikoff, 2014), F_i^H is fuel consumption per day at design speed when transporting products *i* by ocean shipping (tons/day), and v_i^d is design speed when transporting products *i* by ocean shipping (knots).

$$F_i^H = \left(SFOC_i EL_i PS_i\right)\frac{24}{10^6} \tag{12}$$

$SFOC_i$ is the fuel consumption rate of the main engine when transporting products i by ocean shipping (g/kwh). EL_i is the engine load of the main engine when transporting products *i* by ocean shipping, and PS_i is the power of the main engine when transporting products *i* by ocean shipping (kw).

$$C_i^{1,fuel} = P_i^{1,out} M_i^{1,out} + P_i^{1,ECA} M_i^{1,ECA} \tag{13}$$

$C_i^{1,fuel}$ is the fuel cost when transporting products *i* by ocean shipping (USD). $P_i^{1,ECA}$ and $P_i^{1,out}$ are the fuel prices used inside and outside ECA for transporting products i by ocean shipping, respectively (USD/ton).

$$F_i^1 = \mu_i \frac{\left(C_i^{1,fuel} - C_i^{1,*}\right)}{18000} + F_i^{1,*} \tag{14}$$

Eq. (14) is the unit freight rate for ocean shipping after the implementation of the new sulphur emission convention, which is equal to the unit freight rate before the implementation of the new sulphur emission convention plus the fuel surcharge due to the increase of the fuel cost of ship operators(USD/TEU). Fuel surcharge is equal to the product of the difference between the cost of fuel allocated to each container and the percentage of the additional fuel cost transferred by the ship operator μ_i (%). $C_i^{1,*}$ and $C_i^{1,fuel}$ are the fuel costs before and after the implementation of the new sulfur emission convention respectively (USD)。

$$D_i^k = D_i P_i^k \tag{15}$$

D_i^k is the freight demand when transporting products *i* by transport mode *k*. D_i is the freight demand for product *I* between China and Europe.

$$n_i = \frac{f_i^1 T_i^1}{24 \times 7} \tag{16}$$

Eq. (16) is thr number of ships required for transporting products *i*.

$$REV_i = D_i^1 F_i^1 - f_i^1 C_i^{1,fuel} - n_i C_i^{1,rent} - C_i^{1,load} D_i^1 \tag{17}$$

REV_i is the profit of the ship operator who transports the product *i*. The calculation is carried out on a weekly basis. On the right side of the equation, the first item is freight revenue, the second item is fuel cost, the third item is chartered cost, and the fourth item is handling cost.

4. Case Study and Discussion

4.1. Data Description

Based on the commodity clustering method of Lee et al. (2011), 97 categories of import and export commodities in China Customs statistics are clustered into 9 categories. The specific situation is shown in Table 1. This paper takes these nine categories of goods as the analysis object. The freight demand data for the two transport modes in 2017 are shown in Table 2. Table 3 shows the specific values of other parameters collected.

Table 1: Cargo Categories in the Model

Category	Product	Customs code	Value of goods (USD/TEU)
1	Food Processing and Tobacco Processing Products	1-26	41562
2	Textile products	50-60, 63	20211
3	Textile and apparel, shoes and hats, leather, down and their products	41-43, 61, 62,64,65	86957
4	Wood Processing, Paper and Paper Products	44-49	21355
5	Chemical raw materials and chemicals manufacturing products	27-40	522977
6	Non-metallic mineral products	68-70	41667
7	Metal Smelting and Processing and Products	71-83	769231
8	Equipment Manufacturing Products	84-91,93	1111111
9	Other manufacturing products	66, 67, 92, 94-97	149254

Source: Value Table of National Key Import Commodities of General Administration of Customs of of The People's Republic of China

Table 2: Freight Demand for Two Transport Modes (TEU/Week)

Category	Ocean shipping	Sino-Euro Railway Express
1	82105	16013
2	23207	842
3	35862	9729
4	15179	2125
5	11259	6755
6	1796	65
7	6531	622
8	12058	9970
9	9831	1495

Sources: Ministry of Commerce of The People's Republic of China and General Administration of Customs of of The People's Republic of China

Table 3: Known Parameters for Two Transport Modes

Parameter	Ocean shipping	Sino-Euro Railway Express
Sailing distance in ECA (n miles)	1800	/
Total sailing distance (n miles)	28800	/
Service frequency (shift/week)	/	1
Investor's capital opportunity cost (%/year)	2.97	2.97
Freight rate (USD/TEU)	2224	7000
On route time (h)	1440	864

4.2. Current Situation Analysis of Modal Split

Based on the current freight demand data, the current modal split is calculated, as shown in Table 4. It can be seen that at present, 97% of textile products (category 2) and non-metallic mineral products (category 6) are transported by ocean shipping, while the Sino-Euro Railway Express basically does not serve these two types of goods, and 91% of metallurgical processing and its products (category 7) are shipped by ocean shipping. The three categories of goods with the highest transport share in China and Europe are textile and apparel, shoes and hats, leather, down and its products (category 3), chemical raw materials and chemicals manufacturing (category 5) and equipment manufacturing products (category 8), among which the modal split in Sino-Euro Railway Express reaches 21%, 38% and 45% respectively.

Table 4: Modal Split of Two Transport Modes

Category	Ocean shipping	Sino-Euro Railway Express
1	84%	16%
2	97%	4%
3	79%	21%
4	88%	12%
5	63%	38%
6	97%	3%
7	91%	9%
8	55%	45%
9	87%	13%

4.3. Analysis on the Change of Modal Split in Sino-Euro Railway Express

It can be predicted that by 2020, the new sulfur emission convention will be implemented, and the limitation of sulfur emission in the global sea area will increase the cost of shipping, which will inevitably lead to the decline of the competitiveness of shipping. With the support of the Chinese government, the frequency and on route time will change, which will increase the competitiveness of the Sino-Euro Railway Express. Following is an analysis of the changes split in Sino-Euro Railway Express, along with the attributes changes in the development of Sino-Euro Railway Express and the proportion of ship operators transferring additional fuel costs (hereinafter referred to as transfer ratio).

According to the relevant data of Sino-Euro Railway Express in recent years and the assumption of Sino-Euro Railway Express 's construction and development plan (2016-2020), the frequency of Sino-Euro Railway Express has increased from 1 shift/week to 4 shift/week, and the on route time (including trip and return) has been reduced from 864 hours to 624 hours. The choice of marine fuel in shipping attributes has changed. The choice of fuel in global sea area has changed from 372USD/t heavy oil to 526USD/t fuel with 0.5% sulfur content. The choice of fuel in emission control area remains unchanged, and the price of fuel is 619USD/t (http://www.cn-eship.com/SteelPrice/gjgkryg.jsp).

Fig. 1 shows the change of modal split in Sino-Euro Railway Express with the development of the frequency and the increase of the transfer ratio. The frequency of Sino-Euro Railway Express increased from 1shift/week to 4shifts/week, and when the travel time decreased from 864 hours to 644 hours, there was a great difference in the modal split in Sino-Euro Railway Express of nine kinds of goods. Among them, metallurgical processing and its products industry products (category 7) have the largest growth rate, of which modal split in Sino-Euro Railway Express increased from 8.70% to 52.97%, an increase of 5.09 times; chemical raw materials and chemicals manufacturing products (category 5) and equipment manufacturing products (category 8) have also increased significantly, from 37.50% to 46.59%, from 45.26% to 65.48%. The value of the above three kinds of goods is relatively high. For these goods, increasing the frequency and reducing the on route time of modal split in Sino-Euro Railway Express, further strengthening the timeliness of modal split in Sino-Euro Railway Express, can greatly increase the competitiveness of the modal split in Sino-Euro Railway Express, widen the gap between the effectiveness of the modal split in Sino-Euro Railway Express and ocean shipping, and increase the modal split of the modal split in Sino-Euro Railway Express.

The modal split of textile products (category 2), wood processing, paper and paper products (category 4) and non-metallic mineral products (category 6) in Sino-Euro Railway Express varies slightly with the change of on route time and service frequency in Sino-Euro Railway Express. When the freight rates of the two modes of transport remain unchanged, the service frequency of the Sino-Euro Railway Express increases from 1 shift/week to 4 shift/week, and the on route time decreases from 864 hours to 644 hours, the model split of the three goods in Sino-Euro Railway Express increases from 3.50% to 3.63%, from 12.28% to 13.12%, from 3.47% to 3.68%, and the growth rate is lower than 10%.

When the service frequency is 4 shifts per week, the travel time is 624 hours, and the transfer ratio changes from 0% to 100%, the model split of textile products (category 2), wood processing, paper and paper products (category 4) and non-metallic mineral products (category 6) in Sino-Euro Railway Express has increased significantly, with the growth rate exceeding 150%. Among them, the growth rate of textile products (category 2) is the largest, and the modal split of Sino-Euro Railway Express increased from 3.63% to 21.23%, an increase of 4.85 times. Thus, for such goods with low value, shippers are insensitive to the total time-consuming transportation. It is slight to improve the market share of the Sino-Euro Railway Express by improving the timeliness of the Sino-Euro Railway Express. Reducing the freight rate is an effective means to increase the market share of the Sino-Euro Railway Express.

When the service frequency is 4 shifts per week, the travel time is 624 hours, and the transfer ratio changes from 0% to 100%, the modal split of chemical raw materials and chemical products manufacturing products (category 5), equipment manufacturing products (category 8) and other manufacturing products (category 9) in Sino-Euro Railway Express basically does not change. It can be seen that the above three kinds of goods are insensitive to freight rates, and they are basically not affected by the increase in freight rates brought about by the sulphur emission convention. For such goods, ship operators can choose to transfer all the additional fuel costs to shippers.

The results show that for different goods, the development of Sino-Euro Railway Express and the implementation of sulfur emission conventions play different roles. For some goods, even if the total transport time is greatly shortened, the market share of Sino-Euro Railway Express can not be increased. However, shortening the total transport time can greatly enhance the attraction of the Sino-Euro Railway Express t to chemical raw materials and chemical products manufacturing products (category 5), metal smelting and processing products (category 7) and equipment manufacturing products (category 8), and enhance the competitiveness of the Sino-Euro Railway Express. In addition, the increase in sea freight rates for textile products (category 2), wood processing, paper and paper products (category 4) and non-metallic mineral products (category 6) will lead to changes in their mode of transport and more use of the Sino-Euro Railway Express.

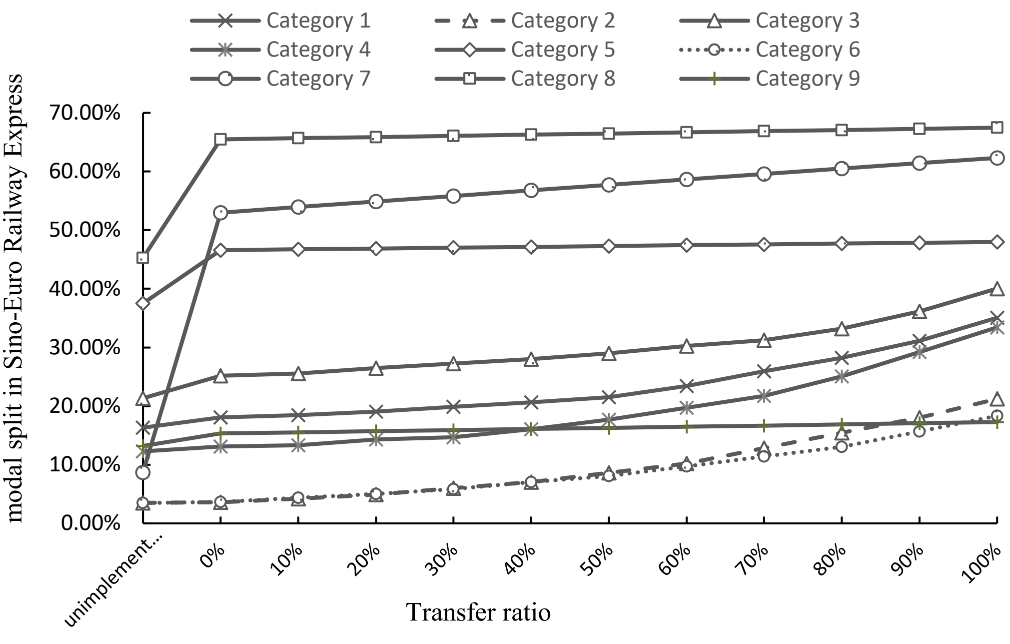

Figure 1: Modal Split in Sino-Euro Railway Express for Nine Categories of Goods

4.4. Analysis on the Change of Ship Operator's Profit

Because the profit of ship operators with category 1 and cargo type 2-8 is quite different, in order to facilitate chart observation and analysis, cargo category 1 and cargo category 2-8 are plotted as Figure 2 and Figure 3 respectively. Figure 2 and Figure 3 show the change of the profit of ship operators with the increase of the transfer ratio for different cargo category s. As shown in Fig. 2 and Figure 3, the profit trends of ship operators are different for different cargo categories. The profits of ship operators corresponding to food processing and tobacco processing products (Category 1), textile products (Category 2), wood processing, paper and paper products (Category 4) and non-metallic mineral products (Category 6) increase first and then decrease with the increase of the transfer ratio. From this, we can see that the best decision for these cargo ship operators is to choose to transfer part of the additional fuel cost to cargo owners. The profits of ship operators corresponding to textile and apparel, shoes and hats, leather, down and their products (category 3) and metal smelting and processing and their products (category 7) show a downward trend with the increase of the transfer ratio. Therefore, the optimal decision for ship operators of these goods is to bear the additional fuel cost alone. The profits of ship operators corresponding to chemical raw materials and chemicals manufacturing products (category 5), equipment manufacturing products (category 8) and other manufacturing products (category 9) show a downward trend with the increase of the transfer ratio. Therefore, the optimal decision for ship operators of these goods is to choose to transfer all the additional fuel costs to the shippers. The reason for this is the freight rate of these goods. Insensitive, the corresponding Sino-Euro Railway Express modal split does not change with the increase of the transfer ratio. In this case, the increase of freight income caused by the increase of the transfer ratio can increase the profits of ship operators.

Table 5 shows the changes in the profits of ship operators of nine categorys of cargo under different transfer ratios. As shown in Table 5, the profits of ship operators corresponding to nine kinds of cargo have decreased, among which the profit of metallurgical processing and its products (category 7) has decreased by 414.40%, followed by equipment manufacturing products (category 8), by 86.14%. The profit of ship operators is mainly related to the increase of cost caused by the increase of fuel price and the decrease of freight revenue caused by the decrease of the modal split of shipping. In addition, when calculating the fuel surcharge for the shippers, the additional fuel cost is allocated to all the container positions. In fact, the ship is not fully loaded, even if the ship operator chooses to pass all the additional fuel costs to shippers is still responsible for the fuel surcharge corresponding to the empty container, which further damages the profit of the ship operator.

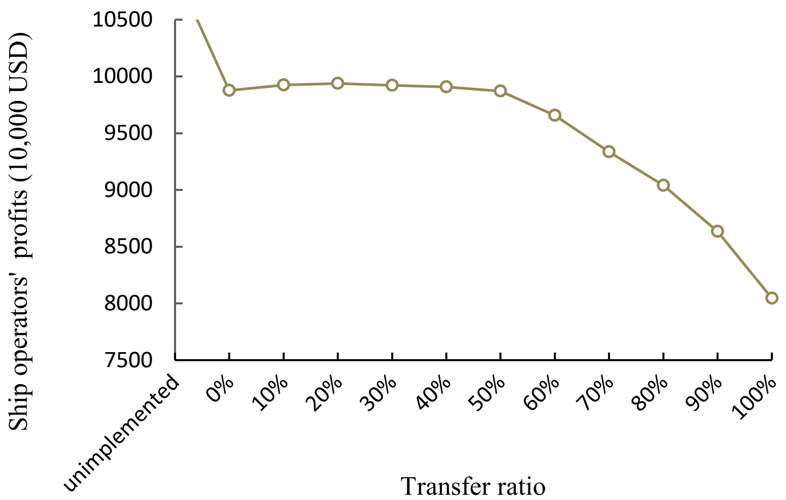

Figure 2: Ship Operator's Profit of Category 1

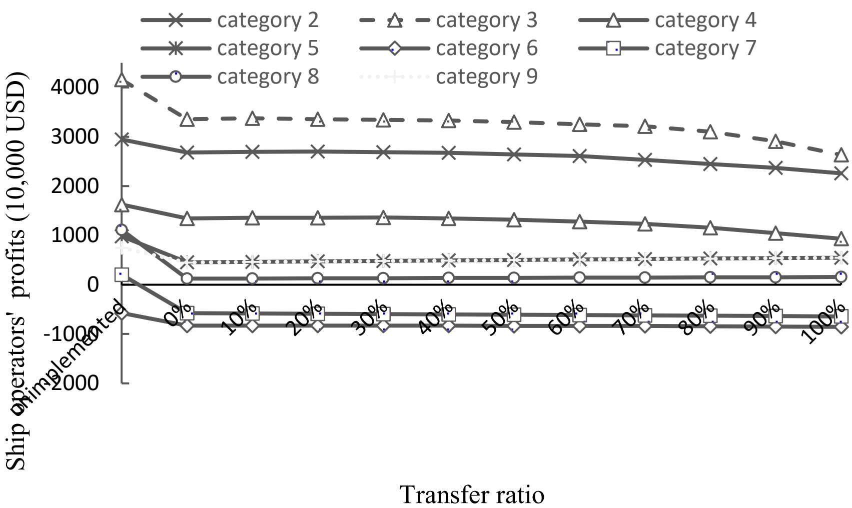

Figure 3: Ship Operator's Profit of Category 2-9

Table 5: Growth Rate of Ship Operators' Profits under Different Transfer Ratio

Category	Transfer Ratio =0%	Transfer Ratio = optimal	Transfer Ratio =100%
1	-9.63%	-26.39%	-9.06%
2	-8.91%	-23.33%	-8.44%
3	-19.25%	-36.69%	-19.25%
4	-17.29%	-42.67%	-16.18%
5	-53.61%	-44.19%	-44.19%
6	-44.99%	-49.02%	-44.93%
7	-379.61%	-414.40%	-379.61%
8	-88.87%	-86.14%	-86.14%
9	-39.79%	-26.65%	-26.65%

Note: Transfer ratio = optimal is the transfer ratio of the maximum profits of ship operators after the implementation of the new sulphur emission convention.

5. Conclusion

Based on the transport modal split model and the generalized transport cost including freight rate (affected by fuel surcharge), cargo in on route time, shipper waiting time and cargo varying with cargo value, a method for calculating market share of Sino-Euro Railway Express in cargo category and profit of ship operators is proposed. Based on the data of Sino-European trade and transportation, the Logit model is calibrated by different categorys of goods. The proportion of additional fuel cost transferred by ship operators (referred to as the transfer ratio) and the impact of total transport time on the competitiveness of Sino-Euro Railway Express in nine kinds of cargo transport markets and the changes of ship operators' profits are studied.

In order to improve the competitiveness of Sino-Euro Railway Express in China-EU trade and transport market, we should first develop the attributes of Sino-Euro Railway Express through multiple channels, especially to improve the timeliness of Sino-Euro Railway Express, further shorten the travel time and increase the frequency of shift. Especially in the face of chemical raw materials and chemicals manufacturing products (category 5), metallurgical processing and its products (category 7) and equipment manufacturing products (category 8), which are sensitive to the total time-consuming transportation, it is more necessary to carry out accurate marketing, seize the market supply, encourage shippers to choose the logistics services of the Sino-Euro Railway Express so as to form the habit of preference for the long-distance transport of the Sino-Euro Railway Express. In addition, price-sensitive goods such as textile products (Category 2), wood processing, paper and paper products (Category 4) and non-metallic mineral products (Category 6) are affected by the rising freight rates brought about by the sulphur emission convention, and the attraction of the Sino-Euro Railway Express for these goods has also increased. If the Chinese government provides more subsidies to Sino-Euro Railway Express freight rates, the modal split of Sino-Euro Railway Express in these freight transport markets can be further increased.

As far as ship operators are concerned, transferring all the extra fuel costs to shippers does not necessarily maximize the profits of ship operators. For goods that are extremely sensitive to freight rates, such as textile and apparel, shoes and hats, leather, down and their products (category 3) and metallurgical processing and their products (category 7), ship operators may consider assuming additional fuel costs on their own in order to avoid losing too many sources of goods and substantially reducing freight revenue. For goods that are extremely insensitive to freight rates, such as chemical raw materials and chemicals manufacturing products (category 5), equipment manufacturing products (category 8) and other manufacturing products (category 9), the increase in freight rates will not significantly reduce the share of shipping, so ship operators may consider transferring all the additional fuel costs to shippers. For food processing and tobacco processing products (category 1), textile products (category 2), wood processing, paper and paper products (category 4) and non-metallic mineral products (category 6), which are relatively sensitive to freight rates, ship operators may consider transferring some additional fuel costs to shippers.

To sum up, the development of Sino-Euro Railway Express and the implementation of the sulfur emission convention in 2020 have greatly increased the competitiveness of China and Europe in part of the freight transport market, promoted the role and status of Sino-Euro Railway Express, and promoted the strategic deployment of the Chinese government's "The belt and Road" construction. In addition, in all cargo transport markets, the profits of ship operators have declined. Ship operators should make reasonable decisions to meet the challenges posed by the development of Sino-Euro Railway Express and the implementation of the 2020 sulfur emission convention.

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Evaluation System Design and Index Model Construction for Container Liner Shipping Operation

Chun-Juan Wang[1]*, Chao Chen*[1]*, and Yang Liu*[1]

[1]International Business School, Shandong Jiaotong University, Weihai 264200, China
Email: [1]joy_1229@qq.com

Abstract

Taking the effect of the container ship large-size increasingly development on the changes of container liner shipping structure as the background, and viewing the complex container liner shipping system of multiple ports called by ships as the object of study, aiming at the complexity that the operation states of O-D segments between different ports in the container shipping liner shipping system are affected by freight demands, trip distances and freight rates etc., this paper puts forward the problem of the evaluation content and the index expression of container shipping service, comprehensively using the integer programming modeling method, technical and economic analysis method and multiple expectation average processing technology, builds a main evaluation system and constructs the index models including the return on investment model, the slot cost model, the break-even volume model, the profit growth rate model, the break-even freight rate model, and the risk tolerance model, to reflect the operating conditions from the whole voyage to each O-D segment. Targeting the profit maximization of the shipping route operation, considering the freight demands, segment distances and freight rates as the decision variables, a profit maximization model is set up at first to optimize the transportation volumes of each O-D segment. And then, comparative analyses are conducted between two typical cases applied as a pendulum line and a circular line. The results show that the evaluation system and the index models designed provide standards and measurements for assessing and evaluating the actual operation process of liner shipping route, even though there are complete differences in the route structure, voyage distance, service time, freight rate, handling cost, and so forth, it is able to carry out comparative and economic analysis of operation conditions for different routes, which verify the effectiveness and practicability of these evaluation system and index models, and provides new ideas and methods to scientific evaluation for container liner shipping operation.

Keywords: Container Shipping route, Evaluation System Design, Index Model Construction, Technical and Economic Analysis, Multiple Expectation Average Processing Technology

1. Introduction

Designing a reasonable evaluation system and constructing scientific index models are not only helpful to assess the surplus-deficit status of container liner shipping operation, but also contribute to instruct the slot allocation of the route deployment and implement process monitoring, which in turn realize scientific management for the container liner shipping operation.

The container liner shipping system consists of three key elements: the ship, the cargo (container), and the port. The travel of the ship carried with containerized cargo between different ports forms the shipping route. Nowadays the larger-scale trend of container ships, rapid increase in the number of calling ports, and the rising complexity of routing structures, contribute to increasingly structure complexity of the container liner shipping system. Accordingly, establishing an evaluation system and index models of a sophisticated container liner shipping system has become a wicked problem to the maritime industry and the academic circles (Meng et al., 2014). The traditional evaluation index, such as the break-even volume and the break-even freight rate, are of certain utility for a simple end-to-end route, as the round trip segment of liner route is completely overlapped with its O-D segments (origin port O and destination port D), which can be used to calculate the operating costs generally and roughly (Shuaian Wang et al., 2014). For an example, a shipping line is: port1→port2→port1, the total costs can be directly distributed onto the incoming segment (port1→port2) and the outgoing segment (port2→port1) which makes it easy to measure the performance of them. However, for a multi-port-called shipping line, it obviously is impossible to process by human intuition with traditional methods, and the operators would like to know the cost and benefit situations in every knot (port) and every segment to help decision-making. The more the calling ports are, the more difficulty in calculation and assessment will be. The allocation of costs of an operating voyage on each O-D segment has become extremely complicated, because of the large number of O-D segments (The number of calling ports is n, and the number of O-D segments will be $n \cdot (n-1)$), the volumes of shipping cargoes, as well as the big differences in trip distance and freight rate between O-D segments. Therefore, the study of evaluation system and index models of container liner shipping operation is not only a practical test faced by the industry, but also a theoretical challenge to the academic world.

There have been many researches related to the optimization of container liner shipping system. Nguyen Khoi Tran and Hans-Dietrich Haasis (2015) conducted a literature survey related to optimization problems and methodologies of container liner shipping mainly in three categories: container routing, fleet management and net- work design. Ship routing combining with problems of fleet assignment and container routing were also studied comprehensively. He also pointed out that most of the studies mainly focused on optimizing the liner shipping system by aiming at the profit maximization or the total cost minimization to obtain optimal container routing or network design, and the reasonable fleet deployment. Linear programming and non-linear programming are often deployed to model network related matters. Lots of recent articles similarly continued working on the models construction, system design optimization and analysis approach (Chen Kang et al., 2014, 2016; Qiang Meng, 2014; Yoonjea Jeong, 2018).

However, from the view of the management requirements, the studies on the performance evaluation of the existing shipping route system are limited due to the difficulty in obtaining data. Shih-Chan Ting and Gwo-Hshiung Tzeng (2003) identified cost items relevant to the planning of a service route and proposed a dynamic programming model for ship scheduling, contributed an estimation of the voyage fixed costs and freight variable costs in liner service route planning. Wei-Ming Wu and Jenn-Rong (2015) Lin proposed a theoretical model to evaluate the total factor productivity growth of the container shipping industry in Taiwan instead of adding up all cost items of ship operation in the traditional vessel-based approach. Yadong Wang et al. (2015) proposed a liner container seasonal shipping revenue management problem, developed a mixed-integer nonlinear programing with a nonconvex objective function by considering the realistic bunker consumption, the sailing speed and payload (displacement). Bo Lu et al. (2015) developed a model which evaluated the economy for the container routes based on financial data and carried out an economic analysis applying such model to the container routes between PSU and America in East Asia. Dongqin Lu et al. (2014) developed a shipping model for the Northwest Passage supposed that the ship could navigate across the Arctic Ocean during ice-free period in the summer season, and compared seven routes of the Northwest Passage with that of the Panama Canal using economic analysis. The existing studies generally addressed the overall evaluation, such as the voyage profit, the slot utilization ratio, the break-even capacity, the break-even freight rate, the rotation rate etc., rather than specifically based on evaluation on each O-D pair, which may lead in unscientific and non-systematical results for an operation of container liner shipping system (Jiasheng Wang et al. 2014; Wendan Zhang, 2016; Wolfgang Drobetza, 2018).

The evaluation issues of container liner operation can be summarized in two respects. The first is the studies on designing an evaluation system to measure the performance; the other is the construction of the index models of the evaluation system. The former is concerned with expressing the management requirements through the index design, whereas the latter focuses specifically on describing the actual efficiency and effectiveness through the model construction. They both determine the rationality and objectivity of evaluation and assessment performance of liner shipping operation system. Accordingly, this paper is based on the management requirements of liner route operation, together with basic functions and guidance effects of evaluation index, considering the influence factors in cost and benefit of O-D segments, regards the index construction as a compound multiple expectation planning problem. In view of the complexity of the interactions among influence factors in liner shipping system, using the integral programming modeling method, technical and economic analysis method and the multivariate expected average processing technology, a main evaluation system and the index models are designed for the container liner operation system.

The remainder of the paper is organized as follows: Section 2 gives a description of the proposed problem. Section 3 introduces the evaluation system with the necessary indicators. Section 4 builds up index models for all the indicators mentioned in section 3. Section 5 shows the programming procedures. Section 6 reports case studies based on a pendulum and a circular liner shipping routes. Conclusions are presented in Section 7.

2. Problem Description

The evaluation system is based on management requirement, the index models are based on resource occupancy. Container liner shipping operation refers to transporting containerized cargoes (containers) on a regularly scheduled service route among a fixed sequence of calling ports. A ship carries cargoes required from an origin port to a destination port with stopovers among several intermediate ports, at which cargoes can be transshipped, and then visits the origin port again after visiting the last one, forming either a pendulum or a round repeated operation cycle for cargo transport (Anthony E. Ohazulike et al., 2013; Zhiyuan Liu et al., 2014). Fig. 1 illustrates an operation process of a pendulum container shipping route. The solid lines and arrows represent the actual sailing legs of the ship, and the dotted lines and arrows represent the cargo flow segments between O-D pairs. It shows that the course operation process is actually the cargo flow between O-D segments. Therefore, the evaluation system and index models of container liner shipping operation should practically take O-D segments as the research objects for specific evaluation, assessment, guidance and monitoring. However, with increasing number of O-D segments due to the growth number of the calling ports, considering influences under big differences in route distances, cargo demands and freight charges among different O-D pairs, the performance measurement on the whole route should be specified to each specific O-D segment on the investment efficiency, the operational efficiency, the revenue contribution and the cost allocation, to assess their contributions to the operation requirements and effectiveness in resource utilization.

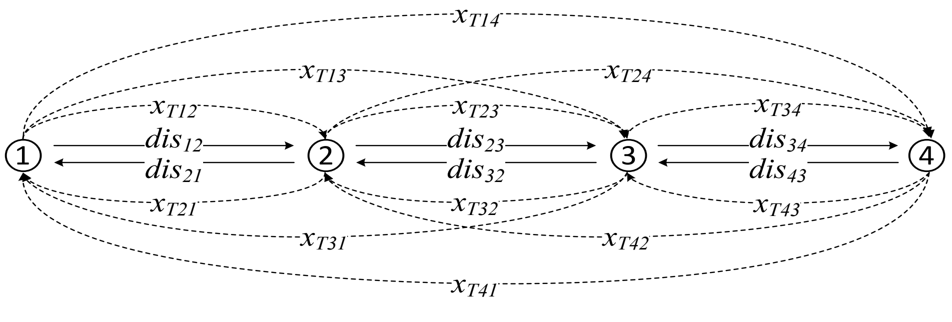

Figure 1: The Operation Process of a Pendulum Container Liner Shipping Route

3. Evaluation system

It is analogous to other production operation system that improving efficiency and effectiveness is also a basic management requirement to a container liner shipping system. In order to present the operation process of the liner route objectively and take full advantage of comparative analysis function and practical guidance of the evaluation system, the evaluation index designed should clearly describe the actual efficiency, specific effectiveness, and limited requirements for the realistic benefits for both overall system and each O-D segment of shipping operation system. From the perspective of comparative analysis, return on investment indicator, is conducive to objectively comparing and evaluating the operation effectiveness on different route structures, ship sizes and service time. From the perspective of operation feasibility, slot cost indicator, is beneficial to dividing the operation costs reasonably on each O-D pair of a voyage, and guiding the freight pricing, cost adjustment and revenue improvement of specific O-D pair. Break-even volume indicator, which helps define the minimum amount of cargoes required for each O-D pair under the stable market freight rate situation; break-even freight rate indicator, which benefits clarifying the minimum freight rate of each O-D pair under the condition that the number of containers transported remains unchanged. From the view of the potential profitability and risk tolerance of route operation, profit growth rate indicator, is helpful to adjust the fleet structure and formulate the development strategies of shipping market for different O-D pairs; risk tolerance indicator, is useful to optimize assessment of fleet configuration, and make market competition decisions for concrete O-D pairs.

4. Index Models

Cost allocation is the foundation of index model construction. Hence, for a given container liner route, taking the segment distance, cargo demand, freight price of O-D pairs as decision variables, the operating revenue and cost as indirect variables, this paper applies multivariate expected average method to deal with the impacts on operation effectiveness of O-D pairs caused by trip distances and profit abilities between calling ports, which can reflect the status of cost apportionment more reasonably.

4.1 Average Unit Model

Due to different types (dry, reefer or dangerous) and sizes (20’ or 40’) of the container, although one size may be a multiple of another, such as 20 feet and 40 feet containers, there is usually non-multiple relationship between the freight rates and the operating costs. Accordingly, a multivariate expected average method is adopted to build the model of freight rate and operation cost per unit expected average TEU. x and y denote the number of laden and empty containers, respectively. m and n separately represents the type and size of the containers. Therefore, descriptions of unit TEUs are as follows：

The number of laden containers (TEUs): $x_T = 2 \cdot x_{40} + 1.5 \cdot x_{30} + x_{20} + 0.5 \cdot x_{10}$

The number of empty containers (TEUs): $y_T = 2 \cdot y_{40} + 1.5 \cdot y_{30} + y_{20} + 0.5 \cdot y_{10}$

Unit TEUs formulation is described below:

$$TEUs = \frac{1}{x_T + y_T}\left\{2 \cdot \left(x_{40} + y_{40}\right) + 1.5 \cdot \left(x_{30} + y_{30}\right) + \left(x_{20} + y_{20}\right) + 0.5 \cdot \left(x_{10} + y_{10}\right)\right\} \quad (1)$$

Here, we use C to represent the operation costs. R_{mn}^{x}, R_{mn}^{y} denote freight rate of laden and empty containers in m types and n sizes. Accordingly, $\overline{R}$ and $\overline{C}$ denote the average freight rate and operation cost per unit expected average TEU, respectively, which can be expressed in mathematical terms as follows:

$$\overline{R}_T^x = \frac{1}{x_T}\left\{\sum_m^4\sum_n^l\left(x_{mn}\cdot R_{mn}^x\right)\right\} \tag{2}$$

$$\overline{R}_T^y = \frac{1}{y_T}\left\{\sum_m^4\sum_n^l\left(y_{mn}\cdot R_{mn}^y\right)\right\} \tag{3}$$

$$\overline{C}_T^x = \frac{1}{x_T}\left\{\sum_m^4\sum_n^l\left(x_{mn}\cdot C_{mn}^x\right)\right\} \tag{4}$$

$$\overline{C}_T^y = \frac{1}{y_T}\left\{\sum_m^4\sum_n^l\left(y_{mn}\cdot C_{mn}^y\right)\right\} \tag{5}$$

4.2 The model of the return on investment

The return on investment (ROI) is an indicator reflecting profitability of liner route operation in unit time. It is especially suitable for comparing different routes, which features in different route structures, service periods and ship sizes, to perform a uniform and fair evaluation. P denotes the total voyage profit, T is the total voyage time, Q_S denotes the slot number (i.e. investment scale), and C denotes the total operation costs. n, C_{ctn}, C_{ship}, C_{oil}, C_{prt} respectively denote the number of calling ports, the costs for container rental, the voyage charterer fees, the bunker costs and the terminal handling costs. According to the description above, the ROI model can be expressed as:

$$\overline{P} = \frac{P}{T\times Q_S} \tag{6}$$

Where, $P = \sum_i^n\sum_j^n\left(\overline{R}_{T_{ij}}^x - \overline{C}_{T_{ij}}^x\right)\cdot x_{Tij} + \sum_i^n\sum_j^n\left(\overline{R}_{T_{ij}}^y - \overline{C}_{T_{ij}}^y\right)\cdot y_{Tij} - C$; $C = C_{ctn} + C_{ship} + C_{oil} + C_{prt}$.

4.3 The Model of the Slot Cost

The slot cost refers to the unit transportation cost which means allocating the total costs onto each O-D segment of a voyage operation. Providing basis and reference for freight pricing, the cost allocation of O-D pairs is affected by the segment distances, cargo demands and freight prices, as well as the handling productivity at ports. x_{Tij} denotes the unit expected average freight volume (TEUs) from port i to port j; dis_{ij} denotes the distance between port i and port j. When the voyage profit equals to zero, which means, the revenue is equivalent to the total costs. At this moment, the slot cost model can be described as follows:

$$SC_{Tij} = \frac{x_{Tij} \cdot dis_{ij} \cdot \left(\overline{R}^x_{Tij} - \overline{C}^x_{Tij}\right)}{\sum_i^n \sum_j^n \left[x_{Tij} \cdot dis_{ij} \cdot \left(\overline{R}^x_{Tij} - \overline{C}^x_{Tij}\right)\right]} \times \frac{C + C_y}{\left(x_{Tij} / \sum_j^n x_{Tij} \right) \cdot Q_{ii}} \tag{7}$$

Where, $Q_{ii} = \sum_j^n \left(x_{Tij} + y_{Tij} \right)$ represents the handling volumes at port *I*; $C_y = \sum_i^n \sum_j^n \overline{C}^y_{Tij} \cdot y_{Tij}$ represents the repositioning costs of the empty containers. Here, It's worth noting when the empty containers are allocated using the empty slots of carriers' own vessels, it does not need to be paid, that is to say, $\overline{R}^y_{Tij} = 0$; $x_{Tij} / \sum_j^n x_{Tij}$ represents the slot allocation rate at port *i*. If ξ_{ij} is introduced as a multiple expectation factor between port *i* and port *j*, Eq. 7 can be simplified as:

$$SC_{Tij} = \xi_{ij} \times \frac{C + C_y}{\left(x_{Tij} / \sum_j^n x_{Tij} \right) \cdot Q_{ii}} \tag{8}$$

4.4 The Model of the Break- Even Volume

The break-even volume refers to the minimum quantity of containers required under the condition of unchanged freight rate to maintain the non-loss operation, which can be expressed that the voyage profit is not less than zero, i.e., $P \geq 0$. As mentioned above, when the allocation of the empty containers is based on the unoccupied slots on the ship, we define the freight rate of empty container as 0. The multiple expectation factor ξ_{ij} is taken to represent the balance between revenue and cost of each O-D segment, which can be deduced as: $\left(\overline{R}^x_{Tij} - \overline{C}^x_{Tij}\right) \cdot x_{Tij} \geq \xi_{ij} \cdot \left(C + C_y \right)$. Obviously, the break-even volume model for the O-D segments and the whole voyage can be respectively described as follows:

$$x^0_{Tij} = \xi_{ij} \times \frac{C + C_y}{\left(\overline{R}^x_{Tij} - \overline{C}^x_{Tij}\right)} \tag{9}$$

$$x^0_T = \sum_i^n \sum_j^n x^0_{Tij} \tag{10}$$

4.5 The Model of the Profit Growth Rate

In actual route operation, the unit quantity (TEUs) of laden containers is usually greater than the break-even volume, which requires that enough space must be reserved for the container allocation. The space capacity is an important indicator to describe the profitability of each O-D pair of a shipping route. The model of the profit growth rate of each O-D pair and the whole voyage can be expressed below:

$$PGR_{ij} = 1 - \frac{x^0_{Tij}}{x_{Tij}} \tag{11}$$

$$PGR = \sum \sum \xi_{ij} \cdot PGR_{ij} \tag{12}$$

4.6 The model of the break-even freight rate

The break-even freight rate refers to the bottom line of the liner operation without profit. In the same process of deducting the break-even volume model, the break-even freight rate model of O-D pairs can be described as follows:

$$R_{Tij}^{0} = \xi_{ij} \times \frac{C + C_y}{\left(x_{Tij} + y_{Tij}\right)} + \overline{C}_{Tij}^{x} \tag{13}$$

The lowest break-even freight rate may be acquired under the condition of completely loaded with heavy containers of a ship, and its model is modulated as follows:

$$R_{Tij\_\min}^{0} = \xi_{ij} \times \frac{C}{x_{Tij}} + \overline{C}_{Tij}^{x} \tag{14}$$

4.7 The Model of the Risk Tolerance

The ratio between the break-even freight rate and the market average freight rate of unit TEU can be used to express the endurance capacity to fluctuation of freight rate of a voyage operation, thus the risk tolerance model of O-D pairs and the whole route can be described in the following way:

$$RSKT_{ij} = 1 - \frac{R_{Tij}^{0}}{\overline{R}_{Tij}^{x}} \tag{15}$$

$$RSKT = \sum_{i}^{n} \sum_{j}^{n} \left(\xi_{ij} \times RSKT_{ij}\right) \tag{16}$$

The maximum risk tolerance of a shipping route may be expressed as a ratio of the lowest break-even rate in case of ships fully loaded with laden containers to the average market freight rate, in that way, that maximum risk tolerance model of O-D pairs and the shipping route system can be formulated as follows:

$$RSKT_{ij\_\max} = 1 - \frac{R_{Tij\_\min}^{0}}{\overline{R}_{Tij}^{x}}\ ; \tag{17}$$

$$RSKT_{\max} = \sum_{i}^{n} \sum_{j}^{n} \left(\xi_{ij} \times RSKT_{ij\_\max}\right). \tag{18}$$

5. Programming Design

Considering the characteristics of the container liner operation, Matlab programming is applied to optimize the liner operation and solve the evaluation index models. The calculation process of those models is designed as follows:

Step 1: Relevant data import, including ship specifications, the number of the calling ports, the costs of handling operation of laden and empty containers, the voyage distances of each O-D segment, the amount of cargo demand and the freight rates of laden containers, etc.;

Step 2: Make judgments on the route operation mode: pendulum route or circumferential route;

Step 3: Design and construct operation models for the pendulum and circular route respectively, and run the corresponding models with data imported;

Step 4: Optimize the models and obtain the optimization results. The allocation of laden and empty containers of each O-D pair and the handling volumes at each port are acquired at this stage;

Step 5: Build index models and input optimization results of route operation;

Step 6: Solve the index models and analyze the evaluation results.

6. Case Analysis

6.1 Case Application

Using the index models designed above to compare two container liner routes, which are described as follows: (1) A domestic coastal pendulum route: port A→port B→port C→port B→port A (A→B→C→B→A in short), the distances between ports are respectively: A–B, 552 n miles; B–C, 912 n miles. (2) A China-Japan circular route: port $1^{\#}$→port $2^{\#}$→port $3^{\#}$→port $1^{\#}$ ($1^{\#}$→$2^{\#}$→$3^{\#}$→$1^{\#}$ in short), segment distances are respectively: $1^{\#}$–$2^{\#}$, 272 n miles; $2^{\#}$–$3^{\#}$, 807 n miles; $3^{\#}$–$1^{\#}$, 858 n miles. The main economic and technical indicators for the ship configuration of two routes are the same, which are given as follows: the deadweight tonnage is 8 200mt; the slot volume is 698 TEUs; the ship average speed and fuel consumption are 15.5kn/26.9mt＋0.33mt/d. The freight demand distributions and freight rates of container market among ports of two routes are extracted from the database of a Chinese liner shipping company (due to confidentiality, appropriate modifications are made here) to shown in table 1–4.

Table 1: The Annual Average Distributions of Cargo Demands and Freight Rates in the Domestic Route

	The annual average distributions of cargo demands (TEUs)	The annual average freight rates of container market (RMB)
A→B	150/20’; 40/40’	1 500/20’; 2 500/40’; 2 000/20’R; 3 340/40’R
A→C	360/20’; 30/40’	2 500/20’; 4 180/40’; 3 400/20’R; 5 600/40’R
B→C	110/20’; 20/40’	1 800/20’; 3 000/40’; 2 400/20’R; 4 000/40’R
C→B	50/20’; 60/40’; 100/20’R; 40/40’R	1 600/20’; 2 700/40’; 2 800/20’R; 3 970/40’R
C→A	160/20’; 60/40’; 20/20’R; 10/40’R	2 800/20’; 4 700/40’; 3 400/20’R; 5 200/40’R
B→A	80/20’; 30/40’	1 400/20’; 2 340/40’; 1 800/20’R; 3 000/40’R

Table 2: Handling Rates of Laden / Empty Containers at Ports in the Domestic Route Unit: RMB

	port A	port B	port C
Load, laden containers	220/20'; 330/40'; 240/20'R; 360/40'R	265/20'; 360/40'; 260/20'R; 380/40'R	250/20'; 395/40'; 295/20'R; 410/40'R
Load, empty containers	110/20'; 160/40'; 120/20'R; 180/40'R	145/20'; 165/40'; 130/20'R; 185/40'R	150/20'; 175/40'; 140/20'R; 190/40'R
Unload, laden containers	200/20'; 300/40'; 230/20'R; 250/40'R	250/20'; 320/40'; 240/20'R; 360/40'R	230/20'; 360/40'; 280/20'R; 390/40'R
Unload, empty containers	110/20'; 160/40'; 120/20'R; 180/40'R	140/20'; 165/40'; 120/20'R; 180/40'R	150/20'; 170/40'; 130/20'R; 180/40'R

Table 3: The Annual Average Distributions of Cargo Demands and Freight Rates in the China-Japan Route

	The annual average distributions of cargo demands (TEUs)	The annual average freight rates of container market (USD)
$1^{\#}\rightarrow 2^{\#}$	0	0
$1^{\#}\rightarrow 3^{\#}$	110/20'; 90/40'; 50/20'R; 50/40'R	822/20'; 1 281/40'; 1 381/20'R; 2 435/40'R
$2^{\#}\rightarrow 3^{\#}$	160/20'; 50/40'; 46/20'R; 36/40'R	585/20'; 899/40'; 1 244/20'R; 2 226/40'R
$3^{\#}\rightarrow 2^{\#}$	1/20'; 1/40'	415/20'; 614/40'; 643/20'R; 1 206/40'R
$3^{\#}\rightarrow 1^{\#}$	1/20'; 1/40'	552/20'; 831/40'; 781/20'R; 1 234/40'R
$2^{\#}\rightarrow 1^{\#}$	0	0

Table 4: Handling Rates of Laden / Empty Containers at Ports in the China-Japan Route Unit: USD

	port $1^{\#}$	port $2^{\#}$	port $3^{\#}$
Load, laden containers	56/20'; 100/40'; 85/20'R; 140/40'R	60/20'; 110/40'; 95/20'R; 150/40'R	110/20'; 210/40'; 110/20'R; 210/40'R
Load, empty containers	40/20'; 60/40'; 56/20'R; 110/40'R	45/20'; 70/40'; 70/20'R; 120/40'R	110/20'; 210/40'; 110/20'R; 210/40'R
Unload, laden containers	45/20'; 80/40'; 65/20'R; 120/40'R	50/20'; 90/40'; 70/20'R; 130/40'R	110/20'; 210/40'; 110/20'R; 210/40'R
Unload, empty containers	30/20'; 50/40'; 45/20'R; 90/40'R	30/20'; 60/40'; 50/20'R; 90/40'R	110/20'; 210/40'; 110/20'R; 210/40'R

The bunker costs are the standard market prices of port A and port $1^{\#}$, respectively. Port service costs (including pilotage and tugboat costs), terminal handling charges, operation costs such as port miscellaneous charges, cargo handling charges, and hatch operation costs etc., are in reference to prices at specific ports. Voyage charterer fees, container rental costs and fuel costs refer to the current market prices. The handling operation time at each port is 1 day; the slot occupancy rate of the ship is 85%. Using the index models designed in this paper, relevant financial index and evaluation index data of the two operating routes are calculated, as shown in table 5–6:

Table 5: Comparative Analysis of Financial Index between the Domestic and the China-Japan Route
Unit: RMB

	The domestic route	The China-Japan route
Voyage days	12	10
Chartering costs	327 600.00	273 000.00
Container rentals	261 010.00	321 165.80
Bunker costs	532 716.00	400 890.00
Port service charges	56 000.00	104 000.00
Empty container allocation costs	24 150.00	511 642.00
Total operating cost	1 201 476.00	1 610 697.80
Voyage revenue	2 251 940.00	2 663 909.00
Voyage profit	1 050 464.00	1 053 211.20

Table 6: Comparative Analysis of Operational Evaluation Index between the Domestic and the China-Japan Route

	The domestic route			The China-Japan route		
ROI per day (RMB/TEU)	147.62			177.51		
Freight rate (RMB/TEU)	A→B 1 413.0	A→C 2 441.0	B→C 1 720.0	$1^{\#} \to 2^{\#}$ 0	$1^{\#} \to 3^{\#}$ 5 858.0	$2^{\#} \to 3^{\#}$ 4 745.0
	C→B 1 945.0	C→A 2 656.0	B→A 1 301.0	$3^{\#} \to 2^{\#}$ 2 229.0	$3^{\#} \to 1^{\#}$ 2 996.0	$2^{\#} \to 1^{\#}$ 0
Handling costs of laden/ empty containers (RMB)	A→B 419/219	A→C 435/246	B→C 459/261	$1^{\#} \to 2^{\#}$ 0/0	$1^{\#} \to 3^{\#}$ 1 084/961	$2^{\#} \to 3^{\#}$ 1 127/1 013
	C→B 434/216	C→A 408/220	B→A 407/215	$3^{\#} \to 2^{\#}$ 996/888	$3^{\#} \to 1^{\#}$ 964/866	$2^{\#} \to 1^{\#}$ 0/0
Break-even volume of the whole voyage (TEUs)	671			377		

(Continued) Table 6: Comparative Analysis of Operational Evaluation Index between the Domestic and the China-Japan Route

Break-even capacity of each O-D segment (TEUs)	A→B	A→C	B→C	$1^{\#}\to2^{\#}$	$1^{\#}\to3^{\#}$	$2^{\#}\to3^{\#}$
	49	236	53	0	227	146
	C→B	C→A	B→A	$3^{\#}\to2^{\#}$	$3^{\#}\to1^{\#}$	$2^{\#}\to1^{\#}$
	123	180	30	2	2	0
Profit growth rate of the whole voyage	47.2%			34.2%		
Profit growth rate of each O-D segment	A→B	A→C	B→C	$1^{\#}\to2^{\#}$	$1^{\#}\to3^{\#}$	$2^{\#}\to3^{\#}$
	67.3%	43.8%	64.7%	0%	48.4%	4.6%
	C→B	C→A	B→A	$3^{\#}\to2^{\#}$	$3^{\#}\to1^{\#}$	$2^{\#}\to1^{\#}$
	18.0%	57.1%	80.0%	99.5%	98.1%	0%
Break-even freight rate (RMB)	A→B	A→C	B→C	$1^{\#}\to2^{\#}$	$1^{\#}\to3^{\#}$	$2^{\#}\to3^{\#}$
	741.3	1 559.9	899.5	0	3 539.0	4 564.9
	C→B	C→A	B→A	$3^{\#}\to2^{\#}$	$3^{\#}\to1^{\#}$	$2^{\#}\to1^{\#}$
	1 665.6	1 668.6	596.0	1 660.0	1 794.9	0
The lowest break-even freight rate (RMB)	A→B	A→C	B→C	$1^{\#}\to2^{\#}$	$1^{\#}\to3^{\#}$	$2^{\#}\to3^{\#}$
	741.3	1 559.9	899.5	0	3 539.0	4 564.9
	C→B	C→A	B→A	$3^{\#}\to2^{\#}$	$3^{\#}\to1^{\#}$	$2^{\#}\to1^{\#}$
	1 665.6	1 368.5	583.4	969.7	1 009.0	0
Total risk tolerance of the whole voyage	34.6%			27.9%		
Total risk tolerance of each O-D segment	A→B	A→C	B→C	$1^{\#}\to2^{\#}$	$1^{\#}\to3^{\#}$	$2^{\#}\to3^{\#}$
	47.5%	36.1%	47.7%	0%	39.6%	3.8%
	C→B	C→A	B→A	$3^{\#}\to2^{\#}$	$3^{\#}\to1^{\#}$	$2^{\#}\to1^{\#}$
	14.4%	37.2%	54.2%	25.5%	40.1%	0%
The largest risk tolerance of the whole voyage	38.4%			28.0%		
The largest risk tolerance of each O-D segment	A→B	A→C	B→C	$1^{\#}\to2^{\#}$	$1^{\#}\to3^{\#}$	$2^{\#}\to3^{\#}$
	47.5%	36.1%	47.7%	0%	39.6%	3.8%
	C→B	C→A	B→A	$3^{\#}\to2^{\#}$	$3^{\#}\to1^{\#}$	$2^{\#}\to1^{\#}$
	14.4%	48.5%	55.2%	54.7%	67.6%	0%

(Continued) Table 6: Comparative Analysis of Operational Evaluation Index between the Domestic and the China-Japan Route

Slot cost (RMB)	A→B 322.3	A→C 1 124.9	B→C 440.5	$1^{\#} \rightarrow 2^{\#}$ 0	$1^{\#} \rightarrow 3^{\#}$ 2 455.0	$2^{\#} \rightarrow 3^{\#}$ 3 437.9
	C→B 1 231.6	C→A 960.5	B→A 176.4	$3^{\#} \rightarrow 2^{\#}$ 13.0	$3^{\#} \rightarrow 1^{\#}$ 5.7	$2^{\#} \rightarrow 1^{\#}$ 0

6.2. Comparative Analysis

Table 5 and table 6 show the index data for each O-D segment of the two routes mentioned above, such as slot cost and break-even volume etc., which provide standards and measurements for assessing and evaluating actual operation process of liner shipping routes, and are of great significance on guiding practical production and operation. That is to say, even if there are complete differences in the route structures, voyage distances, service time, freight rates, handling costs, and so forth, it is able to carry out comparative analysis of operation conditions for different routes effectively by applying the index data and models above. The specific comparison on financial and evaluation index between the two tables—table 5.5 and table 5.6, shows that the former is difficult to make a comparative evaluation and specific analysis of the operation process, while the latter can better compare and analyze the specific differences of that in various aspects. And route operators are able to monitor the operation status of each segment during service time, as well as instantly justify the volume allocation, and also to help measure performance of different route or segment managers. It also can be seen from table 5.6, there is no big difference in profit of the China-Japan route compared with the domestic route, but the former has a higher returns on investment, and smaller amount of break-even volume, and further relatively easier in cargo source development, only is inferior to the latter on profit growth rate and risk tolerance. This is mainly due to the low import cargo demand in the China-Japan route, which makes the operational risks concentrated on the export cargo flow segments. In conclusion, it is better to ensure a certain level of risk tolerance in planning and design of the China-Japan route, especially in the off-season, and be fully prepared to resist losses in route service.

7. Conclusion

This paper put forward and constructed the evaluation system and index models of container liner shipping system, considering feasibility requirements, profitability and risk tolerances of route operation, comprehensively applied integer programming modeling, technical and economic analysis method and multiple expectation average processing technology, designed evaluation index models including the return on investment, the break-even volume, the break-even freight rate, the slot cost, the profit growth rate and the risk tolerance etc., which provided new ideas for evaluating the operation process, improving the evaluation index system, and functioning as comparative analysis and guidance roles of indicators. Through case application, experimental data analyses showed what evaluation system and index models designed and constructed in this paper are more effective and practical compared with the conventional financial index in describing the operation process of container liner routes, comparing and evaluating the operational differences for different routes and guiding the actual production and operation.

8. Acknowledgements

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Using Analytic Hierarchy Process to Analyze the Development Strategies of Multi-temperature Logistics Center in Free Trade Zone

Dr. Feng-Ming Tsai[1], *Chih-Hung Wu*[1] *and Pin-Yen Hsieh*[1]

[1] Department of Shipping and Transportation, National Taiwan Ocean University, Keelung, Taiwan

Abstract

The purpose of this study is to set up a "regional multi-functional low-temperature logistics center" free trade zone (FTZ) of Keelung port, which can provide the niche of tax concessions and reduce the operation cost of the effect. And thus conducive to low-temperature logistics warehousing center engaged in the FTZ and cruise-related supply chain business. On the one hand contribute to the development of cruise industry in Taiwan, on the other hand, increase the import and export business in Keelung port. In this case, Keelung port becomes a comprehensive international business port, as well as increase the employment opportunities in Keelung port. Based on the above-mentioned stakeholders, this study draws out four dimensions and fourteen criteria, which are used as the framework of this study. Through expert analysis and expert questionnaire, analytic hierarchy process (AHP) is used to find out that "Relaxation of customs regulations and simplified procedures", "Provision of quarantine special venues and equipment", and "In accordance with the relevant laws and regulations to establish a logistics center control procedures." are the most important three criteria for setting up a multi-functional low-temperature logistics center in FTZ.

The results of this study can be used as a reference for the development and investment of logistics companies, cruise lines and port operators.

Keywords: International Cruise Home Port, Analytic Hierarchy Process (AHP), Development Strategy, Free Trade Zone (FTZ).

1. Introduction

This study envisages the establishment of a Regional Multi-functional Low-temperature logistics center in FTZ of Keelung Port, which can use the clustering effect to attract customers, enjoy the benefits of tax incentives and reduce operating costs. In addition, it is beneficial to the low-temperature logistics center to engage in FTZ and cruise-related transhipment replenishment business. On the one hand, it will contribute to the development of Taiwan cruise industry, on the other hand, it will also increase the import and export business of Keelung Port, and let Keelung Port turn to more comprehensive development. It can lead to an increase in the employment of Keelung Port. Analysis and research on the topic are expected to provide a reference for investors and relevant units to develop their development strategies in the future. Therefore, based on the aforementioned research motivation, the purpose of this study is as follows:

1. Understand the necessity and niche advantages of establishing a regional low-temperature logistics center in FTZ. This research area explores the necessity of establishing a regional low-temperature logistics center in FTZ of Keelung Port and its niche advantages.

2. Analyze the service coverage of establishing a low-temperature logistics center in FTZ. Through the data collation and analysis of this research, we understand the needs of the upstream and downstream, and related units for the low-temperature logistics center, in order to understand the planning and preparation before the establishment of a new business in FTZ, the restrictions of each stage of the regulations, and combined with the traditional container storage operation, the multi-temperature logistics center will be stably implemented in FTZ.

3. Discuss and propose relevant strategies and recommendations for reference by industry and relevant units. Since this research project is planned to establish a brand-new business in FTZ, there will be more presentations on the collection of relevant materials. Therefore, it is expected that the industry and the Taiwan International Ports Corporation will provide innovative services after the completion of this research. Have a deeper understanding, but also can provide relevant suggestions for the investors who want to invest as a reference for investment and operation. Collect and list the various aspects and directions through the literature of relevant cases, and use AHP analysis the implementation strategies for the construction of multi-temperature logistics center. AHP analysis provides sufficient information on investment and operator selection of appropriate investment options to reduce the risk of investing in multi-temperature logistics center. Relevant information disclosed by the above-mentioned upstream and downstream supply chain, cruise replenishing operators, container terminal operators, customs and quarantine units as data collection objects to assess the need to provide and integrate services for the establishment of a multi-temperature logistics center in FTZ. At the same time, government and investors can understand the direction and problems that should be paid attention to when establishing a regional multi-temperature logistics center in FTZ. Based on the collected literature, establish various directions and assessment dimension, and then create an expert questionnaire and use AHP to confirm the factor weight relationship between the levels, as the conclusion of the whole study.

Looking forward to this paper, we explore the development strategy of setting up a regional multi-functional low-temperature logistics center in FTZ of Keelung Port, provide conclusions to relevant operators and investors, and provide implementation for the future investment in planning a multi-functional low-temperature logistics center in FTZ of Keelung Port.

2. Literature Review

2.1. Concept and Definition of the Professional Logistics Centre

Yi-Long Jaw (1991) believes that logistics centers are divided into six categories based on their background and operational characteristics:1.M.D.C., Distribution Center builds by Manufacturer, which mainly cooperates with the manufacturer's production and sales demand, and gradually converts its storage into an independent distribution center; 2.Re.D.C., Distribution Center build by Retailer, such logistics centers are mostly chain stores, in order to obtain the niche on the supply and demand of goods; 3.W.D.C., Distribution Center build by Wholesaler, which was transformed by some dealers and import commission agents.; 4.T.D.C., Transportation, Distribution Center, the freight industry itself has the experience of managing fleets, loading goods and routing options, and the focus of operations is on the pursuit of high performance in freight distribution ; 5.R.D.C., Regional Distribution Center, responsible for distribution center operations in specific areas; 6.F.D.C., Frontier Distribution Center, as transshipment point for temporary storage of goods.

Ru-Jia Guo (2002) pointed out that the low-temperature logistics center is composed of hardware and software. The hardware includes low-temperature storage equipment, low-temperature handling, picking, and transportation equipment, software including information and management system; Wang, Earl-Juei (2004) pointed out that "Cryogenic Logistics" is the provision of warehousing and distribution of low-temperature

foods, and it is not possible to change the storage temperature conditions originally set by the product in any process.
Yu-Qin Zeng (2003) pointed out that "international logistics" is a global circulation of goods, including raw materials, manufactured goods from the place of production to the place of consumption or assembly, through the management process to effectively combine transportation (Sea, Land or Air or multiple cross application), warehousing, loading and unloading, customs clearance, distribution, handling, simple logistics processing, reforming, packaging, inventory control, order processing, internet e-commerce, banking, signing Institutions and other diversified functional community activities aim at creating high added value, making immediate delivery of global distribution or island-wide distribution, reducing inventory.
Yu-Hern Chang (2010) refers to International multi-market logistics: Most of the global markets are controlled by independent governments. In order to promote their economic development, governments have set more or less barriers to entry in their markets to control bilateral or multilateral trade practices. Such as (1) tariff barriers (2) import quotas (3) different taxation systems and tax rates (4) different transportation policies (5) different product laws (food, drugs, labels, etc.) (6) ingredient Regulations (7) Currency system, foreign exchange control, etc.

Ching-Chiao Yang et al. (2012) said that in the future, in the safety management of goods, international logistics center operators should start with safety policy, safety attitude, safety training and storage equipment management. The industry should first establish a clear safety goal and Safety is the main principle of the standard, to establish a comprehensive standard of safe operating practices and measures to strengthen the promotion of employees' approval of the company's safety policy and put into operation. Chuen-Yih Chen et al. (1999) pointed out that the establishment of Asia-Pacific distribution center pointed out that all aspects of international logistics management should consider: 1.order processing, 2.vendor management, 3.inventory management, 4.pre-distribution,5.bar-coding,6.labelling, 7.slip sheeting, 8.quality inspection, 9.customs, 10.exchange rate.

Kuo-Hsiung Tseng (2004) pointed out in Maritime Quarterly that the multi-level logistic center planning was established in FTZ. Therefore, in order to implement the spirit of free movement of goods and the administrative intervention of customs duties, it is recommended that the Customs should relax FTZ. The control of the inside, the Customs should control the attention, is the control when the goods enter and exit the "portal gates", to avoid the circulation of goods without customs clearance or notification. The recommendations in this section are as follows: 1. The logistics center shall set up a centralized inspection area to cancel the provisions of some mandatory import into the warehouse of the port area. The main purpose of the port area is to allow the customs to check the goods entering and leaving FTZ. Based on the overall planning of the storage space and circulation efficiency of the logistics center, a unified space for inspection will be set up. This space is provided to customs and quarantine; 2. The Customs shall reduce the control of the risk management of the circulation and storage of goods in the zone.

2.2. Types and functional characteristics of multi-temperature logistics centers

Taiwan Sugar Company (2001) pointed out that multi-temperature layer logistics can be frozen from normal room temperature to low temperature due to different temperature settings. Four temperament narratives:1. Normal temperature type: The product is stored at room temperature2. Air-conditioning type: The product must be stored in a temperature between 15 °C ~ 25 °C; 3. Refrigerated type: the product must be stored in the temperature between 2 ° C ~ 10 ° C;4. Freezing type: The product must be stored at a temperature of -18 ° C ~ 25 ° C, the frozen type logistics may even have ultra-low temperature logistics, the temperature is about -45 ° C ~ -55 ° C, most of which is stored in the tuna product, so the floor of the warehouse and the surrounding layer of the wall must be thicker. Chien-Ming Yeh et al. (2009) cold chain shipments can be broadly divided into two categories, Deep Frozen Cargo and Chilled Perishable Cargo. Deep Frozen Cargo refers to the temperature control that needs to be stored at low temperature during storage. The temperature control is controlled by the whole process, and the temperature is controlled at the preservation temperature, generally -25 °C, some high quality seafood It may even require a low temperature of -60 °C. Ru-Jia Guo (2003) pointed out that the low-temperature logistics center is composed of related hardware and software. The hardware of the low-temperature logistics center includes low-temperature storage equipment, low-temperature handling equipment, low-temperature cargo handling system, low-temperature transportation. Fu-Rong Zhang (2005) pointed out that low-temperature logistics, because of the high investment cost, must be more cautious in management to make its investment more efficient. Fu-Rong Zhang (2005) pointed out that due to the advancement of architectural design, the concept of space application has changed. Professional logistics companies have adopted a building-style, and the other is used as a container carrying car loading and unloading site on the lower floors. It operates through the handling system in the high-rise building, and the high-floor part is the warehouse. Jian-Rong Liao (2003) believes that most of the planning methods for multi-story buildings are set for small and medium-sized logistics operators, but they are rarely used in domestic. Chi-Hung Li (2008) believes that the Keelung FTZ must achieve a competitive advantage - the deep processing strategy of the port area, there is still a problem of the insufficient installation area and the inability of the Kaohsiung Port hinterland to expand inland.

2.3. Interrelationship between International Logistics Center and FTZ

Chuen-Yih Chen et al (2009) in the investigation and analysis of the "development of Kaohsiung Port as an international logistics center" that traditionally has some of the international logistics functions, but only provide transportation services that called single service function. In recent years, international logistics has flourished and has gradually formed an international logistics center, providing integrated logistics services including distribution, warehousing and distribution processing. With the development trend of international logistics, the port has been transformed from a port of entry and exit into an integrated logistics port. Shin-Ying Wu (2014) stated that FTZ is the best place to develop international logistics. As far as port operations are concerned, handling, and storage of goods in FTZ is no different from that of transshipment and containers for coastal shipping. It is only necessary to use the existing on-site human resource to cope with the special control operations of marine bureau and customs. Nuo Wang (2008) said that the amount of related resources consumed by a cruise ship for a day at sea is very considerable. With the development of large-scale cruise ships, the number of materials consumed will be larger. The distribution of cruise material has the characteristics of large quantity, high value and strict time requirements. Cruise homeport development cruise related resource distribution requires convenient transportation, modern professional terminal facilities and a functional material distribution center as well as information services and security, but also in government taxation, Port customs clearance and other aspects have certain policy advantages. In view of the current development status of homeport cruise ship related resources distribution, it is necessary to fully recognize the importance and urgency of developing cruise related resource distribution, accelerate the establishment of a specialized cruise related resource distribution center in cruise port, and provide specialized terminal facilities for concentration. Purchasing, centralized supervision, centralized distribution, and centralized settlement, and the breakthrough of cruise tax regulations and policies on cruise ships, and improve the efficiency of cruise material customs clearance.

3. Research Methods

3.1. Analytic Hierarchy Process (AHP

This study uses AHP analysis as a research tool to evaluate and select the development strategy indicators of multi-temperature logistics center. Based on analysis steps and procedures, the AHP hierarchy of this study was

established as a strong basis for the selection of the index parameters and weights of the selected multi-temperature logistics center.
AHP combines quantitative and qualitative methods to expression. Saaty (1990) and Davies (1994) believe that the main purpose of AHP is to stratify complex problems through systematic decomposition, pairwise comparison of two factors, and quantify the problem to reduce multiple criteria.

Teng, Junn-Yuan and Tzeng, Gwo-Hshiung (1989) stated that the use of hierarchical analysis has the following advantages:

1. AHP theory is simple, easy to operate, and can effectively draw opinions from most experts and strategists.

2. AHP can be included in the model for the relevant elements that affect the research objectives and consider the various levels of elements in conjunction with the research objectives.

3. Relevant influencing factors can be specified by specific experts and scholars after evaluation of mathematical methods.

4. Display the priority of each criteria.

5. Present complex assessment elements in a simple hierarchical structure that is easy for decision-makers to accept.

3.2. AHP steps and processes

1. Establish a hierarchical structure

The highest level in the construction is the evaluation. Targets, elements of similar importance should be placed at the same level as much as possible. Saaty (1980) suggested that the elements in each level should not be too many, and the criteria at each level should not exceed seven at most, which in turn affects the weight of each criterion and ultimately affects decision making.

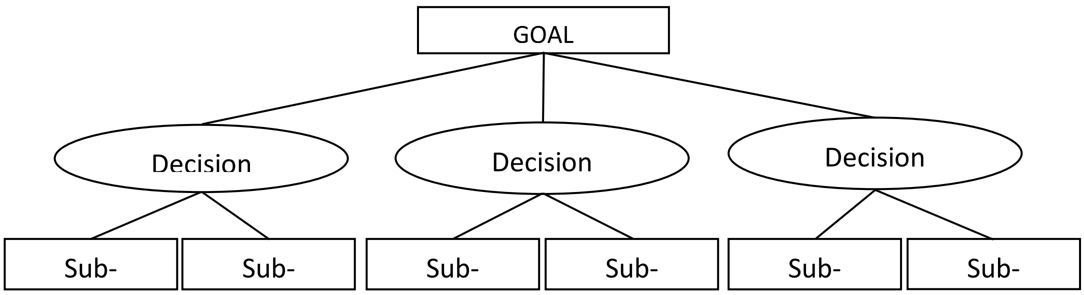

Figure 3-1: AHP Hierarchical Architecture Diagram
Source: This study

The hierarchical structure of this study is shown in Figure 3-1. The first layer is the target layer, the second layer is the decision criteria, and the third layer is the sub- criteria.

2. Establish a pairwise comparison matrix

The AHP is evaluated by means of a pairwise comparison matrix. The evaluation scale is used to distinguish between the evaluation scales. The evaluation scale is mainly based on Saaty (1980). The pairwise comparison is divided into five items. The measured values of the scales 1-9 are shown in Table 3-1.

Table 3-1: AHP Evaluation Scale

Evaluation scale	Definition	Description
1	Equal Importance	Two factors are equally important (Equally)
3	Moderate Importance	One of the factors is considered to be slightly more important than the other. (Moderately)
5	Essential or strong	Strong preference for a certain factor□□ (Strongly)
7	Very/strong Importance	Actually very inclined to prefer a certain factor□ (Very Strong)
9	Extreme Importance	Under two comparisons, a certain factor is extremely important (Extremely)
2,4,6,8	Compromise between adjacent scales	When the compromise value is needed

Source: Saaty (1980)

If there are no elements in each level, then n(n-1) /2 pairwise comparisons are needed. The values used in the pairwise comparison are from 1/9, 1/8..., 1/2, 1, 2, 3, ..., 8, 9. The result of comparing the n element measures is placed in the upper triangular part of the pairwise comparison matrix , and the value of the lower triangle is the reciprocal of the relative position of the upper triangle. The matrix is as follows:

Factor	B	C	D	E
B	1	a12	a13	a14
C	a21	1	a23	a24
D	a31	a32	1	a34
E	a41	a42	a43	1

1. Calculate eigenvalues and eigenvectors

Pairwise comparison is completed, the weights of the various levels of elements can be obtained. Next, use the Eigen-value solution commonly used in numerical analysis to find the feature vector or the priority vector to obtain the weights in each level element. Saaty (1980) proposed four approximation methods to obtain the solution of eigenvalues and eigenvectors:

(1) Row vector average normalization method

$$W_i = \frac{1}{n}\sum_{j=1}^{n}\left(\frac{a_{ij}}{\sum_{i=1}^{n} a_{ij}}\right)$$

(2) Standardization method for column average

$$W_i = \frac{\sum_{j=1}^{n} a_{ij}}{\sum_{i=1}^{n}\sum_{j=1}^{n} a_{ij}}$$

(3) Standardization of row vectors and reciprocals

$$W_i = \frac{\left(1 \Big/ \sum_{i=1}^{n} a_{ij}\right)}{\sum_{j=1}^{n}\left(1 \Big/ \sum_{i=1}^{n} a_{ij}\right)}$$

(4) Column vector geometric mean normalization method

$$W_i = \frac{\left(\prod_{j=1}^{n} a_{ij}\right)^{\frac{1}{n}}}{\sum_{i=1}^{n}\left(\prod_{j=1}^{n} a_{ij}\right)^{\frac{1}{n}}}$$

General research, usually uses Normalization of the Geometric Mean of the Rows to first find the geometric mean of each column of the evaluation matrix and then obtain it by standardization.

$i, j = 1,2,...,n$

2. Consistence (1) Computational Consistency Index

Saaty recommends using the Consistency Index (C.I.) and the Consistency Ratio (C.R.) to verify the $i, j = 1,2,...,n$ consistency of the pairwise comparison matrix. The formula for calculating the consistency index is as shown in Formula 3-1:

$$C.I. = \frac{\lambda_{\max} - n}{n-1} \qquad (3\text{-}1)$$

$i, j = 1,2,...,n$

n is the number of criteria; λ_{man} Maximum eigenvalue, Table 3-2 shows the difference in meaning of the consistency indicator:

$i, j = 1,2,...,n$

Table 3-2: Differences in Meaning of Consistency Indicators

C.I.	Representative meaning
C.I.=0	Judgment is completely consistent
C.I.＞0	Judging inconsistency
C.I.≦0.1	Although completely inconsistent, it is an acceptable bias

Source: Teng, Junn-Yuan and Tzeng, Gwo-Hshiung (1989)

(2) Computational Consistency Ratio；C.R.

The consistency indicator produced under different orders is called Random Index, R.I., and Table 3-3 lists the order n and its corresponding stochastic index R.I.

Table 3-3: The Random Index of the Evaluation Matrix

n	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
R.I	0	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49	1.51	1.48	1.56	1.57	1.59

Source: Teng, Junn-Yuan and Tzeng, Gwo-Hshiung (1989)

$$C.R. = \frac{C.I.}{R.I.} \qquad \text{(3-2)}$$

The consistency ratio is calculated by the formula 3-2. Saaty (1980) suggests that when CR≦0.1, when the decision maker establishes the pairwise comparison matrix, the weight judgment of each element is still within the acceptable range and consistent.

(3) Overall level architecture consistency check

The C.I. values of each level are obtained, the next step is to obtain the C.R.H. value by formula 3-3 Consistency ratio of the hierarchy, C.R.H., which defines the consistency of all levels divided by all stochastic indicators:

$$C.R.H = \frac{C.I.H.}{R.I.H.} \qquad \text{(3-3)}$$

Among them $C.I.H. = \sum_{j=1}^{n}\sum_{i=1}^{n} W_{ij} \times C.I._{i,j+1}$

$$R.I.H = \sum_{j=1}^{n}\sum_{i=1}^{n} W_{ij} \times R.I._{i,j+1}$$

W_{ij} : Weight values of the j th and i th elements

$C.I._{i,j+1}$: The consistency indicator of all the evaluation elements of j+1 level to the i-th element of j level.

$R.I._{i,j+1}$: The random index of all the evaluation elements of j+1 level to the i-th element of j level.

The overall consistency check, if C.R.H.<=0.1, indicates that all levels of the structure are rated as acceptable. Otherwise, you need to modify the hierarchy and re-edit it.

(4) Whole level weight calculation

The AHP structure is designed into an AHP questionnaire, and the questionnaire is distributed to experts and scholars. After the questionnaire is collected, the maximum eigenvalue and the characteristic vector are calculated, and the consistency of the questionnaire is further verified. A hierarchical architecture consistency check is performed, and finally, the overall weight is calculated to provide reference information for decision makers (Saaty, 1997). Multi-criteria evaluation refers to the evaluation process when decision makers face some feasible solutions and consider multiple criteria. The architecture is shown in Table 3-4:

Table 3-4: Basic Components of the Multi-Criteria Evaluation Problem

Weight	Criteria	Alternative			
		A_1	A_2	…..	A_m
W_1	C_1	e_{11}	e_{12}	…..	e_{1m}
.	.	.	.	…..	
.	.	.	.	…..	
W_n	C_n	e_{n1}	e_{n2}	…..	e_{nm}
Performance		S_1	S_2	…..	S_m

When calculating the weight values of the evaluation criteria of the hierarchical structure, the next step is ranked the advantages of the different evaluation criteria according to the performance of each evaluation criterion. For example, *Sj* represents the overall performance of the *j*th program, The formula is (1):

$S_j = \sum_{i=1}^{n} w_i e_{ij}$, n is the number of evaluation criteria (1)

4. Empirical Analysis

Establishing a development strategy for measuring the development of multi-temperature logistics center, First, through literature review and expert data, establish hierarchy structure in FTZ, and use the second application analytical hierarchy process to calculate the development dimension and criteria weight of the multi-temperature logistics center. The third comparison adds the fuzzy theory. The dimension and guidelines are described below and summarized in Tables 4-1 and 4-2.

Table 4-1: Explanation of the Interpretation of the Research Aspect

Dimension	Description
A. Assess investment and operating costs.	Evaluate the software and hardware equipment and the best operational location required to build a logistics center. And consider the overall human resources needed for long-term operations.
B. Simplify and facilitate the administration of customs.	It is able to provide site equipment and information connection management system, and apply for self-management of logistics center to achieve the purpose of simplifying and facilitating customs and administration.
C. Provide logistics integration management and processing delivery services	Establish the site required for processing and demolition cabinets and add value transfer and integrated logistics functions to enhance the business development of the free-chain port area and the ability to integrate resources in the market.
D. Provide quarantine support subsidiary functions.	Provide animal and plant quarantine bureau, food and drug administration, customs and relevant government units carry out inspection and seizure of cold chain goods. And can cooperate with relevant government units to use as a decommissioning warehouse for storage and storage.

Table 4-2: Interpretation of the Evaluation Criteria

Dimension	criteria	Description
A. Assess investment and operating costs.	A1 Logistics center land acquisition cost	As the land in the port area belongs to the port company, it is required to rent land from the port company in accordance with the Commercial Law.
	A2 Assess the cost of building a logistics center	The number of logistics center service projects is relatively proportional to the structural materials and equipment.
	A3 Employment methods and salary	Can be hired by a dedicated staff resident management and or matching appointments to carry out on-site implementation work.
	A4 Evaluate the best location and base area of the logistics center	Consider the traffic lines and storage operations, and choose the best logistics center setting location.
B. Simplify and facilitate the administration of customs.	B1 Release customs regulations and simplify operating procedures	Refers to the revision of the customs and quarantine laws, streamlining the process and shortening the operation time.
	B2 Single window for customs clearance	Informatization of the Archives connect to the customs management system, the purpose of simplifying and facilitating customs and administration.
	B3 Establish special venues and equipment for import and export related business	Apply for the independent management of the logistics center to achieve the purpose of simplifying and facilitating the customs and administration.
C. Provide logistics integration management and processing delivery services	C1 Carrying out the transshipment	Refers to the clearance procedures for goods that are transshipment and the parallel procedures for ship supplies, which saves the cost of the operators and enhances the willingness of the cruise line.
	C2 Provide a venue for simple processing services	Provide processing facilities, develop complete warehousing and process operations and other supporting measures (site, process operations, etc.)
	C3 Establish cargo information management system	The establishment of the image recognition system combined with the TradeVan network container dynamic database system accelerates the aging of the transfer operation and saves the cost of manual escort operation of the transfer cabinet.
	C4 Establish a 24-hour composite delivery mechanism	In addition to its own dedicated fleet, it also cooperates with logistics carriers to develop 24-hour delivery services.
D. Provide quarantine support subsidiary functions.	D1 Provide quarantine-specific venues and equipment	Obtain relevant international licenses that meet the requirements of the quarantine office for reprocessing and cruise replenishment
	D2 Provide human, technical support	Cultivate industry management and management professionals
	D3 Establish logistics center control in accordance with relevant regulations	Entrusted or appointed by the competent authority of the destination, the management office of FTZ can handle the issuance of the import and export visa, the certificate of origin and the certificate of re-export.

4.1. Analysis of the Questionnaire

AHP sent 10 questionnaires to the experts or scholars through actual visits, and 9 of them were recovered. The effective recovery rate is 90%. The sample analysis of the recovered samples is shown in Table 4-3, and the following are explained:

1. Analytical results of the second layer dimension:

The pairwise comparison matrix of the evaluation target is shown in Table 4-3, and the consistency ratio CR= 0.051< 0.1. The decision result is consistent, the weights and ordering are shown in Table 4-4.

Table 4-3: Pairwise Comparison Matrix of the Second Layer Dimension

	Assess investment and operating costs	Simplify and facilitate the handling of customs	Provide logistics integration management and processing delivery services	Provide quarantine support subsidiary functions.
Assess investment and operating costs	1.0000	0.6190	0.4055	0.3943
Simplify and facilitate the handling of customs	1.6156	1.0000	1.6901	1.6901
Provide logistics integration management and processing delivery services	2.4662	0.5917	1.0000	0.6551
Provide quarantine support subsidiary functions.	2.5360	0.5917	1.5265	1.0000
	C.I.=0.04，R.I.=0.9，C.R.=0.051			

Table 4-4: Weight Table of the Second Layer Dimension

Item	Assess investment and operating costs	Simplify and facilitate the handling of customs	Provide logistics integration management and processing delivery services	Provide quarantine support subsidiary functions.
Weight	0.136	0.346	0.231	0.285
Ranking	4	1	3	2

The main purpose of setting up a multi-temperature logistics center is to promote the transformation of FTZ and promote the growth of passenger and cargo volume. Among the four dimensions, the respondents attach more importance to the “simplification and facilitation of customs administration”. The consideration is that there are too many restrictions in the administrative regulations of the current FTZ, which makes the private sector unwilling to invest. It is foreseeable that if private capital investment is introduced and social resources are effectively utilized to achieve the goals and benefits of establishing a multi-temperature logistics center, these goals and benefits will affect the future policy development of FTZ. The " assess investment and operating costs " aspect has the lowest weights. It can be seen that the private sector and government agencies believe that the sources of funds for building and investing in multi-temperature layers are not the main considerations. As long as the customs administrative procedures are open, the industry is willing to invest in a multi-temperature logistics center.

2. Analytical results of the third-level evaluation indicators:

The third level of evaluation indicators is the secondary criterion for the continuation of the second level of sub-criteria. The results of the various criteria are as follows:

(1) "Assess investment and operating costs" measurement analysis:

The comparison matrix of the evaluation criteria of the four measurement items is shown in Table 4-5. The consistency ratio CR= 0.005< 0.1, the decision results are consistent. The weights and rankings of the guidelines are shown in Table 4-6.

Table 4-5: Pairwise Comparison Matrix for the Criterion of Assess Investment and Operating Cost Aspects

	Land acquisition cost	Factory cost	Employees hire salary	Optimum location and base area
Land acquisition cost	1.0000	1.1298	3.5988	0.7834
Factory cost	0.8851	1.0000	3.0711	0.7834
Employees hire salary	0.2779	0.3256	1.0000	0.3256
Optimum location and base area	1.2765	1.2765	3.0711	1.0000
C.I.=0.0049，R.I.=0.90，C.R.=0.005				

Table 4-6: Evaluating Investment and Operating Cost Guidelines Weight Table and Ranking

Item	Land acquisition cost	Factory cost	Employees hire salary	Optimum location and base area
Weight	0.299	0.270	0.093	0.336
Ranking	2	3	4	1

This means choosing a best location to set up a multi-temperature logistics center, and the location of the multi-temperature logistics center is a project that everyone cares about.

(2) " Simplify and facilitate the handling of customs " measurement analysis:

The comparison matrix of the evaluation criteria of the three measurement items is shown in Table 4-7. The consistency ratio CR= 0.02< 0.1, the decision result is consistent. The weights and rankings of the guidelines are shown in Table 4-8.

Table 4-7: Pairwise Comparison Matrix for the Criterion of Simplifies and Facilitate the Handling of Customs

	Release customs regulations and simplify operating procedures	Single window for customs clearance	Establish special venues and equipment for import and export related business
Release customs regulations and simplify operating procedures	1.0000	3.0449	2.2731
Single window for customs clearance	0.3284	1.0000	0.6345
Establish special venues and equipment for import and export related business	0.4399	1.5761	1.0000
C.I.=0.00146，R.I.=0.58，C.R.=0.002533			

Table 4-8: Simplified and Convenient Administrative Evaluation Guidelines Weight Table and Ranking

Item	Release customs regulations and simplify operating procedures	Single window for customs clearance	Establish special venues and equipment for import and export related business
Weight	0.562	0.173	0.261
Ranking	1	3	2

The simplification and convenience of handling the customs aspects have the highest weight, surpassing the rest of the total. It is obvious that the relaxation of customs regulations, has a decisive influence on the establishment of multi-level logistic centers.

(3) " Provide logistics integration management and processing delivery service." measurement analysis:

The comparison matrix of the evaluation criteria of the four measurement items is shown in Table 4-9. The consistency ratio CR= 0.03< 0.1, the decision result is consistent. The weights and the ranking of the guidelines are shown in Table 4-10.

Table 4-9: Pairwise Comparison Matrix for the Criterion of Logistics Integration Management and Processing Delivery Services

	Carrying out the transshipment	Provide a venue for simple processing services	Establish cargo information management system	Establish a 24-hour composite delivery mechanism
Carrying out the transshipment of import and export	1.0000	0.8851	0.9368	1.7247

(Continued) Table 4-9: Pairwise Comparison Matrix for the Criterion of Logistics Integration Management and Processing Delivery Services

Provide a venue for simple processing services	1.1298	1.0000	1.6156	1.1298
Establish cargo information management system	1.0675	0.6190	1.0000	1.7395
Establish a 24-hour composite delivery mechanism	0.5798	0.8851	0.5749	1.0000
C.I.=0.027，R.I.=0.90，C.R.=0.0306				

Table 4-10: Logistics Integration Management and Processing Delivery Service Guidelines Weight Table and Ranking

Item	Carrying out the transshipment of import and export	Provide a venue for simple processing services	Establish cargo information management system	Establish a 24-hour composite delivery mechanism
Weight	0.265	0.296	0.254	0.183
Ranking	2	1	3	4

It can be seen that providing the site for simple processing services is the most important criterion in evaluating the “Provide a venue for simple processing services”.

(3) " Provide quarantine support subsidiary functions." measurement analysis:

The comparison matrix of the evaluation criteria of the three measurement items is shown in Table 4-11. The consistency ratio CR= 0.006< 0.1, the decision result is consistent. The weights and ranking of the guidelines are shown in Table 4-12.

Table 4-11: Pairwise Comparison Matrix for the Criterion of Provide Quarantine Support Subsidiary Functions

	Provide simple dedicated venues and equipment	Provide human, technical support	Establish logistics center control in accordance with relevant regulations
Provide simple dedicated venues and equipment	1.0000	3.6924	1.4422
Provide human, technical support	0.2708	1.0000	0.5478
Establish logistics center control in accordance with relevant regulations	0.6934	1.8254	1.0000
C.I.=0.01，R.I.=0.58，C.R.=0.006			

Table 4-12: Provide Quarantine Support Subsidiary Functions Guidelines Weight Table and Ranking

Item	Provide simple dedicated venues and equipment	Provide human, technical support	Establish logistics center control in accordance with relevant regulations
Weight	0.519	0.158	0.322
Ranking	1	3	2

3. Select the assessment aspect and the standard weight result analysis:

The second layer evaluates the weight of the aspect multiplied by the relative weight of the third level of evaluation criteria to show the weight of the third level of evaluation criteria in the whole assessment mode. Table 4-13 shows the multi-temperature logistics center, the overall weight of the largest of the evaluation model and the ranking relative weight value.

Table 4-13: Overall Weight and Ranking Table of All Evaluation Criteria

Layer	AHP Evaluation criteria		
	criteria	Whole weight (G)	Ranking
3	A1 Logistics center land acquisition cost	0.300	12
3	A2 Assess the cost of building a logistics center	0.271	13
3	A3 Employee employment methods and salary	0.093	14
3	A4 Evaluate the best location and base area of the logistics center	0.336	9
3	B1 Release customs regulations and simplify operating procedures	0.563	1
3	B2 Single window for customs clearance	0.175	7
3	B3 Establish special venues and equipment for import and export related business	0.262	4
3	C1 Carrying out the transshipment	0.265	6
3	C2 Provide a venue for simple processing services	0.297	5
3	C3 Establish cargo information management system	0.255	8
3	C4 Establish a 24-hour composite delivery mechanism	0.183	11
3	D1 Provide simple dedicated venues and equipment	0.519	2
3	D2 Provide human, technical support	0.158	10
3	D3 Establish logistics center control in accordance with relevant regulations	0.323	3
Consistency ratio= 0.01			

“Release customs regulations and simplify operating procedures” is the first of its total weight. This item is similar to the current status of FTZ development logistics center. It shows its importance. "Provide simple dedicated venues and equipment" is the second largest. This is also the most lacking hardware facilities in FTZ; "Establish logistics center control in accordance with relevant regulations" is the third in total weight, and the control measures are established to maintain the sustainable development of the logistics center in long-term operation

(5) The weight analysis results of the investment alternatives under the guidelines:

This study is based on the assessment of the third level of the 14 th criterion. It is used to calculate the most suitable investment options for “completely self-employed land leased”, “joint venture with port companies” and “joint venture with Ocean Carrier”. The pairwise comparison matrix of its evaluation criterion is shown in Table 4-14, and its weight comparison chart is organized as shown in Figure 4-1:

Table 4-14: Pairwise Comparison Matrix of Evaluation Criterion for Selection Scheme

Dimension	Criteria	Alternative		
		completely self-employed land leased E1	Joint venture with port companies E2	Joint venture with Ocean Carrier E3
A	A1	0.008	0.025	0.007
	A2	0.008	0.015	0.014
	A3	0.003	0.005	0.004
	A4	0.009	0.028	0.008
B	B1	0.047	0.114	0.034
	B2	0.014	0.035	0.012
	B3	0.018	0.056	0.017
C	C1	0.014	0.028	0.020
	C2	0.023	0.032	0.014
	C3	0.015	0.030	0.014
	C4	0.014	0.011	0.018
D	D1	0.049	0.057	0.043
	D2	0.020	0.010	0.016
	D3	0.021	0.048	0.023

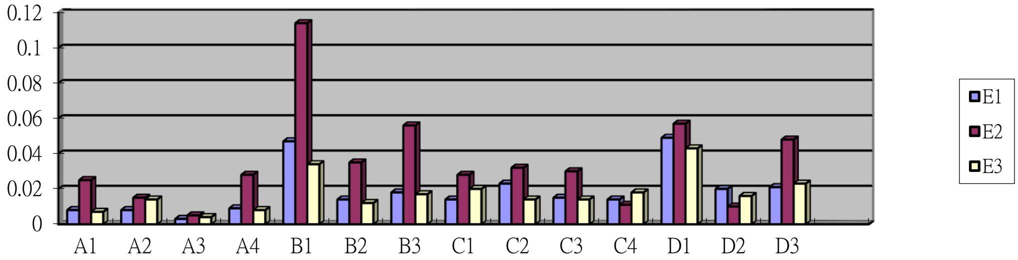

Figure 4-1: Relative Weight Chart of Alternatives under Each Evaluation Criterion

It can be clearly seen from Figure 4-1 that under the various assessment criterion, the "joint venture with port companies" is the best alternative under the maximum of the 14 assessment criterion of the study. It can be seen that the multi-temperature logistics is designed in FTZ. The center is based on factors such as customs regulations, cost considerations, geographic location, etc. The best solution should be designed for joint ventures with port companies.

5. Research Conclusions and Recommendations

The purpose of this study is to understand the best operating model for the establishment of a multi-temporal logistics center in FTZ. Based on the research process and analysis results, the conclusions and recommendations of this study are summarized as follows:

5.1. Conclusion

1. There are already more than 600 FTZ in the world. This figure is enough to represent the active promotion of the operation of FTZ in the world. The world economy is already heading towards the globalization of trade and the globalization of supply chains. Therefore, the operators of FTZ should actively expand their business and actively create their own advantages and meet customer needs. At the same time, we seek cooperation from different industries to gain a foothold in the world.

2. The establishment of a multi-temperature logistics center in FTZ is a development in the evolution of the times. Considering the global competition and the rapid development of low-temperature logistics, if we want to implement a multi-temperate logistics center in FTZ, we must pay attention to customers. At the same time, it also needs the government's relaxation and support in the regulations and releases the incentive conditions and incentives to attract domestic and foreign high-quality manufacturers to invest in FTZ and promote the long-term development of related industries.

3. From the perspective of investment, cooperation between enterprise and the port company is the best alternative. The reason is that the private sector has a professional logistics center investment management experience, but it is not available in suitable land for investment. The port company has substantial land resources, but no experience of the business operators. In summary, if a port company can establish a multi-temperature logistics center in cooperation with a professional private company, it will be the best way to cooperation.

5.2. Recommendations

1. This study is based on the operational model alternatives set up in multi-temperature logistics center in FTZ. Only through literature review and expert interviews, the " completely self-employed land leased ", " Joint venture with port companies " and " Joint venture with Ocean Carrier" are selected. Alternatives, it is recommended that follow-up researchers can join the open exploration and discussion to propose more operational alternatives.

2. It is recommended that investment operators should give priority to considerations such as “promotional conditions for investment in the region”, “transportation of goods”, “transportability of regional distribution” and “integrated logistics infrastructure” when operating and managing in FTZ.

3. In terms of expanding the business, the operators of FTZ suggest that relevant government can provide different incentives for operators to meet their demand. For example, they provide preferential rental conditions for "more emphasis on land cost".

4. This research questionnaire is based on time and labor constraints, and the number of maternal subjects is small. It is recommended that follow-up researchers can increase the number of maternal experts and group the interviewed experts according to their areas of expertise. The decision-making perspective should be different, and the decision-making can also be used as a reference basis to make the overall assessment more comprehensive.

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Maritime Shipping Digitalization: Blockchain-Based Technology Applications, Future Improvements, and Intention to Use

Chung-Shan Yang

Associate Professor, Department of Aviation and Maritime Transportation Management, Chang Jung Christian University, Tainan City, Taiwan, ROC
Email: r58951022@yahoo.com.tw

Abstract

Although a number of studies focus on using the blockchain technology (BT) in various application aspects, there is no comprehensive survey on the blockchain applications in maritime shipping perspective. To fill this gap, we conduct a comprehensive blockchain applications and future improvements survey, and emperically evaluate its effects on intention to use in the context of maritime shipping. Survey data were collected from 121 respondents working for maritime port corporation, shipping company, agency, and shipping forwarder, and then hierarchical regression analysis was conducted to test research hypotheses. Factor analysis was employed to identify key blockchain applications (i.e., customs clearance and management, digitalizing and ease paperwork, tracking and tracing), future improvements (i.e., standardization and platform, business model and regulation), and intention to use. The results suggested that customs clearance and management, digitalizing and ease paperwork, standardization and platform dimensions positively affected intention to use. In particular, this paper gives the maritime shipping blockchain-based digitalization also points out the future improvement directions in the blockchain technology.

Keywords: Maritime shipping, Blockchain technology applications, future improvements, intention to use

1. Introduction

With increasing globalization, the interdependence of various world economies, global logistics plays an increasingly important role in the prevailing dynamic and volatile environment (Chang and Lai, 2017; Hsiao et al., 2010; Murphy and Daley, 2001). Maritime shipping plays an important role in providing low-cost and efficient transportation service and act as a dominant mode of transport since over 90% of the global trade volume is carried by sea, "but maritime shipping supply chain is slowed by the complexity and sheer volume of point-to-point communication across a loosely coupled web of land transportation providers, freight forwarders, customs brokers, governments, ports and ocean carriers" (Lieber, 2017). Meanwhile, "hundreds pages of shipping paper and documents need to be filled and to be physically delivered to dozens of different agencies, banks, customs bureaus and other entities" (Bloomberg, 2018). Therefore, shipping-related companies are looking forward to make trade-related office procedures swifter and more efficient. "Those involved in international trade—whether they are manufacturers, trading houses, transportation companies or banks - are seeking ways to ease the situation and cut time and costs" (Lehmacher and McWaters, 2017). At present, "many blockchain technology initiatives and partnerships have the potential to be used for tracking cargo and providing end-to-end supply chain visibility; recording information on vessels, including on global risks and exposures; and digitalizing and automating paper filings and documents, thus saving time and cost for clearance and movement of cargo" (UNCTAD, 2018).

Blockchain, the technology underlying Bitcoin, is a type of distributed, shared, encrypted database (Apte and Petrovsky, 2016) that serves as an irreversible and incorruptible repository of information (Wright et al., 2017), provides the foundation for collaborative commerce (Luu et al., 2016; Kim and Shim, 2018), takes place within a network and then enables permissioned parties access to trusted data in real time (Lieber, 2017). The main appeal of blockchain technology lies in its ability to create decentralized and immutable ledgers - networks in which decentralized nodes keep copies of the whole blockchain (Önder and Treiblmaier, 2018; Luu et al., 2016) which is maintained by multiple parties and its information is not hacked or destroyed. This increases the security and transparency of all information that is stored on a blockchain across the life cycle of a transaction. A variety of applications using the blockchain technology are being proposed spanning a multitude of domains including finance, healthcare, supply chain, online games, social media and others (Kim and Shim, 2018; Muzammal et al., 2019; Czachorowski et al., 2019). Blockchain was recognized as a technology that is going to be implemented in various supply chains to consider the benefits in visibility, optimization and forecasting (Lieber, 2017).

Blockchain is useful for logistics and supply chain management (Hackius and Petersen, 2017) by enabling synchronized audit trails between partners and optimizing them in a real time. It will increase trust across the supply chain, consequently simplifying the decision making process on every stage (Lieber, 2017). Maersk uses the blockchain solution to track its shipping containers around the world with attributes like GPS location, temperature, and other conditions in international logistics (Jackson, 2017). Blockchain technology marks a milestone to drive the digitization, cuts shipping costs, and shapes the future of global trade. "UPS announced they were going to join the Blockchain in Transport Alliance (BiTA), a forum for the development of blockchain technology standards and education for the freight industry" (Techcrunch, 2018). Blockchain is also being tested by retailers like Wal-Mart Stores Inc. and Samsung for monitoring trade and ensuring food safety, as industries explore what advantages the technology might hold over traditional databases (Lehmacher and McWaters, 2017). Since the birth of blockchain technology, it has shown promising application prospects (Li et al., 2017), which will revolutionize the way we interact in the digital world (Kakavand et al., 2017). It can record the transfer of assets between two parties, without the need of a trusted intermediary (Tapscott and Tapscott 2016), and can be used for any form of asset, including every area of finance, economics, and money (Swan, 2015). Therefore, it is important to find the current applications developed by using blockchain technology.

Identifying other industry applications can help to understand other directions and methods of using blockchains (Yli-Huumo et al., 2016). Using disruptive technology earlier than competitors can provide companies with an advantage and increase their competitiveness (Tellis, 2006). For forward-looking companies that view blockchains as a way to reduce costs, increase efficiency and customer satisfaction, and ultimately attract new business and increase revenue, the possibilities for these industries are attractive (Crawford, 2017). In addition, the use of blockchain applications will benefit shipping companies, port operators, logistics companies, customs authorities, shippers, freight forwarders, transportation companies and other maritime supply chain related operators. With the growth of blockchain applications, the enablers and determining factors that may entice maritime shipping-related bureaus and corporations to accept and use blockchain urgently need to be understood. The determinants of intention to use blockchain in the context of maritime shipping have not yet been empirically verified since blockchain can enable maritime shipping operations to remain efficient and competitive. The research questions for this paper emerge: What might be blockchain technology significant applications and future improvements for intention to use in maritime shipping? Hence, this study draws on the related literature to establish the groundwork for developing a model to examine the influences of blockchain applications (i.e., digitalizing and ease paperwork, tracking and tracing, and customs clearance) and blockchain future improvements on intention to use blockchain in the maritime shipping context.

The remainder of this paper is organized as follows: The second section presents a review of previous research on blockchain applications of digitalizing and ease paperwork, tracking and tracing, and customs clearance, and blockchain future improvements, and postulates five research hypotheses. The third section describes the research methodology, including the research sample and survey measures. The fourth section presents the empirical analysis results, including the results of exploratory and confirmatory factor analysis (CFA), and hierarchical regression analysis. Finally, the fifth section draws conclusions from the research findings and discusses their implications for maritime shipping researchers and operators, and considers the study limitations for further research.

2. Literature review

2.1 Blockchain application - Digitalizing and ease paperwork

In the past, due to the cross-border trade and transportation of the maritime industry, the delivery process involved various languages, government agencies, and customs organizations made the standardization process slow. Global maritime shipping have a lot of paperwork, e.g. bill of lading, purchase order, commercial invoice, packing list, booking confirmation, dangerous goods declaration, certificates of origin, inspection certificate, insurance certificate etc., associated with them and continue to drown in paper. However, these materials are currently stored in paper and digital form, which is very troublesome to manage. The redundancy of document processing is one of the reasons why shipping is lagging behind other industries in turning to digital forms. Meanwhile, documents like the bill of lading might be subjected to fraud (Popper and Lohr, 2017). Global container shipping still involves a lot of paperwork – costing time and money which estimated to be between 15 and 50 percent of the costs of the physical transport (Groenfeldt, 2017). Maersk, the world's largest container-shipping line, has been using blockchain to digitize the ships' cargo inventories. "Using blockchain for storage of digital records solves the problem of data leakage". Since the records are immutable, the records once created cannot be altered even by the owner or the issuing authority itself for any kind of personal gains (Jain et al., 2018).

In most cases, the containers can be loaded on a ship in a few minutes. However, it can be held up in port for many days due to a missing paperwork (Groenfeldt, 2017). "The problems associated with extensive paperwork are not limited to this specific use case but hamper all kinds of trade flows" (Chu et al. 2016; Morabito 2017). Meanwhile, "paper-based freight documents like the bill of lading are prone to loss, tampering, and fraud" (Hackius and Petersen, 2017). Blockchain digitalization system can ease paperwork processing (Hackius and Petersen, 2017), reduction of human error in the process (Dobrovnik et al., 2018), and reduce delays and fraud saving billions of dollars annually and increase worldwide GDP by almost 5% (Lieber, 2017). The new blockchain-based system uses distributed ledger technology to ensure that all parties can issue, transfer, endorse and manage shipping and trade related documents through a secure decentralized network that records can't be duplicated, manipulated or faked, and increased visibility in parts of the supply chain. It means business partners can be certain trading documents are real and paperless (Lehmacher and McWaters, 2017; Kim and Shim, 2018). Thus, this research postulates that:

H1: Blockchain application – digitalizing and ease paperwork will be positively associated with intention to use.

2.2 Blockchain application - Tracking and tracing

Current practices enable the ability to track the shipment of a package through the company's internal tracking system on their home page. "However, at present, the information is often limited to timestamps of when the package enters the logistics service provider's handling system" (Foerstl et al., 2017). It enables the vast global network of shippers, carriers, ports, and customs, every partner monitoring, tracking and tracing transports, and open access to information regarding the time of delivery (Dobrovnik et al., 2018; Allison, 2017; Dickson, 2016) which "prevents organizational silos within existing parts of the supply chain and make the supply chain more efficient and productive" (Tapscott and Tapscott, 2016; Baker and Steiner, 2015).

"Maritime Blockchain Labs (MBL) has announced the start of a scaling phase of its first demonstration project aimed at enhancing traceability and trust in the bunker fuel supply chain from the supply source to the receiving vessel" (Lee, 2018). Walmart partnered with IBM tracking the movements (i.e., farm origin, batch numbers, factory and processing data, expiration dates and shipping details) of food items instantly for all network members (Hackius and Petersen, 2017). "The technology has a broad range of applicability, allowing connecting the supply chain more efficiently, providing the exchange and visibility of time-stamped proofed data" (Czachorowski et al., 2019). Shippers can increase the traceability and transparency (Mougayar and Buterin, 2016), and the estimated delivery times before making a decision on the marketplace. At the same time, carriers can dynamically adjusting the fairest pricing based on supply and demand, and customers gain the ability to evaluate where the product originated and supplier (Mougayar and Buterin, 2016; Hancock and Vaizey, 2016; Hackius and Petersen, 2017; Francisco and Swanson, 2018), by tracking the blockchains along the path, as current systems recording the data may be subject to manipulation. Thus, this research postulates that:

H2: Blockchain application - tracking and tracing will be positively associated with intention to use.

2.3 Blockchain application - Customs clearance and management

"Global supply chains contain valuable goods and verifying documentation in the form of letters of credit or bills of lading that are moving across time and space, are involving multiple actors and, thus, face the risk of forgery, theft, alteration" (Hackius and Petersen, 2017; Lehmacher, 2017), and counterfeit products (Hackius and Petersen, 2017; Hancock and Vaizey, 2016; Apte and Petrovsky, 2016) such as medicines, fine wines and luxury fashions in the global logistics industry. Blockchain technology has thus far been able to provide various mechanisms to assess and ensure quality (Rothschield, 2016; Mathieson, 2017), "prevent unauthorized access with its secured cryptographic algorithms and its immutability makes the data tamper-proof" (Jain et al., 2018), "allow full visibility for all parties involved with proof of work, facilitating inspections, and audits compliance" (Czachorowski et al., 2019; Robinson, 2016), ultimately help to reduce the time and cost for customs clearance and cargo movement (IBM, 2018).

Information about ownership, provenance, authenticity and price are all held in the blockchain (Lehmacher and McWaters, 2017). "Furthermore, this will open doors for replacing current product labeling practices to protect consumers and accelerate customs-clearance processes. Customs authorities will have all the information they need to decide whether to let goods through the border or to block them" (Lehmacher and McWaters, 2017), and thus reduces risk in regard to fraud or counterfeit goods (Hancock and Vaizey, 2016). For example, TradeLens underpinned by blockchain technology and supported by IBM, Maersk, and other major industry players, promotes a more efficient, predictable and secure transfer trade documents and cargo details across organizations to automate customs filings and clearance. Thus, an importer can trust the information in the declaration. Forward-thinking customs agencies are already launching blockchain-related projects, and it's only a matter of time before blockchain-enabled trade and customs ecosystems become commonplace among government agencies, shippers, and traders (Canham, 2017). Thus, we postulates that:

H3: Blockchain application - customs clearance will be positively associated with intention to use.

2.4 Blockchain future improvements - Standardization and platform

The lack of technical standards for blockchain technology as an obstacle to widespread adoption (Heutger and Kueckelhaus, 2018). Therefore, there are technical hurdles to overcome, such as must be trusted by all of its users. In particular, in the logistics industry, which is characterised by a supply chain environment with multiple stakeholders, being able to accurately and safely exchange information is a key advantage (Francisco and Swanson, 2018; Korpela et al., 2017). Understanding the future improvements of the blockchain solution priority areas regarding the development of standards will be an important milestone to maximize the benefits of this technology for global stakeholders. A range of standardization-related initiatives have commenced across the globe, examining different aspects of blockchain (Deshpande et al., 2017). For example, the International Organization for Standardization (ISO) decided to set up a new technical committee (ISO/TC 307) with the assignment to draft standards for all sectors with respect to the application of blockchain and distributed ledger technologies (ISO, 2017).

A blockchain protocol is a set of techniques released under a widely documented open-source license (Peyrat and Legendre, 2017). There are different infrastructures, protocols, technologies, regulations, use cases, jurisdictions, opinions and long term direction views associated with blockchain. As a result, there is the potential negligent or malicious misuse of the technology and its applications (Kakavand et al., 2017). Standardization and common platform is possible future improvement for blockchain implementation, because of differing levels of digital readiness (Shermin, 2017), sector-specific technical and operational practices and standards, and cultural resistance (Crosby and Nachiappan, 2015; Shackelford and Myers, 2017). "It is not very easy to insert a new technology inside established supply chain systems because the integration challenges are not to be underestimated" (Mougayar and Buterin, 2016). In addition, "government has to support RandD for integration with other high technology, standardization of distribution industry's blockchain technology and manpower training to expand technology development" (Kim and Shim, 2018). Thus, this research postulates that:

H4: Blockchain improvement – standardization and common platform will be positively associated with intention to use.

2.5 Blockchain future improvements - Business model and regulation

Digital information exchange for the purpose of ease paperwork, cargo tracking/tracing, and customs clearance and management of maritime shipping participants that can benefit from this progress are key issues in designing blockchain-based business models. There appears to be a lack of understanding among businesses, consumers and authorities about how the technology operates and the likely short- and medium-term market development potential (Brandman and Thampapillai, 2016; Chu et al., 2016). The pain point of the blockchain will no longer be technology, but whether it can find a truly suitable business model and application scenes. Until further evidences of business gains and economic impact tested, uncertainty regarding which use cases are viable and realistic may remain. In the absence of wider adoption among businesses, it is not easy to make a sufficiently clear assessment in the medium to long term (Deshpande et al., 2017). In addition, "the running costs associated with the adoption of blockchain are as yet unclear" (Kakavand et al., 2017), the cost of maintaining blockchain business model may need to be lowered (Lehmacher and McWaters, 2017), absence of client demand, and uncertain point of return on investment (Belle, 2017). To be honest, the real reason why blockchain applications can't be grounded is that there aren't many viable business models at the moment and they have to operate with blockchains.

Perhaps the greatest concern to shipping services leaders is regulatory uncertainty. Given the distributed nature of ledgers and their function as an immutable record, setting out clear rules for the governance of the ledger will be a key challenge (Kakavand et al., 2017; Deshpande et al., 2017). Examples are liability for losses experienced by businesses in the event of an operational failure or compromised keys, or legal responsibility in the event of data loss or theft (Mainelli and Mills, 2016; World Economic Forum, 2016; Lehmacher and McWaters, 2017). The issue of regulatory governance may be the largest hurdle the industry must face if it embraces this technology. Regulating blockchain will likely require new laws, practices and protocols, which may take years to define and implement (Lehmacher and McWaters, 2017). Thus, we postulates that:

H5: Blockchain improvement – business model and regulation will be positively associated with intention to use.

3. Methodology

3.1 Sample

This study examined the effects of blockchain applications and future improvements on intention to use in the context of maritime shipping. The study target sample comprised maritime port corporations, shipping companies, shipping agencies, and shipping forwarders engaged in maritime shipping operations in Taiwan. A questionnaire was issued to 508 respondents in October 2018. Initial issuance elicited 83 usable responses. Follow-up issuance was conducted 4 weeks after the initial issuance, and an additional 38 usable questionnaires were returned. Thus, a total of 121 usable questionnaires were collected, representing 23.8% of the target sample. A comparison of early (those who responded to the first issuance) and late (those who responded to the second issuance) respondents recommended by Armstrong and Overton (1977) was performed to test for nonresponse bias based on *t*-test analysis. No significant differences between the two groups' perceptions were observed at the 5% significance level. Thus, it was concluded that no evidence of nonresponse bias existed.

3.2 Measures

The measures for blockchain applications, future improvements, and intention to use attributes in this study were drawn from relevant studies (Appendix A). To ensure validity, they were discussed with a number of maritime shipping executives and experts who included a senior technician of Maritime and Port Bureau, a senior researcher of Taiwan International Ports Corporation, the chairman of a shipping agency corporation, and the junior vice president of a shipping carrier to refine the design of the questionnaire used for the main survey. Interviews resulted in minor modifications to the wording of and examples provided in some measurement items. After minor changes were implemented and a review had been conducted by two maritime shipping academicians, which were all finally received as possessing content validity, the instrument was sent to the respondents in the main sample for data collection. Appendix A present the final measurement items. Respondents answered all questions by using a 5-point Likert scale (1 = *strongly disagree*, 5 = *strongly agree*).

3.3 Data analysis methods

First, descriptive statistics, exploratory factor analysis, and item total correlation analysis were used to summarise the large quantity of blockchain applications, future improvements, and intention to use attributes into smaller, more manageable sets of underlying factors or dimensions. Confirmatory factor analysis was used to examine the unidimensionality, convergent validity, discriminant validity, and construct reliability of blockchain applications, future improvements, and intention to use. Hierarchical regression analysis was used to examine the effects of blockchain applications (i.e. customs clearance and management, digitalizing and ease paperwork, and tracking and tracing) and future improvements (i.e. standardization and platform, business model and regulation) on intention to use.

4. Results of empirical analyses

4.1 Respondent profile

Table 1 lists the characteristics of the questionnaire respondents and their companies; the figures reveal that the participants comprised vice presidents and those with higher positions (28.1%), managers and assistant managers (34.7%), directors and vice directors (17.4%), , and sales representatives (19.8%). As shown in Table 1, most respondents represented shipping forwarders (40.5%) and shipping company (22.3%). The main departments represented by the respondents were management department (45.5%) and sales department (43.8%), followed by information department (10.7%). Regarding respondent seniority, more than half of the respondents (67.8%) had more than 5 years' experience; this finding indicates that the respondents were sufficiently experienced to complete the questionnaire. Regarding ownership, 5.0% of the respondents worked for foreign-owned firms and 89.2% and 5.8% worked at local and foreign-local firms, respectively.

Table 10: Profile of respondents (n=121)

Characteristics of respondents		Frequency	%
Job title	Vice president or above	34	28.1
	Manager/assistant manager	42	34.7
	Director/vice director	21	17.4
	Sales representative	24	19.8
Department	Management	55	45.5
	Sales	53	43.8
	Information	13	10.7
Seniority	Less than 5 years	39	32.2
	6-10 years	21	17.4
	11-15 years	18	14.9

(Continued) Table 11: Profile of respondents (n=121)

	16-20 years	15	12.4
	More than 20 years	28	23.1
Company category	Port corporation	24	19.8
	Shipping company	27	22.3
	Shipping agency	21	17.4
	Shipping forwarders	49	40.5
Ownership	Local firm	108	89.2
	Foreign-local firm	7	5.8
	Foreign-owned firm	6	5.0
Numbers of employee	Less than 100	41	33.9
	101 - 1000	19	15.7
	1001 - 2000	30	24.8
	Over 2000	31	25.5

4.2 Exploratory factor analysis results

Factor analysis of principal components and a VARIMAX rotation were conducted to reduce the 24 measurement items to a smaller, more manageable set of underlying factors (dimensions). This facilitated detection of meaningful patterns among the original variables and extraction of the main factors (see Appendix A). The six dimensions were labelled customs clearance and management (CC), digitalizing and ease paperwork (DP), tracking and tracing (TT), standardization and platform (SP), business model and regulation (BR), and intention to use (IN). A series of analyses was performed to test the reliability and validity of the constructs; the results revealed that all measurement items had strong loading on all constructs. Cronbach's alpha values indicated that all constructs were reliable for this study (Nunnally, 1978). In addition, the corrected item-total correlation (CITC) reliability test revealed that all CITC values were above 0.508; therefore, we concluded that the scales were reliable (Kerlinger, 1986). Appendix A presents the respondents' agreement levels with blockchain applications, future improvements, and intention to use. The results indicated that the respondents considered BR (mean = 4.132) the most agreeable dimension, followed by TT (mean = 4.122) and IN (mean = 4.096); CC (mean = 4.007) had the lowest agreement level.

4.3 Confirmatory factor analysis

To examine the unidimensionality of the measurement items, confirmatory factor analysis (CFA) was conducted using AMOS 20 software. Table 2 presents the CFA factor loadings. The average variance extracted (AVE) values for all constructs were higher than 0.50 (Fornell and Larcker, 1981). The results revealed good fit according to the following model fit indices: chi-square / degrees of freedom = 1.848 (the acceptable ratio was lower than 2.0 [Tabachnick and Fidell, 2007]), $p = 0.000$, comparative fit index = 0.902 (a value exceeding 0.90 indicated that the research model had reasonably good fit [Hu and Bentler, 1999]), root mean square residual = 0.04 (a value of 0.05 or lower indicated an acceptable model [Byrne, 1998]), and root mean square error of approximation = 0.08 (a value lower than 0.08 is generally considered a good fit [Hu and Bentler, 1999]).

Table 2: Results of confirmatory factor analysis

Latent variables	Unstandardised factor loading	Completely standardised factor loading	Standard error[a]	Critical Ratio[b]
ξ1: Customs clearance (CC) (AVE: 0.680)				
CC1	1.000	.777	--[c]	--
CC2	1.086	.873	.104	10.468***
CC3	1.110	.877	.105	10.527***
CC4	.953	.780	.105	9.094***
CC5	1.106	.809	.116	9.522***
ξ2: Digitalizing and ease paperwork (DP) (AVE: 0.614)				
DP1	1.000	.848	--[c]	--
DP2	.921	.824	.085	10.829***
DP3	.736	.701	.086	8.556***
DP4	.794	.811	.075	10.555***
DP5	.782	.722	.088	8.922***
ξ3: Tracking and tracing (TT) (AVE: 0.608)				
TT1	1.000	.773	--[c]	--
TT2	1.169	.828	1.000	9.353***
TT3	.924	.792	1.169	8.899***
TT4	1.012	.721	.924	8.000***
ξ4: Standardization and platform (SP) (AVE: 0.651)				
SP1	1.000	.771	--[c]	--
SP2	.970	.872	.096	10.110***
SP3	.971	.754	.114	8.538***
SP4	.987	.826	.104	9.512***
ξ5: Business model and regulation (BR) (AVE: 0. 0.542)				
BR1	1.000	.580	--[c]	--
BR2	1.377	.883	.244	5.656***
BR3	1.157	.714	.204	5.673***
ξ6: Intention to use (IN) (AVE: 0.793)				
IN1	1.000	.869	--[c]	--
IN2	1.162	.951	.077	15.164***
IN3	1.050	.848	.085	12.376***

Note: a. S.E. is an estimate of the standard error of the covariance; b. C.R. is the critical ratio obtained by dividing the estimate of the covariance by its standard error. ***Correlation is significant at the 0.001 level; c. Indicates a parameter fixed at 1.0 in the original solution.

We used CFA to obtain convergent and discriminant validity. Convergent validity can be tested using t values that are significant on factor loadings (Dunn et al., 1994). In the AMOS text output file, the t value is the critical ratio (CR), which represents the parameter estimate divided by its standard errors. Furthermore, a construct with a loading of indicators of at least 0.50 (Kline, 2011), a significant CR (CR > 1.96), or both is considered to have convergent validity. For our model, all factor loadings were greater than 0.50 and all CRs were greater than 1.96, thereby demonstrating convergent validity. Finally, we verified the discriminant validity of our instrument by comparing the AVE for each latent construct to the square of correlation between each construct and other constructs (Segars and Grover, 1998). The results in Table 3 confirm discriminant validity; the AVE for each construct was greater than the level of the square of correlations involving each construct. In addition, the results of interconstruct correlations showed that each construct shared higher variance with its own measures than with other measures.

Table 3: Correlations and AVE

Construct	CC	DP	TT	SP	BR	IN
CC	**0.680**					
DP	0.281	**0.614**				
TT	0.423	0.423	**0.608**			
SP	0.281	0.384	0.423	**0.651**		
BR	0.073	0.053	0.109	0.137	**0.542**	
IN	0.303	0.410	0.360	0.533	0.144	**0.793**

Note: AVE are on the diagonal; square correlations are off-diagonal

4.4 Test of hypotheses

We conducted hierarchical regression analysis to test the hypotheses. As shown in Table 4, we conducted the analysis in three stages. First, we entered the control variables, namely job title, depaetment, and company category, into the regression for intention to use (Model 1). Second, we added the blockchain applications (i.e., CC, DP, and TT) into the regression as a block (Model 2). Third, we added the future improvements (i.e. SP and BR) into the regression as a block (Model 3). To examine multicollinearity, we examined the variance inflation factors (VIFs) for each regression equation. The maximum VIF within the models was 2.65, which was well below the rule-of-thumb cut-off value of 10 (Neter et al., 1990).

Table 4: Hierarchical regression analysis results (standardized β coefficients)

Variables	Model 1 (Intention to use)	Mode 2 (Intention to use)	Mode 3 (Intention to use)
Control variables			
Job title	0.032	0.171*	0.130*
Department	-0.030	-0.078	-0.076
Company category	0.032	0.014	0.045
Independent variables			
BT applications			
CC		0.217*	0.153*
DP		0.427***	0.276***
TT		0.195*	-0.003
Future improvements			
SP			0.462***
BR			0.088
F-value	F(3,117)=.09804	F(6,114)=20.179***	F(8,112)=24.625***
Adj.R^2	0.025	0.490	0.612
Δ Adj.R^2		0.465	0.122

Note: *Significant at p≦0.05, **Significant at p≦0.01, ***Significant at p≦0.001

Regarding the effects of CC (β = 0.153, $p < 0.05$) and DP (β = 0.276, $p < 0.001$) on intention to use (Table 4), Model 3 showed that the coefficients were positive and significant. Thus, H1 and H2 were supported. Regarding the effects of SP on intention to use, we predicted a positive relationship; as shown in Model 3 (β = 0.462, $p < 0.001$), the coefficient was positive and significant. Accordingly, H4 was supported. Regarding the effects of the control variables, namely job title on intention to use, the result of Model 3 indicated that the coefficients for job title (β = 0.130, $p < 0.05$) was significant.

5. Conclusions and implications

To provide insights into the research question, this study discussed applications, future improvements, and intention to use a blockchain bundling model, and empirically tested the key factors for blockchain use intention to assist maritime shipping in achieving effectiveness, efficiency and competiveness through technological and managerial innovations. We developed measures and conducted exploratory analysis, confirmatory analysis, and hierarchical regression to empirically test our hypotheses. Some possible future improvements are also discussed. Factor analysis was conducted to arrange blockchain applications, future improvements, and intention to use attributes into six critical dimensions (factors): customs clearance and management (CC), digitalizing and ease paperwork (DP), tracking and tracing (TT), standardization and platform (SP), business model and regulation (BR), and intention to use. Hierarchical regression analysis findings indicated that CC, DP, and SP positively influenced intention to use, which acted as key drivers to enhance intention to use blockchain technology, "thereby helping managers to systematically assess where to start building organisational capabilities in order to successfully adopt and deploy blockchain-based technology" (Dobrovnik et al., 2018). As our research results show, the BT applications and future improvements have a considerable impact on the use intention of maritime-related industries and should be seen as an inevitable trend. It is recommended that managers to dedicate resources to significant blockchain applications and understand how much of the entire blockchain applications and future improvements can evolve into a value-added service portfolio of their shipping supply chain and thus contribute to competitive advantages before competitors do it.

In addition, regarding the effect of job title on intention to use, the results of Model 3 revealed that the coefficient was significant. This implied that the respondents with higher job title had less intention to use blockchain technology. The finding was not surprising, because older people in senior positions are less receptive to new technologies and face a sceptical attitudes about the benefits of new technology (Mitzner et al., 2010). Blockchains could revolutionize the underlying digitalizing and ease paperwork (DP) and customs clearance and management (CC) in maritime shipping, thus upgrading and transforming them. Not only does bolckchain technology make shipping digitalization and ease paperwork, especially when going through customs management, it also greatly enhances cross-border trade security and safety. It is worth noting that the future improvement of business model and regulation (BR) have sparked extensive discussion in the adoption of blockchain innovation, although not significant in this study. As previous researchers have said, "history is not stopped by current obstacles, as the technical, regulatory, and other problems of blockchain technology will ultimately be resolved" (Guo and Liang, 2016).

In the implications of this study, three blockchain applications denote unanimous recognition and affirmation by maritime shipping operators; likewise, these distinctive blockchain applications are empirically valuable for enhancing efficiency and effectiveness in maritime shipping context. We believe that framing the role of blockchain applications in this manner not only fills a research gap but also contributes to maritime shipping literature, and thus could aid future theoretical development in this line of research. From a managerial perspective, this study provided enlightening insight into blockchain applications to revolutionize the underlying technology of the maritime shipping and logistics supply chain systems, thus upgrading and digital transforming them, which will reduce cost, save transit time, enhance efficiency and predictability, and increase safety and security. Managers might employ these measures of blockchain applications to exploit relative strength than their competitors, and conduct personnel training to integrate and reconfigure internal and external competencies to address rapidly changing environments (Teece et al., 1997). In order to boost blockchain-based logistics/distribution industry, the government, institutionally, needs to back up adding legal plan of shipping, logistics and distribution, reviewing standardization of electronic switching system and coming up with blockchain-based industrial road maps (Kim and Shim, 2018). "Similar to other new technologies, to realize its full potential, blockchain will be developed through numerous iterations and will inevitably go through trials, evolution, failures and ultimately widespread adoption" (Kakavand et al., 2017).

6. Limitations and future research

To shed light on this emerging field, this study revealed that maritime shipping blockchain applications and future improvements had significantly positive effects on intention to use. We hope that future research can extend these findings. Although the present study's objectives were accomplished, several limitations that could be addressed in future studies should be noted and need to be carefully interpreted. First, although we conducted this study in the context of maritime shipping, our conceptual model should be applicable to other industries. Interesting directions for future research to examine whether our model based on the context of shipping is generalizable to other industries to verify the findings. Second, the results of our study do not imply that this is the only valid model for examining intention to use blockchain; however, the model proposed in this study provided good fit with the data. Future research could apply the technology acceptance model or unified theory of acceptance and use of technology to test how users empirically accept the use of blockchain. Third, similar to most empirical studies, this study took a static view with no consideration of the evolution of maritime shipping operators' perceptions. Future research could use a longitudinal approach to test the pathways proposed in this study over time, since blockchain applications and future improvements are emerging and evolving topics at the moment. Also, we expect future research should explore the following issues that blockchain business model, governance and regulation will become critical.

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Spatial Analysis of AIS-Based LNG Fleet Emission Inventory

Hoegwon Kim[1], Daisuke Watanabe[1,], and Shigeki Toriumi[2]*

[1]Tokyo University of Marine Science and Technology, Tokyo, Japan
[2]Chuo University, Tokyo, Japan
Email: [1]daisuke@kaiyodai.ac.jp

* *Corresponding author*

Abstract

Many states are actively working toward to regulate CO2 emission from wide rage of industry. However, due to international characteristic of shipping, emission from shipping is not yet strictly controlled now. In this study, using AIS data acquired through satellite, estimated emission inventory and bunker consumption from LNG fleet under assumption that LNG fleet is using LNG as and fuel. Using position data included in AIS and calculated, we make a comparison between LNG trade amount and bunker consumption from LNG fleet vicinity of coast of each country and total CO2 inventory of each country and CO2 emission from LNG fleet. The result may provide how emission and bunker consumption from LNG fleet is distributed and about which counties are relatively more taking advantage of LNG trade and which countries are relatively more got probable harmful effect from it.

Keywords: CO2, AIS, ship emission, LNG carrier

1. Introduction

Transportation is the second biggest Green House Gas (GHG) emission sector following electric power sector. And most of them are coming from generating energy using fossil fuel to drive truck, train, plane, and vessel (United States Environmental Protection Agency, 2018). Transportation mode, such as truck, train, and plane, are relatively well monitored compared to shipping. However, shipping is the least controlled area. International Maritime Organization (IMO) just started to collect the vessel GHG emission data and a long-term plan will be established on 2023 after analysing all the data IMO collect from 2018. European Union (EU) is more actively working on controlling emission from shipping. EU released that shipping would be included in EU Emission Trading system, which is market-based measurement based on cap and trade system, if there is no comparable system operating to control GHG emission until 2021.

1.1. Background of Study

1.1.1. Emission from Maritime Transportation

By carrying a huge amount of cargo in one trip, vessel is known as one of the most eco-friendly mode of transportation among major transportation modes (Buhaug et al., 2009). Especially, by carrying huge amount of cargo, carrying cargo by vessel is more efficient way of transportation than other mode of transportations in aspect of CO2 emission (ton*km). Even though CO2 emission from shipping is lower than ways to carry cargo in aspect of ton*km. CO2 emission from shipping reached 796 million tons in 2012 (Smith et al., 2015) which is representing 2.2 % of world CO2 emission on 2012 and had emitted about 3.1 % of global CO2 emission from 2008 to 2012.

1.1.2. CO2 Emission Regulation on Shipping

Regulations on CO2 emission in shipping, which is currently implementing, are divided into two main organization. One is led by International Maritime Organization (IMO) and the other is led by European Union (EU). In IMO, amendment of MARPOL Annex VI makes it mandatory that submit annual report to administrations follow the way introduced in The Ship Energy Efficiency Management Plan(SEEMP) for the vessel, which is larger than 5,000 gross tonnages. It has been entered into force from 1st March 2018, and first data "calendar year" commenced on 1st January 2019.It includes IMO number, period of calendar year covered, and it is also including technical information such as vessel type, gross tonnage, net tonnage, deadweight tonnage, power output, EEID(if applicable), ice class, and fuel oil consumption data (International Maritime Organization, 2017).

In EU, MRV (Monitoring, Reporting, Verification) regulation entered into force on 1st July 2015, and it makes it mandatory to report and verify CO2 emissions for vessel over 5,000gross tonnage calling at any EU member state and European Free Trade Association(Norway, Iceland) port. Every year responsible party, ship owner or any other organization or person, such as manager or the bareboat charterer, whoever has responsible for ship operation, are required to report the result of CO2 emissions emitted and other required information including list of voyage, distance traveled, time spent at sea, the amount of cargo carried and the number of passenger(European Union, and European Parliament, 2015). And European Parliament is planning to include shipping on EU ETS(Emission Trading Scheme), basically a cap and trade system, from 2023 if IMO does not establish a comparable system(European Parliament, 2018).

1.2. Research Review and Objective

Under IMO regulations, SOLAS(Safety of Life at sea) chapter V, it is obliged to carry AIS(Automatic Identification system) for the vessel has gross tonnage over 300 on international transport. The main purpose of the AIS is that by emitting position to avoid collision at sea, However, advent of communication technology has made area of application wider. Many studies have been carried out to estimate ship inventories using AIS data. Smith et al.(2015) implemented full-scale ship emission inventory analysis using AIS data, and Sérgiomabunda et al.(2014) estimated ship emission inventory near the strait of Gibraltar, Coello, J., et al.(2015) estimated emission inventory from UK fishing fleet, Winther M. et al.(2014) implemented emission inventory estimation in the artic though S-AIS(Satellite Automatic Identification System), and X. Yao et al.(2016) estimated ship emission inventories in estuary of the Yangtze river.

The reasons why we chose to analyze data of LNG carrier are, first demand of gas energy is expected to increase 1.8 % per year from 2015 to 2040. It is much quicker than other conventional mode of energy sources (Organization of the Petroleum Exporting Countries, 2017), such as oil (0.6 % per year) and coal(0.4 % per year). Second, distribution of size of LNG carrier is not very wide which may make easy to assume coefficients related to calculation of emission LNG carrier. Third, international LNG trade statistic is open to public and import of East Asia countries is occupying more than 60 % (International Gas Union, 2017).

The purpose of this study is that have clear understanding and insight about LNG carrier emitted GHG by visualizing the results of calculation and AIS data acquired by satellite, and using geo-spatial analysis get in depth quantitative insight pertaining to distribution of ship emission inventory. To visualize and compare calculated AIS-based bunker consumption and other data, such as trade of LNG and total CO2 emission of each country, aggregated the data through grid or point and buffer depending on purpose of each chapter. And, adopted spatial autocorrelation to figure out relationship between each attribute.

2. Automatic Identification System (AIS)

2.1. Introduction to AIS

From 31st December 2004, it is obliged to carry CLASS A AIS for vessels of over 300 gross tonnage engaged on international voyage, cargo vessels of over 500 gross tonnage not engaged on international voyage. The motivation of adopting the regulation for carriage of AIS is preventing collision at sea by transmitting vessel data, such as time, position, vessel ID, basic vessel dimensions, and draught, data is emitted and received interval of 2-10 seconds while underway and 3 minutes at anchored. However, advent of positioning and communication system broaden the fields where AIS data can be used such as vessel management, power prediction, and tracking trade flow.

2.2. Data Description

The data used in this study is collected by the company named exactEarth. It founded in 2009 for the purpose of making Satellite AIS data services. It currently tracking more than 165,000 vessels through AIS. As exactEarth collect AIS data through satellite, it is possible to get AIS data through the ocean regardless of the position of the vessel and regardless of the weather the vessel faced.

The AIS data used this research is comma-separated values (CSV) form. Every data is divided by day based on Greenwich Mean Time (GMT). Figure 2.1 shows original data provided by exactEarth. It includes vessel name, callsign, Maritime Mobile Service Identity(MMSI), vessel type , vessel type cargo, vessel class, length, width, flag country, destination, Estimated Time of Arrival (ETA), draught, longitude, latitude, SOG, Course Over ground (COG), Rate Of Turn (ROT), heading, navigation(nav) status, source, time, vessel type main, and vessel type sub. . Message emitting interval of AIS is 2-10 seconds while underway and 3 minutes at anchored. Table 2.2 shows the ship type, period, number of vessels, and total number of data used in this study.

Table 2.1: Summary of the Data, LNG Carrier

vessel type	LNG carrier
Period	2016-01-01 UTC To: 2016-06-30 UTC
Number of vessels	327
Total number of data	9,072,300

Table 2.2 and 2.3 shows the statistical summary of data interval of AIS messages used in this study. The mean of interval is about 520 seconds, and 25 % and 75% are 6 and 42 seconds respectively. Looking into more details of sampling rate of AIS data, about 31.7 % of data has interval less than 10 seconds which is AIS message emitting interval for underway vessel. And, about 90.6 % of message have data interval less than 3 minutes which is same as AIS message emitting interval for anchored vessel. And, about 99.3 % of data has data colleting interval less than 2 hours. It seems small %, however, considering that the total number of data is more than 9 million, it is not easy to say it is small number. This data sampling rate have to be improved in the future to improve accuracy of all kind of AIS-based calculations.

Table 2.2: Summary Statistics of Data Interval

	Hour	Minutes	Seconds
Count (number)	9,072,291	9,072,291	9,072,291
mean	0.14	8.68	520.52
std	6.61	396.84	23,810.39
min	0.00	0.00	0.00
25%	0.00	0.10	6.00
50%	0.00	0.28	17.00
75%	0.01	0.70	42.00
max	4055.61	243336.70	14,600,200.00

Table 2.3: Distribution of Data Interval

Data interval, hours (A)	Ratio (%) of data interval less than (A)	Number of data with longer sampling rate (A)
2/3600(2 Seconds)	7.928	8,353,080
10/3600(10 Seconds)	31.656	6,200,363
180/3600(3 Minutes)	90.594	853,331
0.5(30 Minutes)	95.851	376,392
1	97.501	226,720
2	99.297	63,758
6	99.805	17,707
24	99.963	3,387
168	99.992	688

Figure 2.1 shows distribution of number of data acquired. South and west of Africa, south of South America, north-east of Australia, and Indian ocean are marked as high concentration area. And areas, such as East China Sea, South China Sea, Mediterranean sea are not marked as areas with heavy traffic. It may because AIS data collected through satellite shows longer data collecting interval when the vessel is sailing areas with high traffic compare to areas with less traffic. And, few data are observed deviate from the routes of the vessel and land side, it might be error occurred when collecting the data through satellite. In this study, such kind of error included data is filtered using time, position, speed recorded in AIS message.

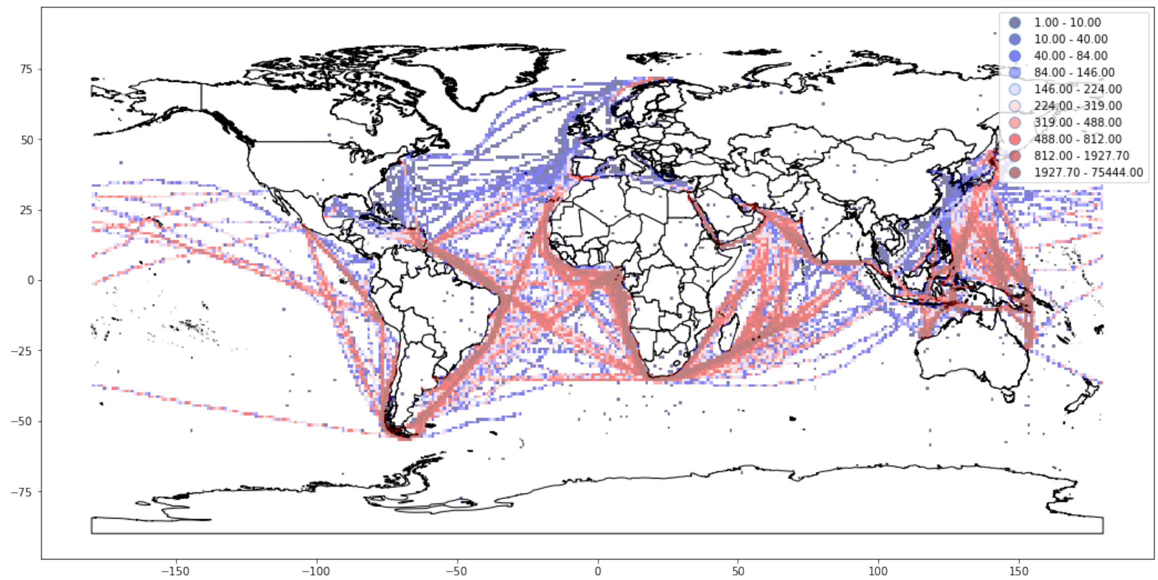


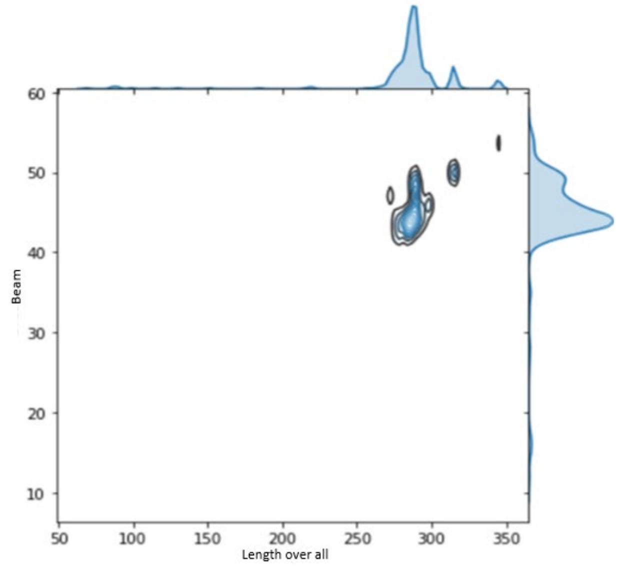
Figure 2.1: Distribution of Number of Data Acquired

Figure 2.2 shows the distribution of vessel size on this data, there are few small size vessels but most of the vessels are size from 250 to 300m in L_{OA}(Length Over All) and 40-50m in beam. As the cost of transportation occupying 10 to 30 % of LNG value chain (Office of fossil fuel, 2005), effort to minimize the cost of transportation may have affected the size of the vessel. Table 2.4 shows the more detail information about size of the vessel AIS data used in this study. For L_{OA}, 25% and 75% is 283m and 291m respectively. And for beam, 25% and 75% is 44m and 48m respectively.

Table 2.4: Basic Statistical Summary of LNG Fleet Size

Length over all		Beam	
mean	284.5m	mean	44.8m
std	35.4	std	5.6
min	69.0m	min	11.8m
25%	283.0m	25%	44.0m
50%	288.0m	50%	44.0m
75%	291.0m	75%	48.0m
max	345.0m	max	55.0m

Figure 2.2: Distribution of L_{OA} and Beam



2.3. Origin-Destination Data

As the AIS data included where is next port of call, it is possible to analyse origin-destination of voyage. From AIS data, origin-destination data derived. Through origin-destination trip data and capacity of the vessel, calculated assumed LNG import amount (Table 2.5). Japan is the biggest LNG import country followed by unknown (Destination country is not cleared), Korea, Egypt, Taiwan, China, and India. We will discuss more details of it with statistical data in chapter 3.

Table 2.5: Top 10 Assumed LNG Import Amount from AIS Origin-Destination Data (Jan – Jun 2016)

No.	Name of country	Import amount (Million tons)	No.	Name of country	Import amount (Million tons)
1	Japan	22.74	6	China	3.02
2	Unknown	22.73	7	India	2.93
3	Korea	6.95	8	Spain	1.52
4	Egypt	4.1	9	Qatar	1.01
5	Taiwan	3.1	10	United Arab Emirates	0.91
⋮					
				Total :	79.97

3. Vessel Emission Calculation

Figure 3.1 illustrate the process of data filtering, ship emission calculation, and visualization process of this chapter. Filtered data of LNG fleet from original AIS data using ship type recorded in AIS message. And drop the messages with wrong position using time, position, speed recorded on AIS data. Then using vessel dimensions, speed, and position data included in AIS message calculate total resistance when the vessel sailing speed V b by following the way included in the ITTC recommended procedure (International Towing Tank Conference, 2017). As the vessel performance could be vary depending on the condition of hull, weather, current etc., margin should be considered when calculate the power requirement. From calculated power, using SFOC (specific fuel oil consumption) and emission factor, calculation can be done to get bunker consumption and emission inventory. For data manipulation, Python(Version 3.6.6) is adopted as and data manipulation language. And adopted Pyhton module Pandas(Version 0.23.4) to aggregate calculated emission and Qgis (Version 2.14.21) is adopted for visualization.

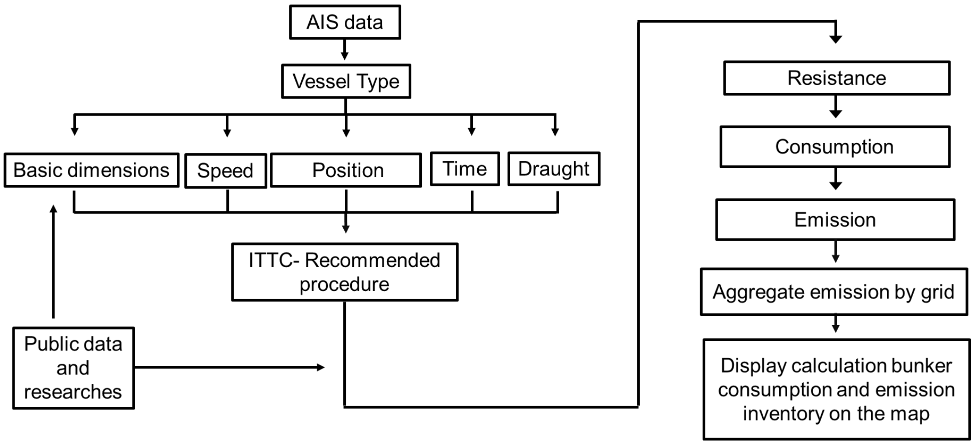


Figure 3.1: Flow Chapter of Data Manipulation

Several studies have been carried out to make estimation of vessel resistance which is key to calculate required power and bunker consumption when the vessel sailing specific speed V. In this study, I used method recommended on ITTC (International Tank Towing Committee, 2017) to estimate the total resistance which is key to derive power requirement. Detail parameters used in this study taken from various authorities, and public sources (i.e. Takahashi H., Goto A., Abe M., 2006, and Kristensen H. O., Lützen M., 2013).

3.1. Total Resistance

When calculate total resistance draught, *T*, and speed, *V*, which are included in AIS data are used as variable. Speed and draught are changing by time due to external forces, how much cargo and bunker on board ship. In order to calculate power required when the vessel sail in speed *V*, It is necessary to derive total resistance first. Total resistance can be denoted as(International Towing Tank Conference, 2017);

$$R_T = \frac{1}{2} * C_T * \rho * S * V^2 \quad (1)$$

Where R_T is Total resistance, C_T is Total resistance coefficient, ρ is density of water., S is Wetted surface of the hull, and V is Speed of vessel,

C_T, total resistance coefficient, can be derived;

$$C_T = C_F + C_A + C_{AA} + C_R \quad (2)$$

Where C_F is Frictional resistance coefficient, C_A = Incremental resistance coefficient, C_{AA} = Air resistance coefficient, C_R = Residual resistance coefficient. C_F, frictional resistance, of the hull is often occupying some 70-90% of the vessel total resistance for low-speed vessel (Bulk carriers and tankers), and sometimes less than 40% of vessel total resistance for high-speed vessel (MAN Diesel & Turbo, 2011). C_F can be described as (International Towing Tank Conference, 2017);

$$C_F = \frac{0.075}{(log_{10}R_n - 2)^2} \quad (3)$$

Where R_n is the Reynolds number, described as;

$$R_n = \frac{V * L_{WL}}{\varphi} \quad (4)$$

φ is Kinematic viscosity of water. In this study, value for φ is adopted from study done by Lienhard, J. (2016).

C_F, the frictional resistance coefficient is about roughness of hull surface. As surface roughness of the model is different from the roughness of the vessel, when calculating resistance coefficient, an incremental resistance coefficient, C_A, is added. Value of C_A can be estimated using following expression (Kristensen H. O. et al. 2013);

$$1000 * C_A = Max\left\{-0.1;\ 0.5 * log(\Delta) - 0.1 * \left(log(\Delta)\right)^2\right\} \quad (5)$$

Where Δ is displacement of vessel which can be denoted as;

$$\Delta = C_B * L_{PP} * B * T \quad (6)$$

Where C_B is Block coefficient of the vessel, L_{PP} is length between perpendiculars, B is Beam of the vessel, and T is Draught of the vessel.

The value for C_R is derived from study carried out by Harvald S.A.(1983), and Kristensen H. O. et al. (2013). And value for C_{AA} is adopted from study implemented by Kristensen H. O. et al. (2013). Finally, wetted surface, S, for tankers and bulk carriers can be derived by (Kristensen H O et al., 2013);

$$S = 0.99 * (\Delta/T + 1.9 * L_{WL} * T) \quad (7)$$

Where L_{WL} is Length of the waterline.

3.2 Power Prediction

Based on calculated total resistance of vessel, estimating required power when the vessel sailing at speed V in calm sea condition can be calculated by considering the components of propulsion efficiencies. Installed power is the power required to tow vessel with speed V in a calm sea. Service power can be derived from (Molland, A. F. et al., 2016);

$$P_I = \frac{R_T * V}{(\eta_D * \eta_T)} + m \quad (8)$$

Where P_I = Installed power, η_T is Transmission efficiency, η_D is Quasi-Propulsive Coefficient, and m is Sea margin.

3.3 Result

Table 3.1 shows the result of bunker consumption and amount of each emission amount each air pollutant calculation based on AIS data of LNG fleet from Jan – Jun 2016. Total consumption and CO2 emission amount is about 3.5, 9.7 million ton respectively. From the calculated bunker consumption, using emission factor, emission inventory of LNG fleet is derived.

Table 3.1: Emission Inventory of LNG Fleet (2016 January – June)

Calculated total bunker consumption (MT)	Emission Pollutant	Emission amount (MT)
3,540,342.2	CO2	9,735,941.050
	CH4	181,265.521
	N2O	389.438
	NOx	27,720.879
	CO	27,720.879
	NMVOC	10,656.430

To achieve deeper insight into the distribution of bunker consumption, we plotted the result of it on the maps (Figure 3.2). The distance between black vertical/horizontal line is 30 degree. Highly concentrated routes are mostly located from Middle East to Far East (Arabian sea-Indian ocean-Malacca strait-Singapore strait-South/East China Sea, and West Pacific) and Middle East to Europe (Arabian sea-Red sea-Suez-Mediterranean sea), and Oceania to Far East (Indonesian archipelago – South/East China Sea, and /West Pacific). As emission inventory derived by product of bunker consumption and emission factor, distribution of each air pollutant is same as figure 3.2.

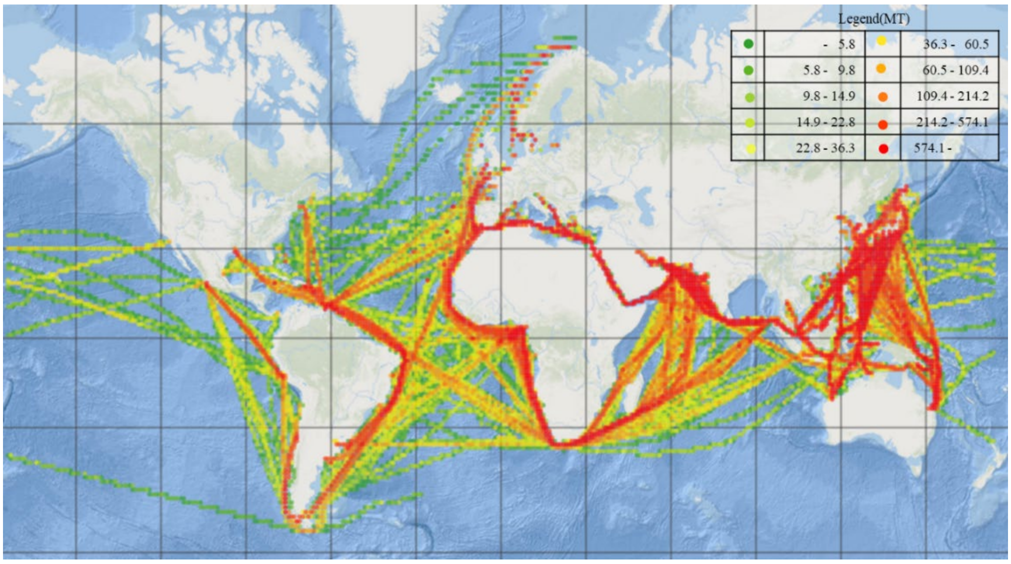


Figure 3.2: Distribution of Bunker Consumption by LNG Fleet, 1*1 Degree (Jan – Jun, 2016)

Compared to figure 2.4 (Distribution of number of data acquired), figure 3.2 shows high density in Mediterranean sea, south of Bay of Bengal, Malacca strait, South China Sea, East China Sea, coast of Japan and Korea. It might be the factor supporting that number of data does not mean that there are more vessel activities in that area for specific ship type.

4. Comparison between Bunker Consumption Vicinity of Each Country and LNG Trade Amount, and CO2 Emission from LNG Fleet and Each Country

Using emission data calculated on chapter 3, position recorded on AIS message, and global country boundary data, we aggregated bunker consumption from 0.2 degree from the coast of each country. Geopandas (Version

0.4.0) is used for the tool for buffering and aggregation in this chapter. From the aggregated data by country, we made comparison with international trade data (International Gas Union, 2017) to get more clear understanding about which countries are taking advantage from LNG trade and which countries are got more not favorable effect from the trade of LNG. In addition to it, from the aggregated bunker consumption, calculated CO2 emission, and compare it with entire CO2 inventory of each country.

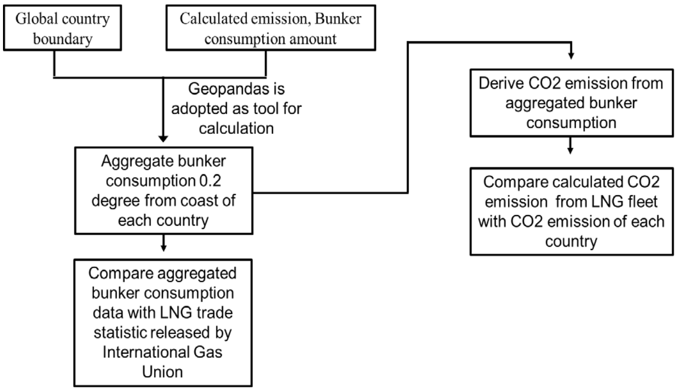


Figure 4.1: Flow of Chapter and Data Manipulation

4.1. Buffer

To aggregate the bunker consumption vicinity of coast of each country, we adopted buffer. Buffer is areas around the point, line, polygon or group of it. For example, buffering a point returns round shape area, buffering a line returns lane shape area. Buffer could be great analysis tool. For example, same as what we did in this study, it can create the area from fixed distance (0.2 degree) away from the coast of each country. The reason why we adopted 0.2 degrees in this study is that 0.2 degrees is 12 minutes which means 12 nautical miles in equator. In United Nations convention on the law of the sea part 2 “TERRITORIAL SEA AND CONTIGUOUS ZONE”, section 2 “LIMITS OF THE TERRITORIAL SEA”, article 2 state that every state has the right to establish the breadth of its territorial sea up to a limit not exceeding 12 nautical miles, measured from baselines determined in accordance with this convention. Data for coastline of each country get from ESRI. As every calculated bunker consumption has position, we aggregate the bunker consumption inside of buffer.

4.2. Result

4.2.1. Comparison Bunker Consumption near the Coastline of Each Country and LNG Trade Amount

Table 4.1 illustrate details of how much bunker consumption made inside of buffer created. The counties listed on this table are not only located at the end of the route but also located along the main passage of transportation.

Table 4.1: Bunker Consumption Made from 0.2 Degrees from Each Country (Metric Ton, MT), Top 20

No.	Name	Cons(MT)	No.	Name	Cons(MT)	No.	Name	Cons(MT)
1	Malaysia	69193.2	8	Oman	15807.31	15	Chile	4065.93
2	Indonesia	42643.16	9	Qatar	9291.88	16	Trinidad and Tobago	3358.28
3	Egypt	38887.04	10	Philippines	7625.87	17	Korea	3335.94
4	Japan	33839.04	11	Papua New Guinea	6222	18	Greece	2954.19
5	Yemen	25016.19	12	Spain	5561.6	19	Djibouti	2542.9
6	Iran	23185.27	13	India	5219.54	20	Morocco	2444.64
7	Singapore	18171.99	14	Australia	4822.99			

Table 4.2 illustrate summation of LNG export and import of each country LNG export and import data from IGU World LNG report 2017(International Gas Union, 2017). Few countries listed on table 4.1 are not listed in table 4.2 and order of list is quite different. This may give more clear understanding related to which countries are actively involved in LNG trade and which countries may be affected pollutant emitted by LNG fleet. Especially, countries such as Sri Lanka, and Djibouti, are not actively involved in trade of LNG, however, those countries have more possibility of being affected by air pollutant emitted from LNG fleet.

Table 4.2: Sum of LNG Export and Import (MTPA, Million tons per annum), Top 20

No.	Name	Sum	No.	Name	Sum	No.	Name	Sum
1	Japan	83.34	8	Nigeria	18.57	15	Spain	9.88
2	Qatar	77.24	9	Indonesia	16.59	16	Oman	8.14
3	Malaysia	51.07	10	Taiwan	15.04	17	Egypt	7.83
4	Australia	44.34	11	United Arab Emirates	14.09	18	United States	7.44
5	Korea	33.71	12	Algeria	11.52	19	United Kingdom	7.37
6	China	26.78	13	Russia	10.84	20	Papua New Guinea	7.36
7	India	19.17	14	Trinidad and Tobago	10.57			

Source: International Gas Union (2017)

Figure 4.2 is the scatter plot of bunker consumption aggregated inside of buffer created and LNG trade amount of each county. It shows that considering trade amount county plotted on right side of the red line is relatively less affected by emission from the emission materials from LNG fleet than countries plotted on the left side. Few countries are enjoying the advantages of international shipping, however, countries including Malaysia, Indonesia, Yemen, Oman, Philippines, Sri Lanka, Chile etc. where share the coast with main passage of shipping(Strait of Malacca, Indonesian archipelago, Arabian sea, Mediterranean sea, Magellan strait etc.) but not a node may not get enough benefit from international shipping.

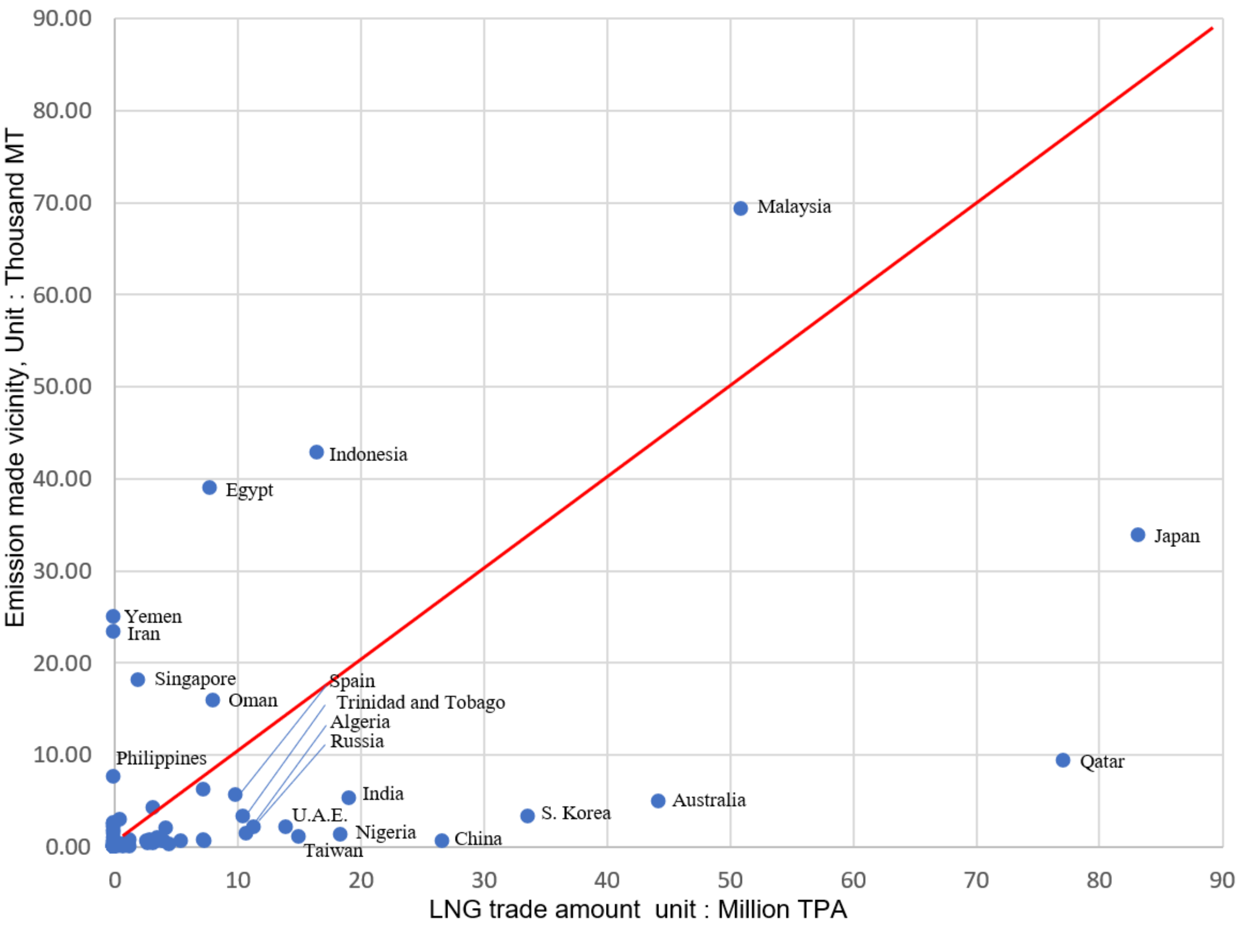


Figure 4.2: Scatter plot of LNG Trade Amount and Sum of Emission Made from 0.2 Degrees away from the Coast

4.2.2. Comparison CO2 Emission from LNG Fleet and CO2 Inventory of Each Country

We compared the CO2 emission amount from LNG fleet calculated in this study with CO2 emission of each country (Emission Database for Global Atmospheric Research, 2017). Table 4.3 is the Quantile map showing ratio of CO2 emission from LNG compared to CO2 emission of each country. Countries, such as Malaysia, Timor-Leste, Yemen, Papua New Guinea, Oman, Egypt, Indonesia, and Sri Lanka are relatively more affected by emission from LNG fleet in country scale.

Table 4.3: Comparison of Calculated CO2 Emission and Entire CO2 Emission by Country (Top 20 sort by CO2 from LNG fleet ‱)

	Calculated bunker consumption(ton)	Yearly CO2 emission of whole country (Kilo-ton)	Half of yearly CO2 emission(ton), A	Calculated CO2 emission amount(ton), B	CO2 from LNG fleet (‱), $A/B * 10^5$
Eritrea	2,347	684	342,070	6,455	188.6958
Timor-Leste	1,653	496	247,845	4,546	183.4409
Djibouti	2,543	1,509	754,425	6,993	92.6928
Gibraltar	807	573	286,355	2,219	77.4875

(Continued) Table 4.3: Comparison of Calculated CO2 Emission and Entire CO2 Emission by Country (Top 20 sort by CO2 from LNG fleet ‰)

Puerto Rico	720	713	356,380	1,980	55.5715
Yemen	25,016	25,648	12,823,995	68,795	53.6452
Comoros	105	108	54,210	289	53.295
Papua New Guinea	6,222	9,087	4,543,495	17,110	37.6593
Sao Tome and Principe	27	56	28,090	74	26.3846
Saint Helena	6	13.13	6,565	16	24.5506
Singapore	18,172	48,382	24,190,880	49,973	20.6578
Malaysia	69,193	266,252	133,125,770	190,281	14.2933
Equatorial Guinea	507	2,156	1,078,185	1,393	12.9236
Anguilla	6	30	15,130	17	11.1093
Oman	15,807	87,836	43,917,885	43,470	9.898
Egypt	38,887	219,377	109,688,675	106,939	9.7494
Trinidad and Tobago	3,358	34,974	17,487,130	9,235	5.2812
Qatar	9,292	98,990	49,495,040	25,553	5.1627
Mauritius	283	3,192	1,596,155	779	4.8823
Indonesia	42,643	530,036	265,017,825	117,269	4.4249

5. Validation

To figure out that calculated bunker consumption and air pollutant amount can be explained, first, we re-arranged the daily sum of bunker consumption. From the daily sum of bunker consumption, we made series of data which is sum of few days including that day, i.e., data for 4th January in sum of three days means that sum of bunker consumption from 2nd – 4th January. As the period of summation for each data increase, difference between mean and median decrease and increase of standard deviation is relatively smaller than that of mean of data(Table 5.1).

Table 5.1: Summary Statistics of Consumptions (Unit : Thousand MT)

	Daily sum	Sum of 3 days	Sum of 7 days	Sum of 14 days	Sum of 28 days	Sum of 56 days	Sum of 84 days
Mean	19.452	58.599	137.464	275.954	549.980	1092.822	1632.556
STD	12.454	20.612	24.243	26.084	33.956	39.601	42.469
Median	15.371	49.367	143.356	275.350	551.461	1090.390	1633.070

As Japan and Korea were world's biggest and second biggest LNG importer (International Gas Union, 2017), we adopted LNG import statics of Japan (Japanese Ministry of Economy, Trade and Industry, 2017) and, as monthly import amount of LNG was not included in data released by Korea Gas Corporation, used monthly number of voyages for Korea (Korea Gas Corporation, 2017). LNG import of Japan, March 2016 recorded highest import amount followed by February and January. Des voyage in Korea, January recorded highest number of voyages followed by March and February. For both LNG import amount of Japan and number of voyages of Korea, January to March are noticeably higher than values recorded on April to June(Table 5.2). The reason why we used number of voyages for Korea's case is that we were not able to find monthly import amount data for Korea found monthly voyage data released by Korea Gas Corporation.

Table 5.2: LNG Import Amount of Japan and Number of Voyages KOGAS

Month	LNG import Japan (Unit : ton)	DES voyage KOGAS	Imported amount KOGAS (Unit : ton)
2016/01	6,571,013	30	16,551,091
2016/02	7,022,133	22	
2016/03	7,830,571	26	
2016/04	6,113,092	11	
2016/05	5,337,500	11	
2016/06	5,669,585	12	
2016/07	6,581,212	9	
2016/08	7,055,543	8	
2016/09	6,586,966	11	
2016/10	6,252,994	24	
2016/11	7,026,373	22	
2016/12	7,163,109	25	

Source: Japanese Ministry of Economy, Trade and Industry (2017), Korea Gas Corporation (2017)

Looking into detail of Japanese statistical data of LNG trade volume and LNG trade volume assumed from AIS data, the ratio assumed trade from AIS data is about 59 % (See Table 5.3) compared to data released by ministry of Economy, Trade and Industry (METI). Depending on the month, assumed percentage of assumed trade volume from AIS, compared to data from METI, varied from 47 % to 83 % (See Table 5.3).

Table 5.3: Monthly Comparison of Statistical Data and Assumed LNG Trade Volume from AIS, Japan

Month	assumed from AIS (A) Million Ton	A sum	from METI(B)	B sum	A/B	A sum/B sum
1	3.07	22.74	6.57	38.54	0.47	0.59
2	4.48		7.02		0.64	
3	4.06		7.83		0.52	
4	3.84		6.11		0.63	
5	2.56		5.34		0.48	
6	4.73		5.67		0.83	

In case of Korea, as there is no monthly statistical data of LNG trade amount, we assumed monthly amount of import from KOGAS's data. From the total number of voyages and total amount of LNG imported in table 5.2, derived average amount of LNG carried per voyage (D in table 5.4). Then, calculated B by multiple number of voyages (N in table 5.4) with D. As KOGAS imported about 46 % (D / C on table 5.5) of total LNG import amount of Korea, divide B (In table 5.4) by 46 %. The result of this calculation is C in table 5.4. Depending on the month, 26-65 % of LNG trade volume has calculated by AIS origin-destination data. In both assuming, % of assumed amount from AIS is highest in June, 3rd is April, 5th is May and lowest in January(See table 5.3 and 5.4).

Table 5.4: Monthly Comparison of Statistical Data and Assumed LNG Trade Volume from AIS, Korea

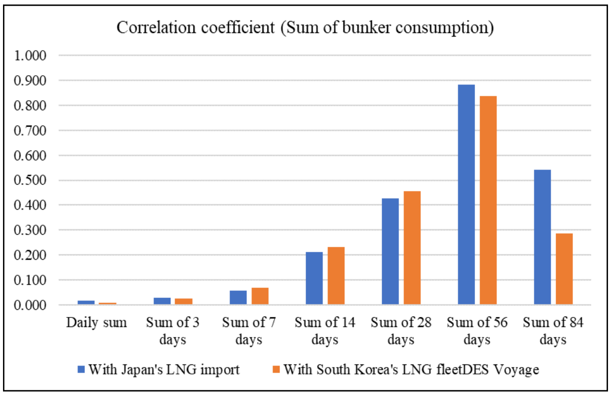
Month	Assumed from AIS(A) Million Ton	number of voyage(N)	average carried amount per voyage(D), MT	KOGAS (B) Million ton	Extrapolated import amount (C), Million ton	A/C
1	1.29	30	78441.19	2.35	5.04	0.26
2	1.48	22		1.73	3.69	0.40
3	1.43	26		2.04	4.37	0.33
4	0.89	11		0.86	1.85	0.48
5	0.55	11		0.86	1.85	0.30
6	1.30	12		0.94	2.01	0.65

Table 5.5: LNG Statistics and Assumed Trade Volume from AIS comparison, Korea

AIS assumed (A)	KOGAS Jan-Jun	KOGAS(D)	MOTIE Jan-Jun extrapolated (B)	MOTIE 2016(C)	A/B	D/C
6.95	8.79	15.30	18.81	32.75	0.45	0.46

The reason why assumed trade volume based on AIS data is smaller than that of statistical data might be errors in destination country, classifying loading conditions, error in method to separate voyage, or error in loading capacity of vessel, incomplete destination database and tracking.

Figure 5.1 shows Correlation between sum of bunker consumption and LNG import amount of Japan, and number of voyages of Korea. As the period of summation increase, both correlations show similar trend. Especially, correlation coefficient with sum of 56 days, 8 weeks, shows higher than 0.8. It may say that LNG fleet movement is related to planned LNG import amount of 1-2 month later.



	Japan LNG import	DES Voyage(KOGAS)
Daily sum	0.016	0.009
Sum of 3 days	0.028	0.025
Sum of 7 days	0.055	0.067
Sum of 14 days	0.211	0.231
Sum of 28 days	0.426	0.455
Sum of 56 days	0.884	0.837
Sum of 84 days	0.541	0.286

Figure 5.1: Correlation Coefficient between Sum of Bunker Consumption LNG Import Amount (METI, Trade and Industry, 2017) and Number of Voyage (Korea Gas corporation, 2017)

6. Conclusion

In this paper, we estimated vessel resistance in accordance with ITTC recommended procedure. Then, derived bunker consumption and emission inventory based on AIS. By plotting it on the map, deeper understanding about emission and bunker consumption may have been obtained. Then we applied geospatial analysis on ship emission inventory to figure out how air pollutant emission and bunker consumption distribution is clustered. In addition, by calculating sum of bunker consumption which can be easily converted to emission inventory from the coast of each country, illustrate how much each country might be affected by emission from LNG fleet.

Emission had made along the main routes of LNG shipping such as strait of Malacca, Indonesian archipelago, Arabian sea, Singapore Strait, Mediterranean sea, Magellan strait etc. Many countries, such as Sri Lanka and Philippine, located vicinity of those routes are not actively involved in trade of LNG or does not enjoy much of the prosperity from shipping but has high amount of bunker consumption near the coast of each countries. By comparing amount of bunker consumption 0.2 degree away from the coast of each countries with international LNG trade, and CO2 amount emitted 0.2 degree away the coast of each countries, gained understanding about which counties are relatively more taking advantage of LNG trade and which countries are relatively more got probable harmful effect from it. International society may need to think about how they can compensate those countries for possible damage from ship emitted pollutants.

This research could be improved in many ways. First, accuracy of calculation can be improved by solving problem that unstable AIS data collecting interval which can make some change in aggregation of data. Second, as the type of engine LNG carrier equipped is changing and advancing, if efficiency of new type of engine and type and ratio of fuel LNG carrier using is considered, more accurate result would be gained. Third, with more extensive amount of AIS data period, seasonal and monthly trend could be analyzed. And, finally, by applicating way used in this study to other type of vessel, it may be allowed to gain more extensive understating about ship emission.

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Maritime Accident Risk Probability Prediction of Sea Lanes Based on Dynamic Bayesian Network

Meizhi Jiang[1] *, and Jing Lu*[1]

[1]Transportation Engineering College, Dalian Maritime University, Dalian, China.
Email: [1]1937517385@qq.com

Abstract

The safety of maritime transportation has become increasingly important with the development of international economies and trade. Maritime transport poses risks that may cause damage to crew members, ships, and the environment. An improved Dynamic Bayesian Network (DBN) model is proposed in this paper to predict the dynamic probability of emergencies risk of sea lanes. It is a novel model which can efficiently represent and inference the complex stochastic knowledge. To develop the DBN-based model, the data, which were collected from emergencies investigation reports by International Maritime Organization (IMO), is used to provide guidance for the construction of BN. Second, the prior probability is determined by Evidence Theory model based on historical data. Third, the conditional probability is learned by EM algorithm and the transition probability is obtained by Markov model. Finally, Viterbi algorithm is adopted to predict emergencies risk probability. The emergencies occurred in Indian Ocean from 2009 to 2018 was used as a case study for risk probability prediction. The sensitivity analysis was carried out to identify the significant influencing factors. The results show that risk of sea lanes in Indian Ocean fluctuates within a small range but a downward trend overall. The significant influencing factors include wind speed, waves, visibility and pirate attacks. The findings can be used to provide a reference for maritime stakeholders to make proper decisions.

Keywords: Maritime accidents, Dynamic Bayesian network, Probability prediction, Evidence model, Markov model

1. Introduction

Maritime transport is one of the most important modes of transportation, accounting for over 90% of international trade volume due to its capability of providing relatively low-cost, efficient and green transportation (Valentine, 2015). Historically, maritime trade has been the backbone of economic development. The safety of maritime transportation plays a significant role in economic development. However, it is noticed that the existing maritime transportation system (MTS) is exposed to various risks (Zhang et al., 2018). MTS is a complex system composing of many elements such as transportation network, ships, environment and management. As a result, MTS is exposed to a variety of hazards, many of which can lead to accidents, including collision, contact, sounding, sinking, pirate attacks, hijacking and fire. It has been reported that on September 13, 2017, a products tanker collided with a dredger in the Singapore Strait. It caused the dredger to capsize and the tanker badly damaged, resulted in the loss of 5 five out of 12 dredger's crew. On February 19, 2017, a general cargo ship was attacked by number of pirates in Philippines, 5 crews were kidnapped, 2 crews were dead, and the ship was badly damaged. In addition, in West Africa, a fishing vessel was hijacked by gun armed pirates on January 30, 2015, resulted in 7 crew were kidnapped, 1 crew member was reported killed, and 3 crew were missing. Maritime accidents often cause catastrophic consequences such as deaths, economic loss, environmental pollution and congestion in sea lanes (Luo and Shin, 2019). Therefore, maritime accidents have always been a serious problem of maritime transport, despite every effort has made by human beings to prevent it (Mullai and Paulsson, 2011). Akten (2006) noted that maritime transportation is, and will be, full of risks despite improved technology and safety standards. Accordingly, great efforts have been made by international maritime authorities to improve safety in the shipping industry but despite this, there are still a large number of maritime accidents occurred in recent years recorded in many database. It is therefore a significant interest to predicate the risk probability of maritime accident.

There are many types of ship accidents, but the common ones are collision, pirate attacks, ship hijackings, contact, capsizing, stranding, fire or explosion (Abbassi et al., 2017). Broadly, environmental factors, human error, and mechanical failure are mainly influencing factors result in maritime accidents (Karahalios, 2015; Ugurlu et al., 2015). However, what this paper predicate is the risk of sea lanes itself poses to maritime transportation. Therefore, it only considers environmental factors including natural environment, geographical environment, safety environment, military and political environment, and law environment.

In this paper, an improved DBN model is proposed to predict the dynamic probability of emergencies risk of sea lanes. It can send an early warning signal to the ships of high probability of navigation risk along sea lanes. It includes the following three objectives:

1) Collecting the contributing factors for maritime accidents from investigation reports, database, and literature.
2) Determination and calculation of the prior probability, conditional probability, and transition probability.
3) Predication of risk probability of maritime accident in sea lanes.

To achieve the first objective, the contributing factors for maritime accidents are reviewed based on published full investigation reports, database and literature. Maritime investigation reports prepared by different authorities such as Maritime Safety Administration of China (MSA), European Maritime Safety Agency (EMSA), Marine Accident Investigation Branch (MAIB), Danish Maritime Accident Investigation Board (DMAIB), Transportation Safety Board of Canada (TSBC), and National Transport Safety Board (NTSB) are considered. Maritime database such as the Global Integrated Shipping Information System (GISIS), International Shipping Facts and Figures, Lloyd's Register Fairplay (LRF), and Lloyd's Maritime Intelligence Unit (LMIU), which is the most common database (Knapp et al., 2011; Heij, 2013; Weng and Yang, 2015) are considered in this paper. These databases include considerable information, such as ship particulars (e.g., ship name, ship type, tonnage, age), changes over time (e.g., flag, classification societies) and the casualty data (e.g., incident date and times, types of casualties, consequences, locations). Literatures like Akhtar and Utne (2014), Chauvin et al. (2013), and Chen et al. (2013) are referred in this paper.

Previous studies regarding maritime accident mostly focus on traffic accident such as collision, grounding, stranding, and so on ignored to consider non-traditional safety factors such as pirate attacks and ship hijackings. We noticed that an increasing number of literatures analyse the behaviour of piracy. This paper attempts to consider maritime accidents caused by non-traditional safety factors.

The rest of the paper is organized as follows. Section 2 presents a literature review of maritime accident research, and the application of DBN in maritime risk analysis and prediction. In section 3, the methodology of developing a DBN-based risk probability prediction model for sea lanes is proposed. All the relevant algorithms in constructing the model are described. In section 4, a case study is illustrated to predict the dynamic probability of maritime accidents. Sensitivity analysis is carried out to determine the man contributions to maritime accidents and how they affect the maritime accidents probability. Finally, major conclusions and results are discussed in section5.

2. Literature Review

2.1. Introduction of Maritime Accidents

Maritime accidents refer to unexpected abnormal events in ships that often cause casualties or serious injuries on board and all types of property damage which have always been a major problem in shipping industry (Luo and Shin, 2019). Previous studies of maritime accidents mainly include collision (Zhen et al., 2017; Montewka et al., 2014; Chauvin et al., 2013), fire and explosion (Baalisampang et al., 2018; Wang et al., 2017), pirate attack (Pristrom et al., 2013; Bouejla et al., 2014), ship hijacking (Pristrom et al., 2016), grounding (Bye and Aalberg, 2018) and so on.

Significant efforts have been made to develop proper measures to improve maritime safety, such as better understanding the marine environment, improvement of the technologies in shipbuilding, ship management and ship navigation, and better crew training. In addition, the policies, rules and regulations on safety standards and guidelines made by maritime authorities such as International Maritime Organization (IMO), and Maritime Safety Administrations (MSA) play an important role. It should be noted that most of these standards and guidelines are based on the new findings relevant on the influencing factors and a large number of actual investigations.

Since maritime accidents are extremely hazardous for safety, environment and properties. Therefore, it is crucial to do quantitative risk assessment (QRA) of maritime accidents in order to identify the safety measures needed to prevent maritime accidents or reduce the damage caused by accidents. Several works have been done to carry out QRA of maritime accidents (Pristrom et al., 2016; Baksh et al., 2018; Goerlandt et al., 2017; Haapasaari et al., 2015). A method is presented to predicate whether the accident is navigation-related or not based on the AIS data (Bye and Aalberg, 2018). A case study is demonstrated in China based on BN model with the derived quantitative data with the purpose to identify the factors related to the severity of waterway accidents and to generate useful insights for accident prevention (Wang and Yang, 2018). Fu et al. (2018) present a Frank copula-based fuzzy event tree analysis approach to assess the risks of maritime accidents in Arctic water. And the case study shows that the approach can be considered an appropriate approach for predicting the probability of the consequence of a ship getting stuck in ice. More and more researchers have been interested in the topic of maritime accident analysis and prevention because of the increasing frequency and damages of maritime accidents (Akyuz, 2017; Weng and Yang, 2015).

However, there is a limitation in the traditional QRAs which usually not consider the dynamic effects. Some papers have explored BN in developing better risk models to consider dynamic effects. Sun et al. (2015) present a dynamic Bayesian network model of time sequence traffic data to predicate real-time crash and investigate the relationship between crash occurrence and dynamic speed condition data. Wang et al. (2017) proposed an improved DBN model to predicate the dynamic probability of offshore platform fire. Dabrowski and Villiers (2015) proposed a generative model based on the DBN in the form of a switching liner dynamic system to model maritime piracy.

2.2. Applications of DBN

DBN is used in predication and diagnostic analysis in different time slices for risk assessment. BN has been widely used in the risk analysis of maritime accidents for dealing with uncertain information and risk analysis (Wang and Yang, 2018; Bouejla et al., 2014; Pristrom et al., 2016; Zhang et al., 2016; Zhang et al., 2013; Ma et al., 2016; Akhtar and Utne, 2014). However, the unobserved variables cannot be incorporated easily in the BN model because of the large size of internal conditional probability. In such situations, the DBN model integrated BN with Markov model is applied to predict the dynamic probability of maritime accidents.

A DBN based dynamic availability assessment technique was proposed to design better management strategies and provides more realistic reliance on safety critical systems (Amin et al., 2018). Chen et al. (2019) proposed a model for risk analysis using DBN, and the results show that the method can be served as a decision-making tool under uncertainties. With regarding to the unobserved variables, Uusitalo et al. (2018) proposed DBNs with hidden variables to model the change over time, as the hidden variables can capture the unobserved processes. Rebello et al. (2018) presented an integrated approach to estimate and predict the functional reliability of a system using DBN and Hidden Markov Model.

In summary, the innovation of this paper is attempt to build a DBN contained unobserved variables using BN with Markov model. In addition, the Evidence Theory is applied to determine the prior probability, the EM algorithm and Viterbi algorithm are adopted to learn probability distribution and to predicate emergencies risk probability respectively.

3. Methodology

3.1. Dynamic Bayesian Network

A BN is a probability graphical model that encodes probabilities relationships among a set of variables that connect these variables contained in a directed acyclic graph (DGA). There are several advantages for data analysis when the graphical model is used in conjunction with statistical techniques. First, a Bayesian network can be used to learn causal relationships and to predict the consequences of intervention. Second, it is an ideal representation for combining prior knowledge and data (Heckerman, 1995).

A DBN model is constructed by integrating Markov model with BN that can deal with dynamic data. It is very complex to represent emergencies with dynamic change of random variables. The following assumptions, which are listed as Eqs.1-2, are needed to simplify the modelling of complex systems (Yee and Flesch, 2010).

(1) Stationary hypothesis: the network topology and the transition probability do not change over time.

(2) Markov hypothesis: the probability distribution of future state depends only on the current state and has nothing to do with the sequence of events that preceded it.

$$P(X^t \left| X^1, X^2, \cdots, X^{t-1}\right.) = P(X^t \left| X^{t-1}\right.) \qquad (1)$$

$$P(X^t \left| X^{t-1}\right.) = \prod_{i=1}^{N} P(X_i^t \left| Pa(X_i^t)\right.) \qquad (2)$$

Based on the above assumptions, the DBN can be defined as $(B_0, B_\rightarrow)$, B_0 represents the initial structure, $B_\rightarrow$ represents transfer network. A simple DBN is shown in Fig.1. The relationship between variables at the same time-slice are represented by $X^t \rightarrow R^t$, the relationships between variables among successive time slices are presented by $X^t \rightarrow X^{t+1}$. The joint probability distribution of an initial BN and a DBN are presented by Eqs.3-4.

$$P(X_1, ..., X_n) = \prod_{i=1}^{n} P(X_i \left| Pa(X_i)\right.) \qquad (3)$$

$$P(X^{1:T}) = \prod_{t=1}^{T} \prod_{i=1}^{N} P(X_i^t \left| Pa(X_i^t)\right.) \qquad (4)$$

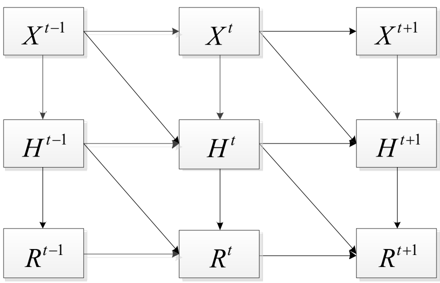

Figure1: Dynamic Bayesian network with three time slices

3.2. The Construction of BN

The sea lane is a complex system involving many natural factors, social factors and political environment factors. Because this study focuses on the risk of the sea lane itself, marine incidents caused by human factors are excluded when collecting data.

A statistical analysis of the incidents that occurred from 2007 to 2018 is made in this paper to effectively and comprehensively identify the main influencing factors of the sea lanes. The Indian Ocean from 20° to 80° east latitude and 40° north latitude to 40° south latitude is used as the research object for the emergencies risk probability prediction of sea lanes.

A total of 460 emergencies, including detailed reports from the database, are collected. The specific data in the sample comes from the Labour Market Association, Remote Sensing Systems and Meteorological Centre. In the subsequent quantitative analysis, the data are required to be discrete values, and the statistical and processing results are shown in tables 1 and 2. The construction result of initial BN is shown as Fig.2.

Table 1: Observed Node Variables of DBN

Observed node	Notation	Descriptions	State
Military base	X_1	The existence of military bases	No; yes
Politics	X_2	The existence of political conflict	No; yes
Military exercise	X_3	The existence of military exercises	No; yes
Terrorism	X_4	The existence of terrorism	No; yes
Risk of war	X_5	The risk of conflict, blockade or war	Low; high
Pirate attacks	X_6	The existence of pirate attacks	No; yes
Ship flow	X_7	Flow of ships passing important nodes	Normal; crowed
Width	X_8	Width of important nodes	Wide; medium; narrow
Depth	X_9	Depth of important nodes	Deep; medium; shallow
Substitutability	X_{10}	Substitutability of important nodes	High; medium; low
Wind	X_{11}	Wind speed condition	Low; moderate; high
Wave	X_{12}	Wave condition	Low; moderate; high
Visibility	X_{13}	Visibility condition	Good; poor
Law	X_{14}	Domestic and foreign legal constraints	Many; medium; few
Organizations	X_{15}	The number of organizations	Many; medium; few

Table 2: Unobserved Node Variables of DBN

Unobserved node	Notation	Descriptions	state
Military and political activities	H_1	Include military base, politics and military exercise	Frequent; normal
Safety environment	H_2	Include terrorism, risk of war, pirate attacks and ship flow	Good; poor
geographical environment	H_3	Include width, depth and substitutability	Good; poor
Natural environment	H_4	Include wind, wave and visibility	Good; poor
Law environment	H_5	Include law and organizations	Good; poor
The risk of sea lanes	R	Include H_1 , H_2 , H_3 , H_4 and H_5	Low; medium; high

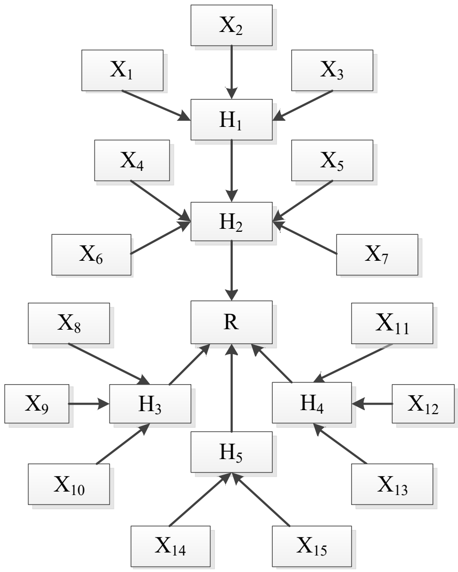

Figure 2: The Initial Structure of BN

3.3. Evidence Theory

The Evidence Theory is applied to determine the prior probability during the construction of DBN. We assume that all the experts have the same ability to assess the prior probability in the specific information. The Evidence Theory allows one to produce a basic belief allocation (belief function) on the set of decision solutions (decision framework) of the corresponding problem, which is the result of the decision. The decision synthesizes the experience and knowledge of many experts to solve uncertain and risk decision-making problems.

The belief of different state, which is scored by some experts, is shown in Eq.5.

$$m(p_i) \to [0,1]; \sum_{p_i \in p} m(p_i) = 1 \tag{5}$$

Belief function from different experts can be combined with different composition operator:

$$[m_1 \oplus m_2](p_i) \begin{Bmatrix} 0 & for p_i \neq \varphi \\ \dfrac{\sum\limits_{p_a \cap p_b = p_i} m_1(p_a) m_2(p_b)}{1-k} & for p_i \neq \varphi \end{Bmatrix} \tag{6}$$

$$k = \sum_{p_a \cap p_b = \varphi} m_1(p_a) m_2(p_b) \tag{7}$$

Where, $m_1(p_a)$ and $m_2(p_b)$ represent the score of experts m_1 and m_2; k denote the conflict of expert knowledge. When there are n experts, the belief function is as Eq.8.

$$m_{1-n} = m_1 \oplus m_2 \oplus \cdots \oplus m_n \tag{8}$$

3.4. Conditional Probability

The conditional probability indicates the causal relationships among variables. In order to improve efficiency, the expectation maximization (EM) algorithm is applied in this paper to learn the parameters of the BN and to compute the probability distribution with incomplete data.

The EM algorithm is widely used to process defect data, truncated data and other incomplete data with noise. The main idea is to find the parameters θ by iterating the probability relationship between the evidence nodes. The specific principle is as follows:

$$\begin{aligned} \ell(\theta; E) &= \sum_i \log p(x_{(i)} | \theta) \\ &= \sum_i \log \sum_{h_{(i)}} p(x_{(i)}, h_{(i)}; \theta) \\ &= \log \sum_H p(H, E | \theta) \end{aligned} \tag{9}$$

Where, E represents the set of observation nodes $x_{(i)}$; H denotes the set of hidden nodes $h_{(i)}$; and the Jensen's inequality is introduced:

$$\begin{aligned} \ell(\theta; E) &= \sum_i \log \sum_{h_{(i)}} Q_i(h_{(i)}) \frac{p(x_{(i)}, h_{(i)}; \theta)}{Q_i(h_{(i)})} \\ &\geq \sum_i \sum_{h_{(i)}} Q_i(h_{(i)}) \log \frac{p(x_{(i)}, h_{(i)}; \theta)}{Q_i(h_{(i)})} \\ &= \sum_H Q(H) \log \frac{p(H, E | \theta)}{Q(H)} \end{aligned} \tag{10}$$

The EM algorithm follows a two-step iterative optimization strategy: the expectation of the E step and maximal calculation of the M step. Repeat these two steps until convergence. The specific process can be described as follows.

Step E: Calculate the posterior probability of the hidden variable based on the initial parameter or the parameter obtained from the previous iteration, that is, the expectation of the hidden variable as the estimated value of the hidden variable:

$$Q(H) = P(H | E, \theta) \tag{11}$$

Step M: Maximize the likelihood function to obtain new parameters θ:

$$\theta = \arg\max_\theta \sum_H Q(H) \log \frac{p(H, E | \theta)}{Q(H)} \tag{12}$$

3.5. Transition Probability

The construction of transition probabilities is the key challenge for building a DBN as the status values of parent nodes which shift over time. The influencing factors are random events. We assume them as accounting process which meets Poisson distribution. Given that the average number of influencing factors per unit time is λ, the probability that factors occur *n* times is:

$$P\{N(t + \Delta t) - N(t) = n\} = e^{-\lambda t \frac{(\lambda t)^n}{n!}} \tag{13}$$

If the factor occurs *n* times till *t*, the probability that the factor does not occur from *t* to $t + \Delta t$ can be calculated as Eq.14.

$$
\begin{aligned}
P\{N(t,t+1)=no \mid N(t)=yes\} &= \frac{P\{N(t)=n, N(t+\Delta t)-N(t)=0\}}{P\{N(t)=n\}} \\
&= \frac{P\{N(t)=n\}P\{N(t+\Delta t)-N(t)=0\}}{P\{N(t)=n\}} \\
&= P\{N(t+\Delta t)-N(t)=0\} \\
&= e^{-\lambda \Delta t}
\end{aligned} \tag{14}
$$

For the influencing factors in this paper, the next state depends only on the current state and not on the sequence of preceding states. This situation meets the transfer chain of Markov hypothesis. If the present state of the factor is no ($X_t = no$), then the occurrence probability of the factor at $t+1$ ($P(X_{t+1} = yes \mid X_t = no)$) can be calculated as Eq.15.

$$
\begin{aligned}
&P(X_{t+1} = yes \mid X_t = no) \\
&= \frac{P(X_{t+1} = yes, X_t = no)}{P(X_t = no \mid X_{t+1} = yes)P(X_{t+1} = yes) + P(X_t = no \mid X_{t+1} = no)P(X_{t+1} = no)} \\
&= P(X_{t+1} = yes, X_t = no) = \lambda e^{-\lambda}
\end{aligned} \tag{15}
$$

Similarly,

$$P(X_{t+1} = no \mid X_t = no) = 1 - \lambda e^{-\lambda} \tag{16}$$

$$P(X_{t+1} = no \mid X_t = yes) = e^{-\lambda} \tag{17}$$

$$P(X_{t+1} = yes \mid X_t = yes) = 1 - e^{-\lambda} \tag{18}$$

3.6. Emergencies Risk Probability Prediction Algorithm

Viterbi algorithm is adopted to predicate emergencies risk probability in this paper. Specific steps are shown as follows:

Step 1is initialization calculation:

$$\delta_1(i) = \pi_i b_i(o_1) \quad 1 \le i \le N, \psi_1(i) = 0 \tag{19}$$

Step 2 is iterative calculation:

$$
\begin{cases}
\delta_t(j) = \max(\delta_{t-1}(i)a_{ij})b_j(o_t) \quad 1 \le i \le N \\
\psi_t(j) = \arg\max(\delta_{t-1}(i)a_{ij})
\end{cases} \tag{20}
$$

Step 3 is the termination condition:

$$
\begin{cases}
p^* = \max(\delta_t(i)) \\
q_T^* = \arg\max(\delta_t(i))
\end{cases} \tag{21}
$$

Step 4 is the best prediction result:

$$q_t^* = \psi_{t+1}(q_{t+1}^*) \quad t = T-1, T-2, \ldots, 1 \tag{22}$$

where $\delta_t(j)$ is a Viterbi variable, it represents the maximum probability of the observed variable that is produced along the transfer path of the hidden variable; $\psi_t(j)$ is an auxiliary variable, it represents the state of unobserved variable at the time of t-1 with the maximized result of $\delta_t(j)$; π_i denotes the probability for the initial network B_0; $b_j(o_t)$ denotes the probability value generated under the state of observation value o_t of the observed node E; a_{ij} represents the probability for the transfer network $B_{\rightarrow}$.

4. Case Study

4.1. Emergencies Risk Probability Prediction of Sea Lanes

In this section, the proposed DBN model is used to predict the dynamic emergencies risk probability. A Ten-Time slice DBN is constructed with an interval of one year. The prior probability, conditional probability and transition probability are put into the DBN model. The prior probability, as shown in Table 3, is calculated using Evidence theory on the historical data. The conditional probability is calculated using EM algorithm. The transition probability can be determined based on the Eqs13-18. The Viterbi algorithm is applied to predicate the emergencies risk probability of sea lanes, the result is shown in Fig.3.

Table 3: Prior Probability of Observation Node Variables for Emergencies

Nodes	State	Prior probability
X_1	No; yes	0.539; 0.461
X_2	No; yes	0.525; 0.475
X_3	No; yes	0.514; 0.486
X_4	No; yes	0.575; 0.425
X_5	Low; high	0.661; 0.339
X_6	No; yes	0.678; 0.322
X_7	Normal; crowed	0.490; 0.510
X_8	Wide; medium; narrow	0.302; 0.413; 0.285
X_9	Deep; medium; shallow	0.380; 0.391; 0.224
X_{10}	High; medium; low	0.336; 0.391; 0.273
X_{11}	Low; moderate; high	0.343; 0.395; 0.262
X_{12}	Low; moderate; high	0.394; 0.400; 0.206
X_{13}	Good; poor	0.585; 0.415
X_{14}	Many; medium; few	0.706; 0.294
X_{15}	Many; medium; few	0.591; 0.409

As can be seen form Fig.3, the DBN for emergencies risk probability of sea lanes is shown in Fig.3. The respective probabilities of high risk are 0.47548 at t0，0.45205 at t1, while the low risk are 0.24754 at t0, 0.25956 at t1. The prediction results at other times are shown in Fig. 4. Among them, the respective probabilities of high risk are 0.43566, 0.44417, 0.42603, 0.43016, 0.40586, 0.40266, 0.41021, and 0.39832 from t2 to t9. The probabilities of low risk are 0.26801, 0.26321, 0.29265, 0.27151, 0.28390, 0.28997, 0.28514 and 0.28995 from t2 to t9 respectively.

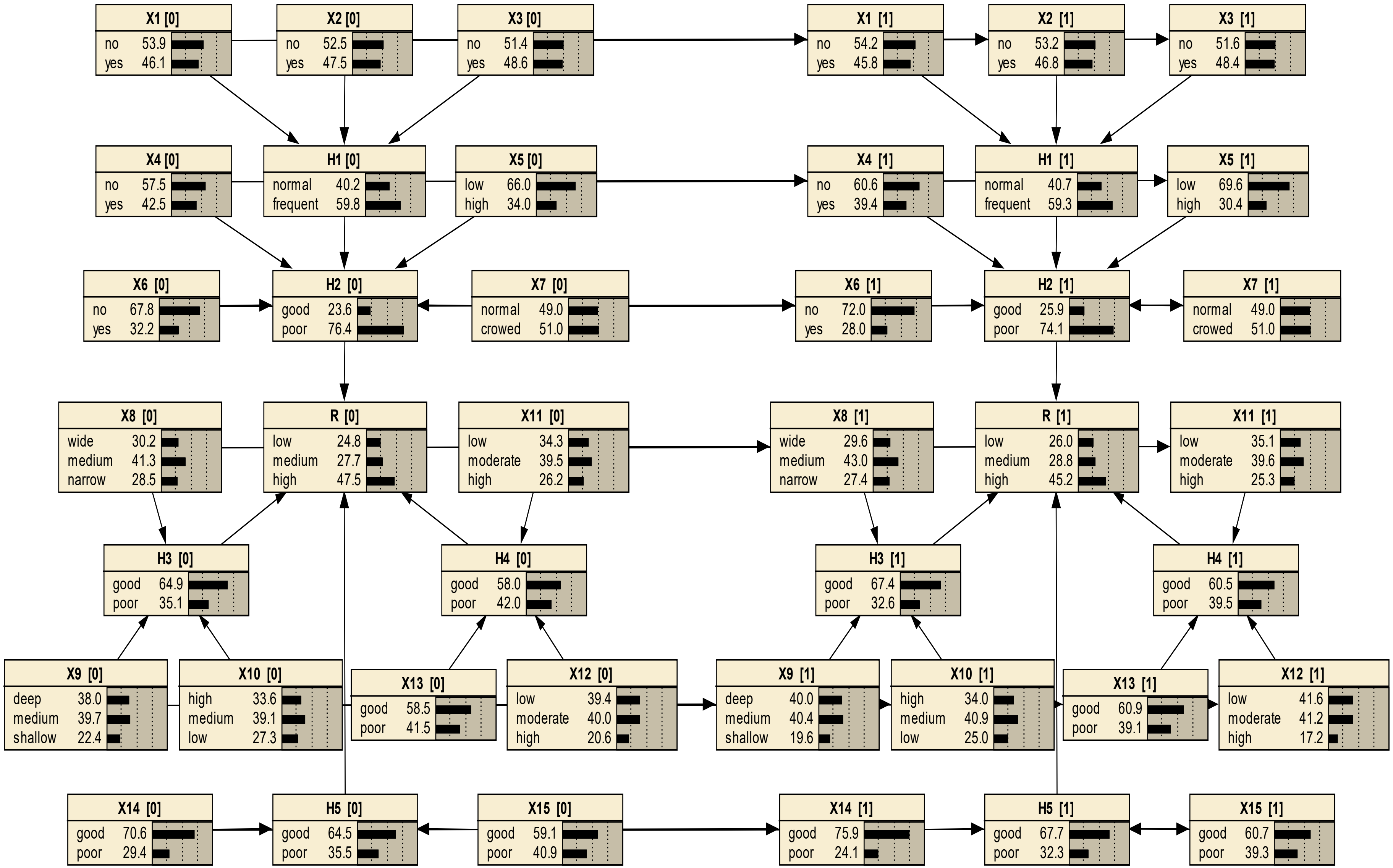

Figure 3: Dynamic Prediction of Emergencies Risk Probability of Sea Lane

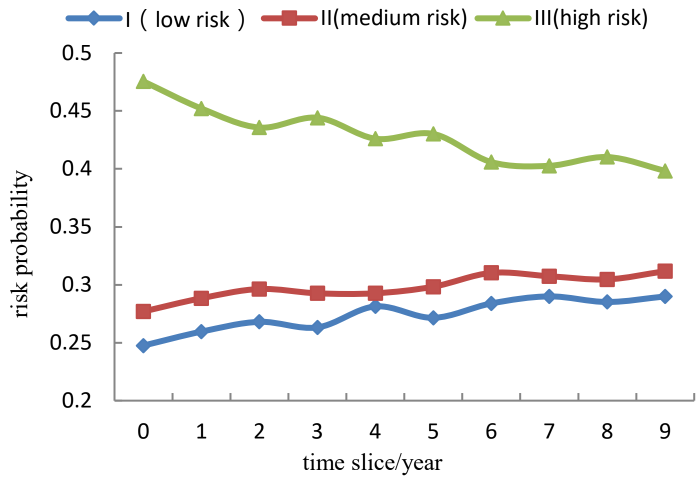

Figure 4: Dynamic Predication of Emergencies Risk Probability of Sea Lanes

4.2. Sensitivity Analysis

The sensitivity analysis is to determine the degree of influence of the observed node on the uncertainty of the query node. The query node in this paper refers to the risk of the sea lanes, that is, using the known evidence to identify the influencing factors that affecting the risk of the sea lanes mostly.

Mutual information represents the amount of information shared between two variables, that is, the degree to which the entropy of the query node is reduced given the probability of evidence nodes, which is a measure of the degree of interdependence between the observed node and the query node. The mutual information of two discrete random variables X and Y can be defined as:

$$H(X;Y)=\sum_{y\in Y}\sum_{x\in X}P(x,y)\log\left(\frac{P(x,y)}{p(x)p(y)}\right) \tag{19}$$

where, $P(x,y)$ is the joint probability distribution function of X and Y and; $p(x)$ and $p(y)$ are the edge probability distribution functions of X and Y, respectively.

As can be seen from Fig.5, it represents the change of probability for the node 'risk of sea lanes' accordance to the changes made to its parent nodes 'natural environment', 'safety environment', 'geographical environment', and 'law environment'. The shapes of the curves indicate that the natural environment is the most sensitivity node to the risk of sea lanes.

In order to determine the degree of dependence between the risk of the sea lanes and its influencing factors, the formula (19) is applied to obtain the mutual information of the sea lanes risk and the observed nodes at t0 and t9 as shown in Fig.6 using the proposed model.

Seen from Fig.6, at t0 and t9, although there are some differences between mutual information of the sea lanes risk and the observed nodes, the order of importance level is identical. The importance of nodes in descending order are: 1 wind, 2 wave, 3 visibility, 4 pirate attacks, 5 depth, 6 law, 7 width, 8 risk of war, 9 terrorism, 10 substitutability, 11 politics, 12 ship flow, 13 military exercise, 14 military base and 15 organizations.

Seen from Fig.7, it represents the change of mutual information of the sea lanes risk and four most sensitive nodes 'wind', 'wave', 'visibility', and 'pirate attacks' from t0 to t9.Althought the value of mutual information fluctuates in a small range, the order of sensitivity level is identical. The node of 'wind' is still the primary important factor followed by 'wave', 'visibility', and 'pirate attacks'.

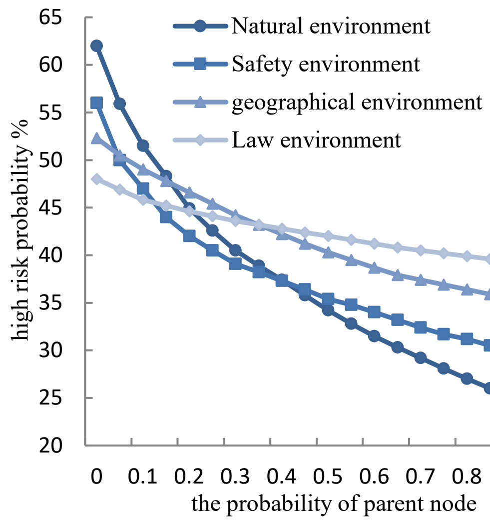

Figure 5: The Sensitivity of Emergencies Risk Based on Prior Knowledge

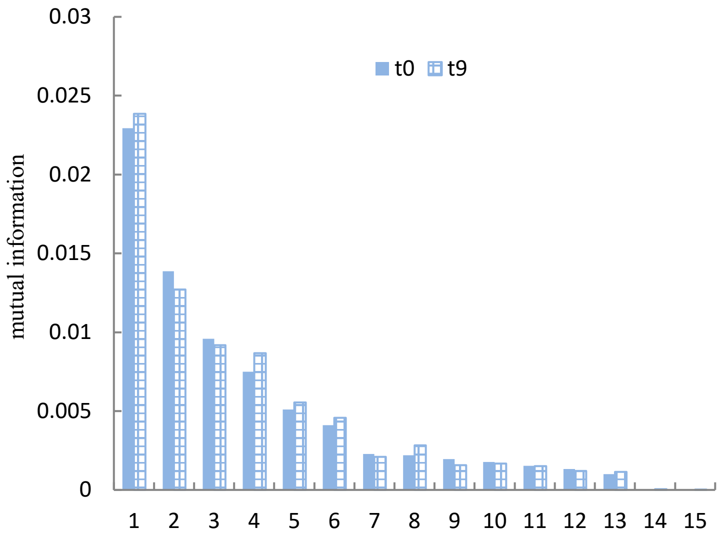

Figure 6: The Mutual Information of the Sea Lanes Risk and the Observed Nodes

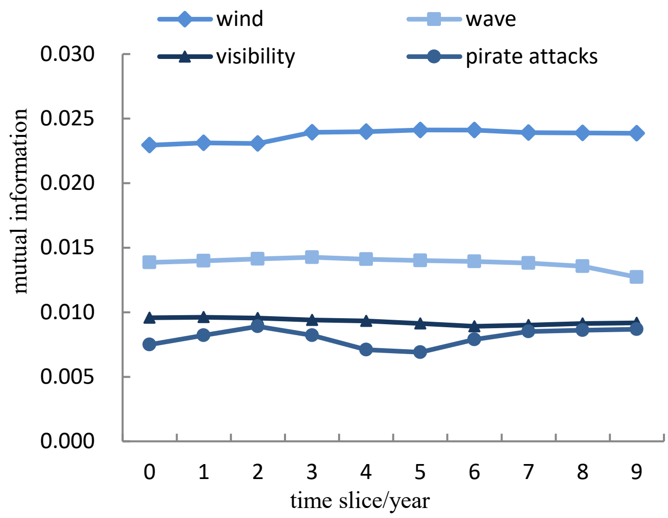

Figure 7: The Mutual Information of the Sea Lanes Risk and the Observed Nodes form t0 to t9

5. Conclusions

(1) A statistical analysis of the incidents is used to provide guidance for the construction of BN. The prior probability is determined by using Evidence Theory model based on historical data. The EM algorithm is devised to learn the conditional probability. The transition matrix of random variables is obtained based on the Markov model. Viterbi algorithm is adopted to predicate emergencies risk probability.

(2) The DBN model is proposed to predict the dynamic probability of emergencies risk. The respective probabilities of high risk are 0.47548 at t0，0.45205 at t1, while the low risk are 0.24754 at t0, 0.25956 at t1.

(3) Sensitivity analysis is proposed to obtain the significant contributors that lead to the emergencies of sea lanes. The results show that wind, wave, visibility and pirate attacks are the main sensitive factors that cause the emergencies of sea lane.

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China's Inland Water Traffic Security Risk Assessment Based on Data Mining

Zhaochen Wang[1]*, and Jingbo Yin*[1]

[1]State Key Laboratory of Ocean Engineering, School of Naval Architecture, Ocean and Civil Engineering, Shanghai Jiao Tong University, Shanghai, 200240, China
Email: [1]wangzhaochen@sjtu.edu.cn

Abstract

China has constructed a relatively completed inland water transportation system, which has achieved unprecedented development in the past few decades. However, the frequent occurance of inland water ship accident with serious consequences is still urgent unsolved problem. The occurrence of catastrophic accident, the *Orient Star* shipwreck, caused huge casualties and property losses, and sounded the alarm about China's inland water traffic safety problems again. To help circumvent such accidents in the future and to improve inland water traffic safety, this paper uses text mining and association rule mining in popular data mining technology rather than traditional quantitative risk assessment model to achieve China's inland water traffic safety risk assessment. Taking advantage of texting mining, risk factors are identified and filtered out from accident reports text data. In addition, risk variables as well as their thersolds are defined by systematizing ship, environment, human, and accident four types risk factors and relationship between variables is explored using association rule mining based on FP-Growth algorithm. The results of the analyses reveal the essential problem facing China's inland water traffic systems— frequent and varied ship accidents. Morever, results also discover that overload or improper loading phenomenon is existed, navigation visibility is poor, sailor quality is below par and the government has insufficient supervision of shipowner and company. Incorporating actual circumstances of domestic inland water traffic operations, recommendations are proposed placing more emphasis on unifying current rules, and promulgating formal laws and regulations for inland water navigation for the government and relevant legal supervisory departments.

Keywords: *Text Mining, Association Rule Mining, FP-Growth Algorithm, Risk Assessment*

1. Introduction

On June 1, 2015, the passenger ship *Orient Star* carrying 454 people encountered strong convective weather on the Yangtze River and finally sank with only 12 survived. This catastrophic event caused huge casualties and property losses, which immediately aroused high degree of concern about China inland water traffic safety.

Although China's inland water transportation system has the unprecedented development in the past few years, while the rate of ship accidents is much higher than occident countries. Furthermore, China's inland water traffic safety problem is historic and complex. Specifically, in term of inland water ships, diverse ship type, older vessel age, small average tonnage, and inconsistent ship standards are common problems in actual navigation. In term of environment, water condition is intricate and has seasonal variability characteristic; low-level channels account for a larger proportion than high-level channels; shallow areas accompanied with curved narrow sections, natural disasters such as flood, coastal landslides, and extreme weather are inevitable. In term of human resources, actual artificial supervision is difficult and some inland waters lack unified legal system. Therefore, ship, environment, and human resources, all these risk factors may directly or indirectly result in accidents occurring.

To help circumvent such accidents in the future and to improve inland water traffic safety, this paper explores inland river water traffic safety risk factors and interrelationship to achieve risk assessment by making use of data mining technology, mainly text mining and association rule mining. These technologies are increasingly applied to searching for valuable information hidden from large amounts of data through algorithms, which have become a research focus in the era of big data.

The remainder of this paper is organized as follows: Section 2 reviews the current literature related to water transportation risk research and cases of text mining and association rule mining application. Section 3 introduces methodologies and techniques in this paper. Section 4 describes the whole data mining process, which uses text mining to achieve key risk factors selection and systematize selected risk factors to determine 18 risk variables and their 53 thersolds from ship, environment, human, and accident, further digs out strong association rules and explores relationship between variables based on association rule mining. Section 5 contacts the actual situation and provides recommendation to the government and relevant legal supervisory departments based on the analysis results. Finally, Section 6 reveals the contributions and implications with respect to this study.

2. Literature Review

2.1. Study of Water Risk Analysis

Reseach of water risk analysis is mainly focused on marine transportation and kinds of risk factors related with marine ship accidents have been exhaustive studied using different methods. With respect to accident factors, Kite-Powell et al. (2011) formulated a Bayesian model to estimate the physical risk of stranding based on surrounding stranding data in three U.S. ports between 1981 and 1995. Goerlandt and Kujala (2011) applied Monte Carlo simulation technique to assess the probability of vessels colliding with each other. The method is capable of determining the expected number of accidents, the locations where and the time when they are most likely to occur, while providing input for models concerned with the expected consequences. With respect to ship and environment factors, Heij and Knapp (2012) selected factors such as vessel age, ship type, ship size, ship owner, and so on to construct a single ship risk assessment model and select factors such as past accidents, inspections, loss, and changes of particulars to construct a company risk assessment model. Trbojevic et al. (2000) carried out the hazard identification and the qualitative risk assessment to establish preventing water environment hazards and integrated controls for managing these hazards into the Safety Management System. With respect to human factors, Akhtar and Utne (2014) constructed a Bayesian network based on the Human Factors Analysis and Classification System to study the risk impacts of fatigue-related factors on ship grounding, and found that the most relevant factors are vessel certifications, human resources and quality control. Eleye-Datubo et al. (2008) introduced a fuzzy-bayesian network incorporating the human element into a probabilistic risk-based model to research marine and offshore safety assessment.

Inland waters has relatively fewer studies than martime field no matter at home and abroad, and relevant research methods are also originated from the relatively mature martime field. For example, Xi and Yang (2015) took advantage of Analytic Hierarchy Process to assess Wuhan inland waters ship navigation safety. Zhen-Kai et al. (2015) achieved comprehensive evaluation on flood risk of Poyang Lake Basin based on multi-level gray system model. Zhang et al. (2016) incorporated a fuzzy rule base technique and an Evidential Reasoning (ER) algorithm to conduct the navigational risk assessment of inland waterway transportation system. Zhang et al. (2013) estimated the navigational risk of the Yangtze River using the FSA concept and a Bayesian network (BN) technique to improve the navigational safety in the Yangtze River.

Meanwhile, most of the domestic research on studying inland water traffic safety is focused on the specific water area rather than whole inland water system, such as Yangtze River, Tianjin Port (Zhang et al., 2016).

2.2. Text Mining Research

The conpect of text mining originated in the 1950s and research focus was on kinds of algorithms. For example, Mladenic and Grobelnik (1999) analyzed and compared the accuracy and speed of different feature evaluation algorithms, and concluded that the weight of text evidence and the expected cross entropy are more efficient.

At present, text mining technology is widely used in various domain research. In security field, text mining is applied to monitor and analyse online plain text sources such as Internet news, blogs, etc for preventing terrorism (Zanasi, 2009). In business field, it is used to improve predictive analytics for churn-prediction models (Coussement and Poel, 2008), it is also applied in stock returns prediction (Gálvez et al., 2017). Morever, Text mining can analyse sentiment studies, which may need a labeled data set or labeling of the affectivity of words (Valitutti, 2005). Even some disciplines form specialized research field based on text mining technology, such as biomedical text mining.

2.3. Association Rule Mining Research

Association rule mining research was first applied to sales analysis to mine co-presence of products in transactions and maked bundled promotions to help sales, and the well-known example is "beer diaper".

Today, association rule mining technology is not only applied to sales analysis, but also widely used in many other fields. Domestic and foreign scholars have conducted lots of research on association rule mining from the perspective of technology and application. Yan et al. (2014) analyzed the relationship between climate indicators and precipitation, and made up for the lack of traditional data analysis taking advantage of association rule mining. Céline et al. (2002) mined strong association rules for large-scale gene-expression data analysis in human SAGE data. Enrique et al. (2009) applied association rule mining to discover interesting information through studentspsila usage data for making recommendations to courseware authors. Joshi and Sodhi (2014) analyzed consumer preferences to improve the scalability of online advertising and propose an internet marketing strategy based on association rule minging. Nahar et al. (2013) based on association mining algorithm to find male and female hearts Disease and health factors.

Considering the fact that applications of text mining and association rule mining are almost blank in inland waters traffic safety research, this paper creatively conbines the text mining and association rule mining to achieve the whole China inland water traffic safety risk assessment by data-driven.

3. Methodology

Although the concept of data mining originates earlier, it has been the focus of current academic research taking advantage of the rapid development of big data technology, itself objectivity and scientific characteristics. Data mining is the process of discovering patterns in large data sets involving methods at the intersection of machine learning, statistics and database systems with an overall goal to extract information from a data set, and transform the information into a comprehensible structure for further use. Data mining has been widely applied to such fields as finance, e-commerce, medicine, logistics etc., which has achieved numerous research results.

3.1. Data Acquisition

This paper collects 536 units of China inland water accident reports for decades as text data, involving 189 units from 2016 to 2018, 309 units from 2000 to 2016 and 38 units before 2000. The number of accident reports from 2000 to 2016 is beyond 35%. Those accident reports provide not only thorough description for each accident but also their reasons for this paper to do following text mining and association rule mining.

3.2. Text Mining

Text mining, also equivalent to text data mining, is the computer process of obtaining potentially valuable information and knowledge from text. Valuable information and knowledge which usually refer to some combination of relevance, novelty, and interest, is typically derived through the devising of patterns and trends through means such as statistical pattern learning.

Text mining usually involves the process of structuring the input text (usually parsing, along with the addition of some derived linguistic features and the removal of others, and subsequent insertion into a database), deriving patterns within the structured data, and finally evaluation and interpretation of the output. Revently mainly tasks include information retrieval, lexical analysis to study word frequency distributions, pattern recognition, tagging/annotation, information extraction, mining techniques, visualization, and predictive analytics. The overarching goal is, essentially, to turn text into data for analysis, via application of natural language processing (NLP) and related algorithms.

In view of all 536 China inland water accident reports are written in Chinese and the fact is that due to differences in language, Chinese text has more difficult separation system than foreign languages so that mining of Chinese text is relatively complicated to achieve better results turning text into data. Therefore, this paper finally chooses $tf-idf$ (term frequency-inverse document frequency) as the algorithm to deal with this analysis process, which is a commonly used in Chinese text. tf (term frequency) is the frequency at which individual terms appear in the document after vectorization, while idf (inverse document frequency) reflects the frequency at which a term appears in all documents.

Suppose that D represents a document or one section of it, N represents all documents and T refers to the basic language unit that can represent the text material, such as words, characters, etc. during text mining.

tf can be defined as:

$$tf_{i,j} = \frac{n_{i,j}}{\sum_k n_{k,j}} \tag{1}$$

Where $n_{i,j}$ means number of the term appears in D_i ; $\sum_k n_{k,j}$ means number of all terms appears in N .

idf can be defined as:

$$idf_i = \lg \frac{N}{1 + \left|\{j : t_i \in d_j\}\right|} \tag{2}$$

Where $\left|\{j : t_i \in d_j\}\right|$ means number of documents contain t_i . If the term is not in the corpus, this will lead to a division-by-zero, so it is common to adjust the denominator to $1 + \left|\{j : t_i \in d_j\}\right|$.

So the weight of t_i can be gained by this way:

$$tf-idf_{i,j} = tf_{i,j} \times idf_i \tag{3}$$

That is, in $tf-idf$, the weight of each term is up to both tf and idf . For example, most every accident report has “accident”, so the high tf value of “accident” leads to the final $tf-idf$ is high; meanwhile, some professional noun related with accident reason likes “moulded depth” and its final $tf-idf$ also can be high because of high idf value. By comparing different weight value, this paper can identify and filter out mining keywords with certain characteristics in text information.

3.3. Association Rule Mining

Association rule mining, called as association rule learning, is a rule-based machine learning method for discovering interesting relations between variables in large databases. It identifies strong rules such as frequent patterns, associations, correlations, or causal relationship, discovered in databases using some measures of interestingness.

According to Agrawal et al. (1993), the problem of association rule mining is defined as:

Let $I=\{i_1, i_2, ..., i_n\}$ be a set of n binary attributes called items and $D=\{t_1, t_2, ..., t_n\}$ be a set of transactions called the database. Each transaction in D has a unique transaction ID and contains a subset of the items in I .

A rule is described as an implication of the form:

$X \Rightarrow Y$, where $X, Y \subseteq I$

Every rule is composed by two different sets of items, also known as itemsets, X and Y, where X is called antecedent or left-hand-side (LHS) and Y is called consequent or right-hand-side (RHS).

In order to select interesting rules from all possible set rules, constraints on various measures of significance and interest, such as support, confidence, lift, and conviction are used. The best-known constraints are minimum thresholds on support and confidence.

Suppose X is an itemset, $X \Rightarrow Y$ an association rule, and T a set of transactions of a given database. Support is an indication of how frequently the itemset appears in the dataset, which is a set of preconditions and becomes more restrictive instead of more inclusive as it grows. The support of X with respect to T is defined as the proportion of transactions t in the dataset which contains the itemset X, as followed:

$$\mathrm{supp}(X)=\frac{|\{t \in T; X \subseteq t\}|}{|T|} \tag{4}$$

Confidence is an indication of how often the rule has been found to be true, which can be express as:

$$conf(X \Rightarrow Y)=\frac{supp(X \cup Y)}{\mathrm{supp}(X)} \tag{5}$$

The confidence value of $X \Rightarrow Y$ with respect to a set of transactions T is the proportion of the transactions that contains X which also contains Y. If the value of $conf(X \Rightarrow Y)$ equals 1, the rule $X \Rightarrow Y$ is inevitable.

Moreover, the indication lift and conviction are derived from support and confidence. They are respectively defined as:

$$lift(X \Rightarrow Y) = \frac{supp(X \cup Y)}{\mathrm{supp}(X) \times \mathrm{supp}(Y)} \tag{6}$$

$$conv(X \Rightarrow Y) = \frac{1 - supp(Y)}{1 - conf(X \Rightarrow Y)} \tag{7}$$

Association rules are required to meet minimum support and a minimum confidence at the same time. In most conditions, association rule generation is divided into two separate steps. The frist step is applying a minimum support threshold to find all frequent itemsets in a database, and the second step is applying a minimum confidence constraint to get these frequent itemsets in order to form rules. Moreover, the first step is much more difficult than the second step since it involves searching all possible itemsets (item combinations). The set of possible itemsets is the power set over I, which has size $2^n - 1$ except the invalid empty set.

Although the size of the power-set grows exponentially in the number of items n in I, some algorithms like Apriorit have been put forward to find all frequent itemsets exploiting the downward-closure property of support, which guarantees that for a frequent itemset, all its subsets are also frequent and thus no infrequent itemset can be a subset of a frequent itemset. However, these algorithms scan the database too many times, and load up the candidate set with as many as possible before each scan using bottom-up subset exploration. Due to this, these algorithms suffer from inefficiencies or trade-offs, also the time and space complexity of algorithm is very high.

This paper applies efficient FP-growth (Frequent Pattern-growth) algorithm to achieve association rule mining, which only need to scan the database two times and avoid generating great amounts of candidate sets effectively taking advantage of the tree structure. FP- growth algorithm mainly contains five steps:

Step one: Scan the data to count occurrence of items (attribute-value pairs) in the dataset, delete the items whose support is lower than the minimum threshold, and stores them to the header table by descending order of their support.

Step two: Scan the data except deleted part again, and build the FP-tree structure by inserting instances. Items in each instance have to be sorted by descending order of their support. Items in each instance that do not meet minimum support threshold are discarded. If many instances share most frequent items, FP-tree provides high compression close to tree root.

Step three: Start growth from the bottom of the header table having longest branches by finding all instances matching given condition. New tree is created, with counts projected from the original tree corresponding to the set of instances that are conditional on the attribute, with each node getting sum of its children counts. Recursive growth ends untill no individual items conditional on the attribute meet minimum support threshold, and processing continues on the remaining header items of the original FP-tree.

Step four: Find the condition pattern base corresponding to the item header item from the bottom item of the item header table. The frequent item set of the item header item is obtained by recursively mining from the conditional pattern base.

Step five: Begin association rule creation after the recursive process has completed.

4. Results

This paper chooses $tf-idf$ algorithm for text mining to identify, filter out key risk factors from 536 China's inland water accident reports text data, and compares the results of $tf-idf$ with other algorithm to confirm its correctness. Then, this paper systematizes four sorts of risk factors containing 15 risk variables, and determines thresholds of each variable according to visualized word cloud analysis and relevant research theory. At last, this paper mines the associations between 15 variables and builds the relationship networks using association rule mining on FP-Growth algorithm.

4.1. Text Mining Results

As stated in the previous section, this paper firstly builds the database based on the 536 units of China inland water accident reports. Secondly, to get plain text data, this paper does preprocessing for report text in database which refers to the elimination of noise documents to improve mining accuracy, or only select a portion of the sample when context of document is too miscellaneous to improve mining efficiency, because of some reports collected from webpage contain much unnecessary information, such as advertisements, navigation bars, html, comments, etc. Thirdly, this paper loads word segmentation dictionary, which contains some professional words in the fields of water traffic engineering, safety engineering, shipping, meteorology, etc. to prevent missing or misunderstang, and delete stopwords, which are abundant in database but have no practical meaning, such as punctuation and some adjectives. This paper uses common Chinese stopword list to achieve part-of-speech tagging, then carried on segmentation (the process of recombining consecutive word sequences into word sequences according to certain norms) for plain text data. Finally, this paper uses $tf-idf$ to achieve processed text mathematical, and extracts top 40 key words sorted by corresponding weights in descending orders. As Figure 1 shown, these 40 key words are *Accident*, *Ship*, *Collision*, *Consequence of accident*, *Main engine*, *Navigation condition*, *Collision avoidance*, *Reason*, *Gross bead weight tonnage*, *Ship breadth*, *Moulded depth*, *Water and Wave* , *Watch*, *Dead weight cargo tonnage*, *Performance parameter*, *Sinkage, Captain and Shipping company*, *General Cargo ship*, *Bottom*, *Bulk carrier*, *Accident type*, *Measure*, *Fairway*, *Power*, *Sailor*, *Speed*, *Length overall*, *Situation*, *Draft*, *Danger recognization*, *Visibility*, *Fishing ship*, *Container ship*, *Wind*, *Internal combustion engine*, *Quay*, *Negligence*, *Effectively and timely*, *Improper loading*, *Full loading.*

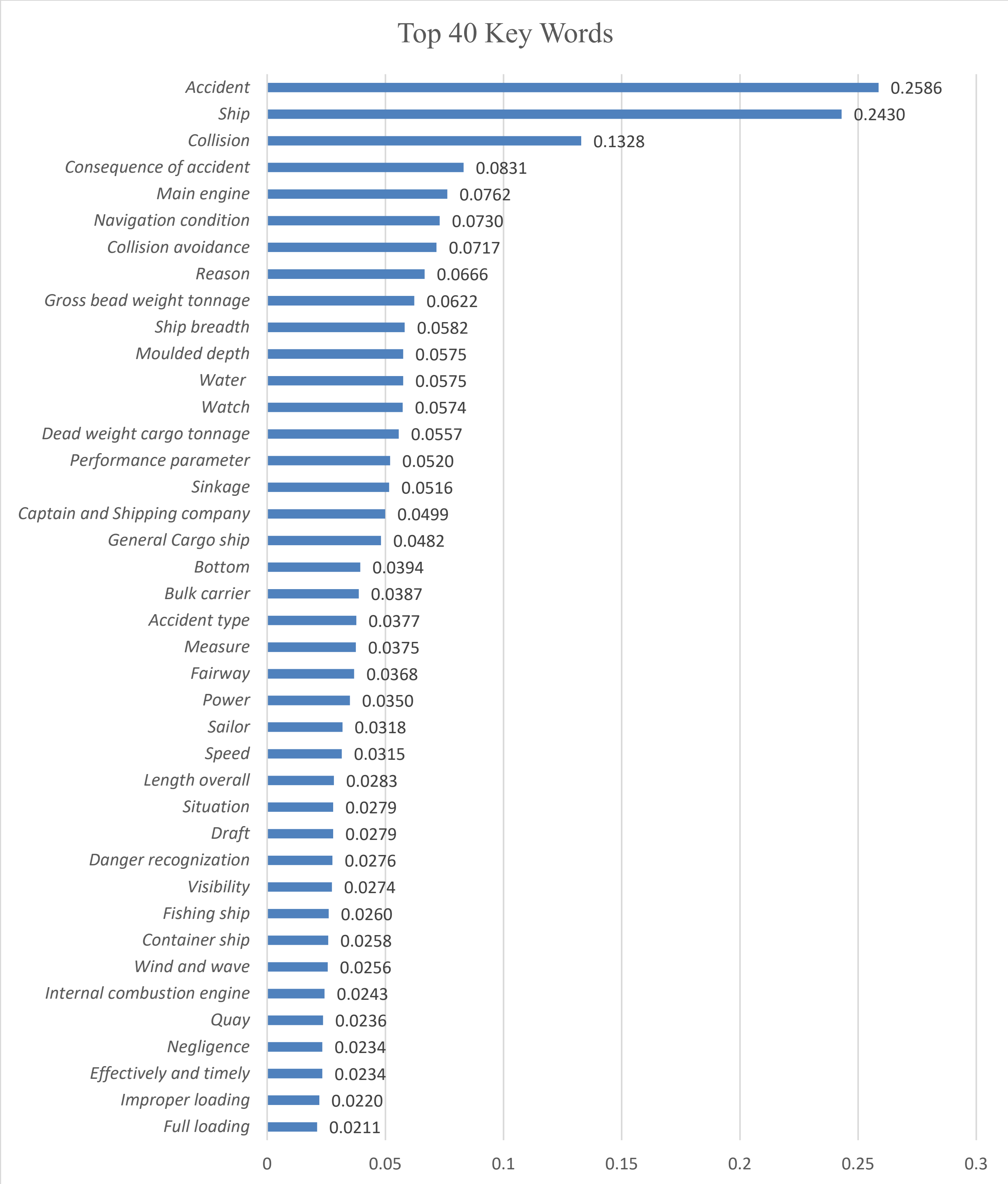

Figure 1: Top 40 Key Words

Visualizating results and making relevant wordclouds show in the left of figure. Similarly, the paper also uses another algorithm, Pagerank, to achieve text mining, the visualization results as the right of Figure 2 shown. Comparing two relusts, the results of $tf-idf$ is better and match the actual situation.

Figure 2: Word Cloud

4.2. Detetmine Risk Variable

In the top 40 key words, some of them decribes same thing, like *Consequence of accident*, *Situation* both describe consequences of accident; *Collision*, *Sinkage* both describe accident types, they both belong to accidents. *Gross bead weight tonnage*, *Dead weight cargo tonnage*, *Draft* all describe gross tonnage; *Ship breadth*, *Moulded depth*, *General Cargo ship*, *Bottom*, *Bulk carrier*, *Length overall*, *Fishing ship*, *Container ship* all describe ship types; *Full loading and improper laoding* both describe *Stability*; *Performance parameter*, *Main engine*, *Internal combustion engine*, *Power* all describe devices, they all belong to ships. *Navigation condition* containing *Fairway* and *Quay*, *Water*, *Visibility*, and *Wind* both belong to environment. *Watch* containing *Negligence*, *Captain and shipping company*, *Sailor*, *Speed*, *Danger recognization* containing *Collision avoidance*, *Measure* containing *Effectively and timely*, these belong to human resoures.

Based appeal analysis, Risk factors of inland water traffic can be divided into four categories—ship factors, environment factors, human factors, and accident factors. This division result is reasonable and explainable. Firstly, ship conditions are the precondition and foundation for safe navigation. Secondly, environment is the significant factor because of various kinds of danger in actual sailing environment. Thirdly, in the past, it appears that most of catastrophic ship accidents are related to human factors. Considering that human particularity depicting that good or bad of the same behavior leads to exactly opposite result, human resources are indeed an important factor. Eventually, Accident are essential for being research objectives of this risk accessment.

As Table 1 (see Appendix) shown, the first column lists all four risk factors, the second and third columns separately list total 15 variables and corresponding thresholds. Ship variables are as follows: *gross tonnage*, *ship type*, *stability* and *device*. Environment variables are as follows: *navigation condition*, *wind* and *visibility*; human variables are as follows: *shipowner and company*, *sailor* (which refers to the general name of captain and crew in this paper), *watch*, *danger recognition*, *speed* and *measure*. Accident variables are as follows: *accident type* and *consequence of accident*. The last column explains reasons why choose these variables. It is worth mentioning that *consequence of accident* is classified into—minor (only injury, loss of less than 1 million), major (1-2 deaths, loss of 1 million to 3 million), critical (3-5 deaths, loss of 3 million to 5 million, environmental pollution), and catastrophic (more than 5 deaths, more than 5 million losses, serious environmental pollution) based on the number of deaths, economic losses, and the degree of environmental pollution.

This classification standards has relevant theoretical basis, many of them have been decribed in previous studies, so this paper refers them directly. For example, Li et al. (2014) showed that gross tonnage is linked with ship accidents; stability is proved to be important according to the labor registration agency (2008) from 1994 to 1995. Hetherington et al. (2006) pointed out that good management is crucial to the safety of navigation, and depends on the shipowner and company; Hänninen, M. and Kujala, P. (2012) found that sailors' seaworthiness, competence, and staffing levels are the most influential factors; Ren et al. (2008) discovered that danger recognition is sensitive to accidents among human factors; Rule 6 in the 1972 International Regulations for Preventing Collisions at Sea stipulates that each ship shall be driven at safe speed at all times (Kang et al., 2009). These studies provide theoretical support for selecting risk factors sub-indicators.

4.3. Association Rule Mining Results

Based text mining technology, this paper has identified key risk variables **and filtered out**, which have great impact on China's inland water traffic safety, and determines their thresholds for further studying after **text mining** processing. Neverless, the specific relationship between those choosen risk variables is still unclear due to choosen risk variables only represent these words have significant status in accident reports. Accident report text not only involves key factors causing these accidents, but also contains the description of ship navigation status, which may related other risk factors, when accident occurred, so other essential risk factors information of these accidents can also appear in text mining results, which is not Accidental causes. For example, one accident report explains the main accident reason is overloading during navigation, and records the 300t fishing ship does watch careful also has good navigation condition, in which case, *300t*, *fishing ship*, *watch careful* and *good navigation condition* all have chances to become the results of texting mining except *overloading*. Therefore, it is necessary to carry on association rule mining to further explore the relationship between different risk variables.

Based on FP-Growth algorithm, this paper selectes 0.02 as support and 0.8 as confidence on the condition that LHS is *Consequence of accident* during association rule mining. Total 779 rules are filtered out after association rule mining, involving 3 rules when *Consequence of accident* = *Catastrophic*, 6 rules when *Consequence of accident* = *Critical*, 36 rules when *Consequence of accident* = *Major*, 754 rules when *consequence of accident* = *Minor*. Figure 3 displays a scatter plot of the 779 rule, where blue dots represent support of each rule and organze dots represent confidence of each rule. In all rules, minor accident rules is up to 96.79%. This is scientific and practical because China's inland water traffic accidents are dominated by small accidents, and critical and catastrophic accidents are rare in actual production.

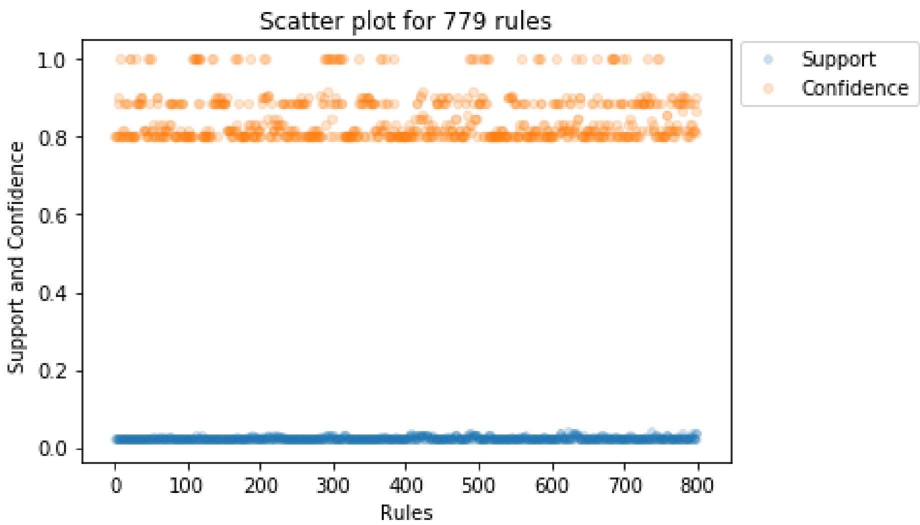

Figure 3: Scatter Plot for 779 Rules

For easy and intuitive visual display of 799 rules, this paper use the software Gephi making them transform into the risk variables relationship network. As Figure 4 shown, different color nodes represent different types of risk variables and their thersolds; the size of node represents its indegree; the line between different nodes represents their the relationship strength (each LHS of rules is given same unit weight, and composition variable nodes get average distribution weight, so the relationship strength can be measured by weight accumulation between same nodes), the stronger relationship is, the thicker the line is.

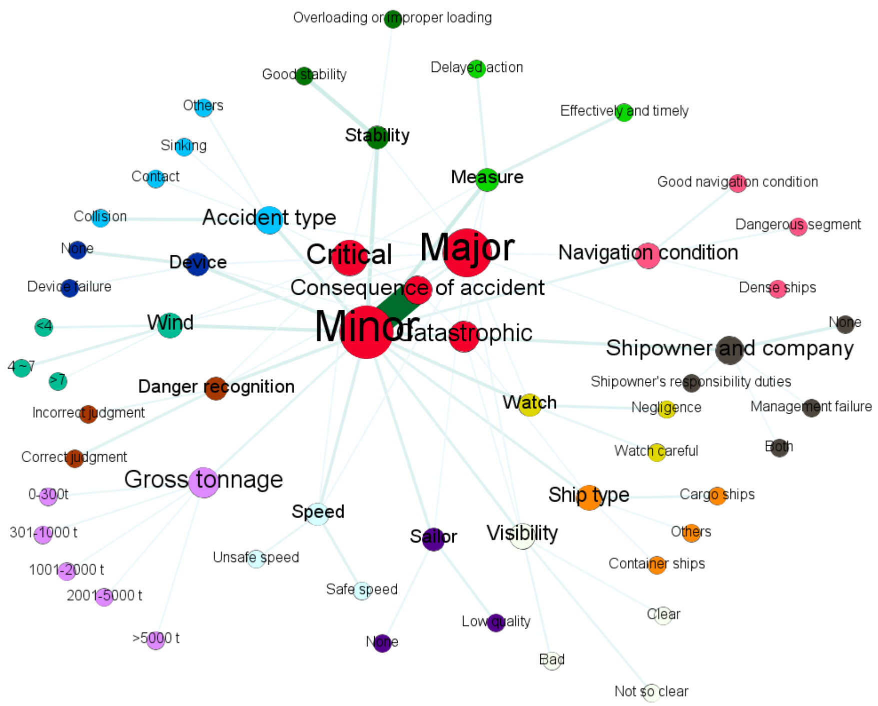

Figure 4: Risk Variables Relationship Network

According to Figure 4, top 5 having strongest association with *Consequence of accident* is as follow: *Accident type = Collision*, *Watch = Negligence*, *Sailor = Low quality*, *Ship type = Cargo ship*, and *Visibility = Not so clear*. In addition, though *Stability = Good Stability* indeed has stronger association with *Consequence of accident* than *Accident type = Collision*, good ship stability has positive effects on navigation, and not match this paper research purpose which studies key risk factors resulted in accidents happening, thus these results are not taken in consideration. Based on the above analysis results, the type of China's inland water traffic accident is is likely to be collision, and accident ship type is cargo ship. Morever, the main causes are negligence watch, low quality sailor, and not good visibility.

While Figure 4 barely reflects general overview of the inland water traffic accidents, mainly minor accidents. As mentioned above, in spite of critical and catastrophic accidents are rare, they can cause huge property damage and casualties. From this point, critical and catastrophic accidents is worth intensive study to prevent them happening. This paper further visualizes critical and catastrophic association accidents rules similarly. Figure 5 clearly reveals significant importance of human risk variables to occurrence of critical and catastrophic accidents excluding Figure 4 shows part results. *Consequence of accident = Catastrophic* and *Critical* associates *Shipowner and company = Both*, *Speed = Unsafe speed*, *Measure = Delayed action*, and *Danger recognition = Incorrect judgement*, these risk variables are belong to human factors without exception. In addition, Overload or improper loading causing lost of ship stability has closely linkage with human factors.

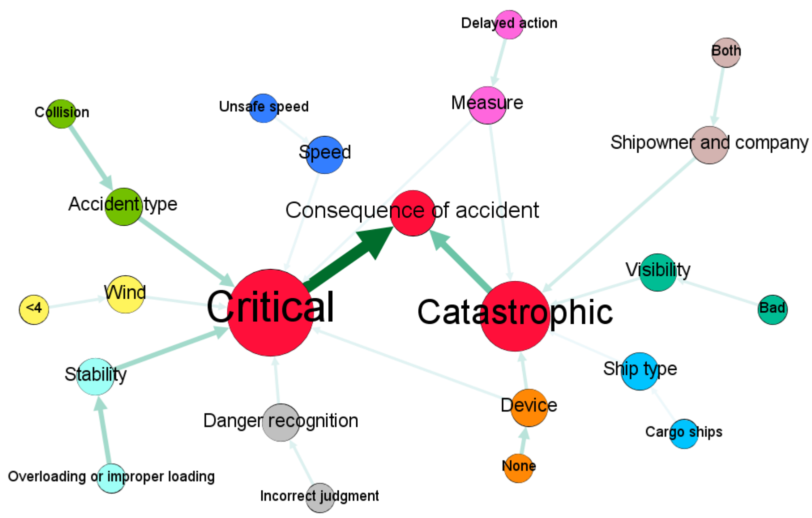

Figure 5: Risk Variables Relationship Sub-network

5. Discussion and Recommendations

Based on these analyses results, these risk variables do have the obvious impact on accidents. With respect to ship factors, *Ship type = Cargo ship* and *Stability= overload or improper loading*. With respect to environment factors, *Visibility = Not so clear*. With respect to accident factors, *Accident type = Collision*. With respect to human factors, *Watch = Negligence*, *Sailor = Low quality*, *Shipowner and company = Both*, *Speed= Unsafe speed*, *Measure= Delayed action*, and *Danger recognition = Incorrect judgement*. Taking all these results of the analyses into consideration, recommendations to improve China's inland water traffic safety are as follows:

1. Prohibit overload behavior

With regard to *Stability= Overload or improper loading*, the maritime affair department should formulate the appropriate regulations and the ship inspection department should strictly supervise the implementation of the regulations. Becides, ports and other departments should also assist to supervise loading of ships at the terminal. Related legal policy should be enacted that authorizes the port department to penalize shipowner or company that responsible for overloading ships and unloading overloaded ships, which essentially eliminates illegal overloading from the source.

2. Pay attention to navigation visibility

With regard to *Visibility = Not so clear* at the piont view of environment, China's government should increase warning sign for cruved and narrow channels with poor visibility, and pay more attention to repairing these channel to expand sailing horizon. Moreover, the government should strengthen the construction of navigation laws and regulations under poor visibility considering that the current related laws and regulations are far from meeting the requirements of the times. An effective early warning mechanism for bad weather also should be established.

3. Standardize shipping companies management

With regard to *Shipowner and company = Both* and *Ship type = Cargo ship*, there are few laws and regulations on safety management for shipping companies at present. Therefore, the relevant departments should review the safety management systems of shipping enterprises, and if these enterprises do not satisfy safety supervision standards, their qualification for ship operation will be cancelled until rectified. As for cargo ship company, they should be paid extra attention due to frequent accidents.

4. Improve sailor competence

With regard to *Accident type = Collision*, *Sailor = Low quality*, *Watch = Negligence*, *Danger recognition = Incorrect judgement*, and *Measure= Delayed action*, all these are associated with sailors. Although China has already enacted laws regulating sailors' responsibilities, obligations and duties, there is no significant effect in practice. In order to improve this situation, the relevant departments should force sailors to attend training, including skills of accurate observation, positive communication with maritime traffic control, precisely judge dangerous trends, and timely measures when dangers occur, making self-competence meet job requirments before sailing. In view of China's inland water sailor generally lower competence, the relevant departments can consider the introduction of relevant talents.

6. Conclusions

Owing to weaknesses in ships, environment, and human factors during navigation, problems of China's inland water traffic security are urgent to be solved. To improve this situation, this paper obtains comprehensive text data based on 536 domestic inland water accident reports. By technology applying of texting mining and association rule mining, this paper first achieves key risk words filtered out, further determines 15 risk variables as well as their 53 thersolds from ship, environment, human, and accident total four aspects to establish completed risk assessment system combining theory and practice, finally digs out strong association rules in risk assessment system, and builds rules relationship visualization network completing the relevant analyses.

The results of the analyses reveal the essential problem facing China's inland water traffic systems—frequent and varied ship accidents. Morever, results also discover that overload or improper loading phenomenon is existed, navigation visibility is poor, sailor quality is below par, and the government has insufficient supervision of shipowner and company. Incorporating actual circumstances of domestic inland water traffic operations, recommendations are proposed placing more emphasis on unifying current rules and promulgating formal laws and regulations for inland water navigation for the government and relevant legal supervisory departments.

7. Acknowledgements

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From Full Freighters to Belly Cargo Aircraft: Stochastic Analysis of Alternatives for Freight in Schiphol Airport

Miguel Mujica Mota[1], *Abdel El Makhloufi*[2], *and Rodrigo Romero*[3]

[1]Aviation Academy, Amsterdam University of Applied Sciences, The Netherlands
[2]Urban Technology, Amsterdam University of applied Sciences, Amsterdam, The Netherlands
[3]VU Amsterdam University, Amsterdam, The Netherlands

Abstract

KLM has revealed the plan to downsize the full-freight cargo fleet in Schiphol Airport, for that reason the company requires to explore the consequences of moving the cargo transported by the full freighters into the bellies of the passenger flights. In this study, the authors analyze the implications of this decision by considering the variability of the load factors and the impact that replacing old aircraft might have. The study addresses how the transition towards the belly operation should impact the current operation of KLM at Schiphol. Our study shows that the replacement of old aircraft with new 787s and 777s will have significant effect on the cargo capacity of the company. The results rise the discussion on future problems to be faced and how to make the transition from full freighter to belly operation.

Keywords: Air freight operations, optimum capacity, air-freight performance, Full Freighters, Belly capacity, scenario, multi-modal transport

1. Introduction

On a worldwide level, the transport of commercial cargo is a key economic indicator of international trade as well as a thermometer for the state of the global economy. As people become more productive, they become richer and they demand more goods. The supply chain and logistics industry exist to connect manufacturers with suppliers and middlemen shippers with the end customer (Feng, 2015).

In terms of the business model between cargo operations and passenger operations, there exist many similarities as well as differences. Air cargo transport is more complex than passenger transport because the former involves more players, more sophisticated processes, a combination of weight and volume, varied priority services, integration and consolidation strategies, and multiple itineraries of a network than the latter.

The key differences between cargo and passenger operations have been reported as uncertainty, complexity, and flexibility (e.g., Bartodziej et al., 2009; Leung et al., 2009; Li et al., 2009; Wang and Kao, 2008):

- Uncertainty: Air cargo transport has higher uncertainty than passenger transport in terms of capacity availability. In passenger transport, passengers may cancel reservations, and a small number of passengers may not show up. In contrast, capacity booking for air cargo, freight forwarders must pledge the use of the cargo capacity on specific flights twelve (or six) months ahead (Amaruchkul et al., 2011). Because freight forwarders do not need to pay for unused capacity, they may book more than the actual needed capacity to reduce risks or to compete with other forwarders. Many bookings in air cargo can be cancelled and/or rebooked because airlines typically do not charge for changing reservations. For this reason, the booking process is subject to considerable volatility (Petersen, 2007).
- Complexity: forecasting cargo capacity is more complex than forecasting passenger capacity. While the capacity of a passenger aircraft is fixed by its number of seats, cargo capacity depends on the type and dimensions of the container used (called unit load devices, ULDs), and specified according to pivot weight, pivot volume, type, and centre of gravity (Leung et al., 2009). Multiple dimensions are a key feature of freight,

which render both complexity and uncertainty to air cargo capacity management.

- Flexibility: Transshipment itineraries between an origin and destination (OD) pair for cargo transport benefit the airline more than passenger transport. In general, all major airlines operate within so-called hub-and-spoke networks. Both, passengers, and cargo are transported from many different origins to a small number of hubs, where passengers and cargo are consolidated and then transported further to other hubs by wide-body aircrafts. The total number of transits are limited for passenger transport, and much larger for air cargo transport i.e. air cargo can be transshipped via several intermediate airports from the origin to the destination to meet the delivery time (Amaruchkul et al., 2011). The airline only needs to declare the origin, stopover (transit) airports, and destination to the forwarders and can decide on the optimal use of transhipment itineraries of air networks.

Air freight is the fastest form of transportation in terms of distance divided by time travelled. However, given extra costs related to delivery time such as customs processing, security considerations, consolidation of loads at a hub, warehousing, etc. air freight is less suitable for short distances transport (less than 700 km, rail is a more efficient transport mode, less costly and less complex than transport by air). Since the key value-added by air transport is time, the quick delivery of goods results in a demand and high willingness to pay for specific types of items. Common items shipped by air include perishables, pharmaceutical products, high-tech and electronics, clothing, animals, and high-value products such as diamond, art, cars among others.

Because of these differences, air freight accounts for less than 1% of total freight carried by all transport modalities (air, sea, water, and road) in terms of both volume and weight. However, air freight accounts for about 40% of its value (Damme et al, 2014) and almost 1% of global GDP is spent on air transport (IATA 2016).

1.1. The Development of World Cargo and its Impact in Schiphol

According to BOEING (BOEING 2016), the growth trend estimates that cargo will be doubled the next 20 years (in Revenue Tons Kilometers) as Figure 1 illustrates.

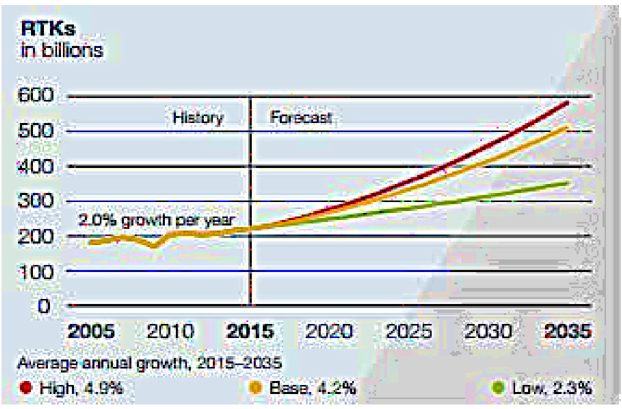


Figure 1: Cargo Trend Worldwide

Purchases of new high-capacity cargo aircraft saw a gradual slow-down between 2012 and 2015, moving from 42 to 25 annual deliveries. This steady downward trend looks set to continue for the next years with 19 deliveries in 2017.

Belly capacity in the passenger aircraft fleet continued to see strong growth thanks to the expansion in the fleet, the latter expected to see annual growth of 5% between 2011 and 2019. For the years to come, around 400 new aircraft (for the most part B777s, B787s and A350s) will be introduced each year with the phasing out of some 100 to 200 aircraft per year (mostly B747s, B767s and A340s). The introduction of new aircraft will have an important impact since the bellies of new aircrafts have more capacity than the older aircrafts. For instance, the belly of the B787-9 can handle 20 tons of cargo in comparison with the 747 used for passenger which is able to handle only 12.5 tons of cargo, or the A340-300 which has a capacity of 14 Tons. In view of this dynamic, several air freight carriers are following the Air France –KLM Group's example by gradually decreasing their full freighter fleets in favour of bellies.

1.2. Schiphol as Important Node in Air-Cargo Networks

The cargo operations at Schiphol faces major challenges from macro- developments such as rapid changes in aviation sector and cargo market, technology/ICT revolution, transitions to green and circular economy, e-commerce, increasing volumes, volatility and uncertainty of airfreight and logistics. Last but not least, changes in freight strategy of the hub carrier KLM cargo. The last one consists in reducing its full-freighter and increase cargo transport in the bellies of the passenger's aircrafts as the recent phasing out of some freighters indicate. However, this transition has several challenges such as synchronization of cargo operations with passenger ones, capacity of ground handlers for increasing the cargo operation in the passenger bellies, time slot coordination, schedule and punctuality among others. Schiphol is important for the logistics sector and economic growth of the Amsterdam metropolitan region economy as well as for the Dutch one. Airfreight operations are fully concentrated at Schiphol airport, with minimal cargo activities in other regional airports such as Maastricht or Eindhoven airports.

Schiphol is ranked third in Europe in term of airfreight aggregated volumes (2 million tons in 2015), behind Charles-de-Gaulle and Frankfurt airports.

There exists strong competition between the three European airports, which all of them function as gateway to the European market. Also, there is increase in the number of European regional airports that focus on airfreight activities/operations, which attract mainly full-freighters (and almost no belly aircrafts). The top four regional airports have home carrier as the main airfreight carrier, such as Cargolux/Panalpina in Luxemburg, UPS in Köln, DHL and TNT in Liège/Belgium.

The main carrier in Schiphol is KLM whose passenger operation accounts for more than 80% of the revenues of KLM-Air-France group, however, an important part of airfreight volumes is transported in combined (belly) aircrafts. In this way, revenues generated from airfreight operations are complementary to passenger operations, especially on intercontinental networks that are difficult to maintain financially.

During the financial year of 2015, the Group transported nine billion Revenue Ton-Kilometers of which 75% in the bellies of passenger aircraft and 25% in the dedicated full-freighter fleet, to a network of 316 destinations in 115 countries. However, starting from 2010 and confronted with the crisis of the sector, the group adopted a new "priority to bellies and combis" strategy, aimed at optimizing the economics of passenger aircraft bellies. The full- freighter fleet then is used as a complement to cover the routes not served with passenger flights, products that cannot be carried in bellies and markets in which belly capacity is not adapted to demand.

Over the past four years, Air France – KLM Cargo implemented a transformation and adaptation program focused on revenues, costs, hub productivity and the quality of bellies and combis, to optimize the payload on its full-freighter fleet.

Roughly speaking, 30% of the total cargo capacity of Schiphol is handled by KLM and Martinair (a cargo subsidiary of KLM). At December 31, 2015, the KLM fleet comprised 113 aircraft (111 at December 31, 2014), of which 65 long-haul aircraft and 48 medium-haul aircraft. KLM reduced Martinair cargo fleet from 10 Full Freighters (FF) to only 4 (KLM 2016)

The current study approximates the consequence for KLM fleet at Schiphol and the knock-on effects that this decision might have. In a previous work (Mujica et al. 2017) we have analysed the impact of the phasing-out of the full freighters under deterministic scenarios. The current work analyses the impact of the variability of the load factors and the effect of replacing old aircraft from the fleet with new ones that have bigger capacity than the current fleet. As it has been mentioned, it is expected that the downsize of the fleet will continue, thus, for KLM and Schiphol group the understanding of the consequences of the fading-out of the remaining full freighters is key for improving the operational management of the airport system. Besides all the restrictions and limitations, the demand will continue with the collateral consequences in congestion, delays, and capacity. In the next sections we present the study where some implications of phasing out the FF and replacing the old fleet are discussed.

2. Methodology: Stochastic Modelling of Cargo OPS

For the evaluation of the transition from Full freighter to the transport of cargo in the bellies of the aircraft (A/C) we took the public information from KLM and Martinair together with the traffic numbers from OAG database for developing and analyzing different scenarios. We performed some assumptions based on different studies and reports and we came up with the numbers and the initial implications of the transition.

2.1. Base Case of Cargo Operation

The model considers different elements which interact with each other: layout, traffic, infrastructure, vehicles, and cargo. The ratio between input/output is calculated from the reports of cargo from Schiphol Group in 2016 (Schiphol 2016). According to those reports, the number of tons transported to and from Schiphol are approximately 823 tons per year. Figure 2 illustrates the amounts that are imports, exports, and road imports or transshipments.

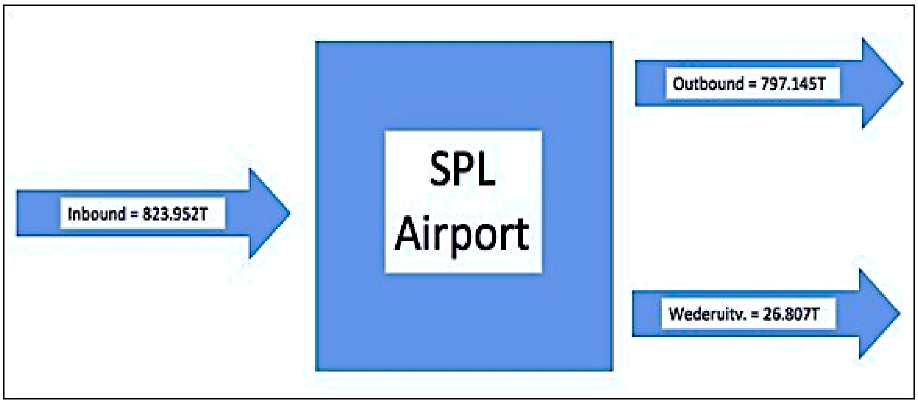


Figure 2: Flow Model of Cargo at Schiphol

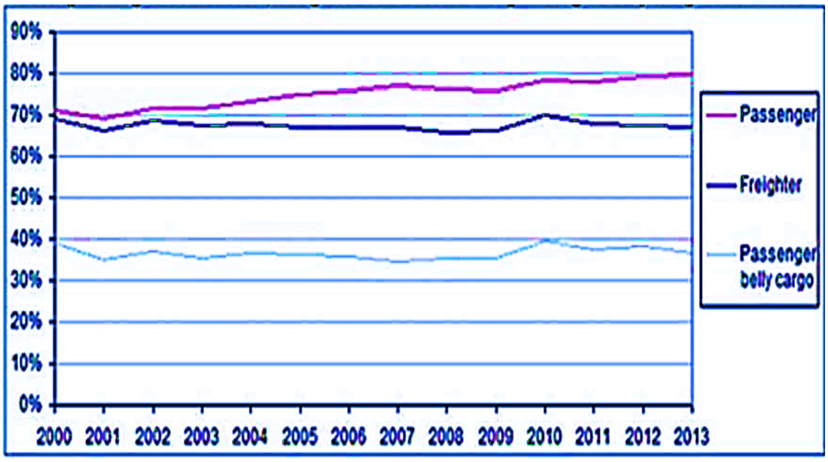
The inbound flux (Figure 2) is a combination of aircraft with cargo that arrive at Schiphol and ground cargo transported by trucks. The outbound flux is the combination of cargo that goes as export products and goes to a destination. The outbound flux – the inbound flux represents the accumulation of goods or the amount of cargo that is either non-reported (not found in the consulted reports) or stays in the warehouses in the surroundings of Schiphol. As it can be appreciated, the airport is just a stopover for the products. We considered these values for estimating the cargo load between the arrivals and departures. Furthermore, the load factors vary during the year, as Figure 3 illustrates. In our approach, we considered this variation for accounting the maximum values of cargo that are transported with the use of the A/C fleet of KLM+ Martinair.

In the model, we considered one day as the representative of the operation, the information of March 16th of 2015 was considered as the input for the model.

Figure 3 presents the variability of load factors of passenger traffic and cargo from the year 2000 until 2013 (CAPA, 2014).

As mentioned, we considered these values for the base case which will include the variability of the load factors.

Figure 3: Evolution of World Load Factors (% 2000 to 2013)



It can be noticed that for the FF the load factor has a variability between 65% to 70% maximum, while for the belly operation the variability is between 35% to 40% maximum. In the variability values considered, we assumed that it was not possible to surpass the higher bounds of 70% for the cargo load factors. Therefore, for the different scenarios, we assumed that 70% load factor is a hard restriction or upper bound in the operation.

2.2. Stochastic Analysis

As initial analysis, the load factors for passenger flights and for the full freighters were modelled using variations of Beta Distribution as Table 2 illustrates. In addition, the table also presents the modifications of load factors of the different scenarios.

Table 1: Values for the Uncertainty in A/C Cargo

	Belly Load Factor				
Scenario	Mean	Min	Max	alpha1 = alpha2	Distribution
1	0.375	0.375	0.375	1	0.375
2	0.375	0.35	0.4	24	0.35+0.05*random.beta(24,24)
3	0.375	0.35	0.4	4	0.35+0.05*random.beta(4,4)
4	0.375	0.375	0.375	1	0.375
5	0.375	0.35	0.4	24	0.35+0.05*random.beta(24,24)
6	0.375	0.35	0.4	4	0.35+0.05*random.beta(4,4)
7	0.375	0.375	0.375	1	0.375
8	0.375	0.35	0.4	24	0.35+0.05*random.beta(24,24)
9	0.375	0.35	0.4	4	0.35+0.05*random.beta(4,4)

(Continued) Table 1: Values for the Uncertainty in A/C Cargo

	Full Freighter Load Factor				
Scenario	Mean	Min	Max	alpha1 = alpha2	Distribution
1	0.675	0.675	0.675	1	0.675
2	0.675	0.675	0.675	1	0.675
3	0.675	0.675	0.675	1	0.675
4	0.675	0.65	0.7	24	0.65+0.05*random.beta(24,24)
5	0.675	0.65	0.7	24	0.65+0.05*random.beta(24,24)
6	0.675	0.65	0.7	24	0.65+0.05*random.beta(24,24)
7	0.675	0.65	0.7	4	0.65+0.05*random.beta(4,4)
8	0.675	0.65	0.7	4	0.65+0.05*random.beta(4,4)
9	0.675	0.65	0.7	4	0.65+0.05*random.beta(4,4)

A total of 9 scenarios were built to assess the impact that different levels of variability in the load factor will have on overall performance. Thus, we considered 3 levels of variability for both the “Belly Load Factor” and the “Full Freighter Load Factor”: zero variability, moderate variability, and high variability. Zero variability was modelled by a constant load factor for each flight. Medium variability was modelled using a Beta distribution with alpha1 and alpha2 parameters equal to 24. High variability was modelled using a Beta distribution with alpha 1 and alpha2 parameters equal to 4.

All the distributions were centered around 0.375 and 0.675 load factors for Belly cargo and Full freighters, respectively. With the use of load factors, we multiplied the capacity of each type of aircraft for the load factors to get the estimation of the amount of cargo transported by the flights and by following this approach we could estimate the impact of the variability in the total cargo transported via Schiphol. Table 3 provides the cargo capacities of the different types of aircraft within the fleet under study.

Table 2: Cargo Capacities of different Aircraft

A/C Type	Cargo Capacity (Kg)
B744	12500
B772	12700
B738	2000
A332	10900
E190	1000
B737	2000
A333	17400
F70	1000
B739	2000
RJ85	1000
B787-9	20000
B777-3	23700

Making the previous assumptions we were able to construct different scenarios where we could give light to the impact of variability in the operation. Once we identified the impact of it, by performing simulations with different scenarios, we could propose solutions for rebalancing the input flow if, for example, one or more full freighters are phased out.

3. Results

For the following scenarios, we included the variability of the load factors in the scenario that has one full freighter less. The purpose of this was for addressing what is the maximum cargo that can be transported assuming a natural variation of the load factors in the aircraft.

For the different scenarios developed, we assumed the traffic mix is kept constant. Thus, the variation in the cargo numbers of the simulations is due only to the different parameters: phasing out of FF and replacement of old 747s and 772s with B787s and B777s.

Regarding the FF, Martinair currently have only 4 aircraft in operation. Some scenarios will evaluate the situation that Martinair will fade out the fleet from 4 to 3 full freighters. If we calculate the implication of that action, we end up with a deficit of 28 k tons annually. We assumed the following fleet flies every day:

- 3 McDonnell Douglas MD11F with capacity of 95 tons of cargo
- 1 Boeing 747 ERF with capacity of 112 tons of cargo

3.1. Base Scenario: Variability in Place

Table 3 shows the average flow of cargo based on flight arrivals separated by inbound (input) and outbound (output) flows from and to the airport for a total of 100 simulation replications for each scenario. Results show that Scenario 9, which considers the highest amount of variability in the load factor of both bellies and FF, is the one that produced the highest total average input and output flows of all the scenarios. These results show that, even though all scenarios had the same mean load factor and a non-skewed distribution, a higher variability in the load factor tended to produce more flow of cargo. Because of Scenario 9 presented the highest values in terms of total flow, it was used as a comparison the Scenarios 10 and 11, where FF capacity was reduced.

Table 3: Results from the Stochastic Analysis (Average Annual kg.)

Scenario	Input Belly	Input FF	Input Total	Output Belly	Output FF	Output Total
1	104,187,334	97,810,875	201,998,209	100,639,427	94,583,116	195,222,543
2	102,754,139	97,810,875	200,565,014	99,177,335	94,583,116	193,760,451
3	103,177,257	97,810,875	200,988,132	99,599,022	94,583,116	194,182,138
4	102,690,195	97,822,396	200,512,591	99,260,388	94,594,256	193,854,644
5	105,120,173	97,822,396	202,942,569	101,536,972	94,594,256	196,131,228
6	105,830,683	97,822,396	203,653,078	102,258,821	94,594,256	196,853,077
7	102,442,588	97,842,173	200,284,761	99,001,098	94,613,381	193,614,479
8	105,060,903	97,842,173	202,903,075	101,479,658	94,613,381	196,093,039
9	105,946,896	97,842,173	203,789,069	102,408,936	94,613,381	197,022,317

3.2. Scenarios 10 and 11

In these scenarios, we removed one FF and assumed that part of the fleet was replaced with new models of aircraft. Table 4Error! Reference source not found. presents the new cargo values once the fleet is reduced to 3 full freighters.

Table 4: Capacity Numbers for Reduction of 25% FF Capacity

(ARR) 25% Less FF	
Cargo Capacity Annually bellies	114,084,400
Cargo Capacity Full Freighters	72,817,500
Total Capacity (Annually)	186,901,900
Missing Capacity (Daily)	-78,400
Missing Capacity (Annually)	-28,616,000

3.2.1. Scenario 10: Replacing all 747s for B777s and 787s Aircraft

For the first additional scenario we assumed that all Boeing 747s were replaced from the fleet to evaluate if it is possible to absorb the cargo capacity of the removed full freighter. This fleet was chosen because it is one of the oldest aircrafts in the fleet of KLM, according to Planespotters (www.planespotters.net). Thus, to compensate for the full capacity of FF, a total of thirteen 747s would be replaced by six 787-9 and seven 777-3. This change of fleet from B747s to aircraft with more capacity will resulted in an added annual capacity of 18k tons, which is still short for absorbing the missing capacity of 28k tons as Error! Reference source not found. shows.

3.2.2. Scenario 11: Replacing all 777-2 with 777-3

Owing to the fact that the proposal of Scenario10 could probably come short of capacity, as it only adds 18k tons of capacity in comparison with the 28k tons that are needed, the second additional scenario considers a change of all 777-2 in the fleet (nine aircraft) to 777-3 aircraft as it has more cargo capacity and 777-2 are the second oldest aircraft in the fleet (www.planespotters.net). This will result in an additional annual capacity of 14k tons, which added to the previous 18k tons, will result in a total of 32k additional capacity.

Table 5: Cargo Flow for Base Scenario Compared with Scenarios where one FF was Phased Out (Annual kg.)

Scenario	Measure	Input Belly	Input FF	Input Total	Output Belly	Output FF	Output Total
Scenario 9	Average	105,946,896	97,842,173	203,789,069	102,408,936	94,613,381	197,022,317
Scenario 10	Average	120,292,263	74,414,857	194,707,120	116,279,296	71,959,167	188,238,463
Scenario 11	Average	133,485,761	74,414,857	207,900,618	129,037,408	71,959,167	200,996,575
Scenario 9	Percentile 95	107,276,044	98,628,231	205,904,275	103,735,934	95,373,499	199,109,434

To assess the impact of phasing out one FF, Error! Reference source not found. compares the average inbound and outbound flows for Scenario 9 (baseline with high variability but full fleet of FF) with Scenarios 10 and 11 (where one FF has been removed).

Results from Table 5 show that removing one FF and substituting all 747s with B777s and 787s aircraft (Scenario 10) results in a reduction in capacity when compared with the baseline scenario (Scenario 9). It is only when all 777-2 fleet is replaced by the bigger 777-3 that the lost average capacity from phasing out one FF is recovered by the additional belly capacity.

In addition, as simulation results vary among replications because of the stochasticity modelled in the load factors. Table 5 presents the results of the 95th percentile of the total inbound and outbound flow for the baseline scenario to perform a risk assessment. In this manner, the 95th percentile of Scenario 9 shows that at most 95% of the times the total inbound cargo needed to be transported is 206k tons per year, instead of an average of 204k tons per year. If we compare this 95th percentile of Scenario 9 with the results from Scenario 11, we can see that, on average, removing one FF and replacing its capacity with bigger belly capacity results in a higher total capacity than what would be needed to be carried the 95% of times in the baseline scenario.

3.3. Discussion

Results from this simulation study show that the total cargo capacity lost, irrespective of origin and destination, by removing even one FF is very difficult to overcome by increasing the capacity in passenger flight's bellies by just replacing old aircraft with new model versions, as a total of 22 aircraft would need to be replaced. Furthermore, results also show that by incorporating variability into the load factor of both the bellies and FF, the fleet would need to transport a bigger quantity of cargo and more cargo capacity will be needed.

Further analysis is needed to investigate the impact in financial terms that removing one FF and replacing it with bigger capacity passenger aircraft will produce in the operations of the airline. Moreover, future research should also consider the actual flows from and to different destinations to Schiphol to assess the real impact of phasing out an FF flight and the impact of increasing the capacity of a passenger flight.

4. Conclusions and Future Work

In the paper we analysed the implications of replacing old aircraft with new models (with bigger cargo capacity) of KLM and Martinair. The objective of this study was to assess whether, in the presence of variability, the replacement of aircraft is enough for absorbing the missing capacity if one of the four full freighters is retired from the cargo fleet. The simulations show that by replacing the old models with new ones the increase in capacity is just barely enough to absorb the capacity missed. Therefore, the results suggest that in addition to the renovation of fleet it is necessary that the load factors (in the bellies) should be increased so that it is possible to absorb the missing capacity if more than one full freighter is planned to be retired. This action implies a better coordination than the current one for ground handlers and the fleet; since due to the punctuality policies of commercial airlines, it is not possible to absorb delay due to the increase of cargo loading operations. Furthermore, if the airline is not willing to quit some routes, because of the lack of capacity, the airline should face the challenge making use of novel techniques mainly from the IT and OR realm to improve the coordination of the cargo operation. As a future work, the authors will investigate what the optimal balance between fleet replacement and increase of load factor will be assuming it is possible to increase the load factors in the bellies by improving the coordination of the cargo operations.

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The Spillover Effect of Liner Shipping Performance on Trade Values for Coastal Countries

Po-Yuan Huang[1], Szu-Yu Kuo[2], Pei-Chun Lin[1], and Chung-Wei Shen[1]

[1]Department of Transportation and Communication Management Science, National Cheng Kung University, Tainan, Taiwan.
[2]Department of Shipping and Transportation Management, National Penghu University of Science and Technology, Penghu, Taiwan.
Email: peichunl@gmail.com

Abstract

Purpose – This paper aims to assess and empirically analyze the effect of spatial interaction on liner shipping performance of coastal countries in order to detect how a country's liner shipping industry interacts with that of others.
Methodology – This study uses a spatial data analysis approach to explore the spatial dependence of port container throughput and liner shipping connectivity of 138 coastal countries in 2017 as well as build spatial econometrics models to estimate the spillover effect and verify the relationship between throughput and connectivity. The data were collected from the UNCTAD database.
Findings – The results show that connectivity is a significant explanatory variable for throughput, and there are positive spillover effects. The container throughput of a coastal country will be affected by neighboring countries.
Practical implications – In the context of globalization, the country's marine freight transportation will be affected by other countries, and this impact will vary according to different relationships between countries. This is important information for the related authority, including port management units, governments, and carriers. They can predict the future trend of freight volume based on the results of this study and focus on those countries that may be affected. Finally, policies for the liner shipping industry should also be beneficial to the country.
Originality – Unlike other regional research, this paper discusses the spillover effect on marine cargo for the global scale. We also use many kinds of spatial weight matrices to define a diverse spatial relationship, helping us determine the spatial spillover effect that exists in different spatial relationships.
Paper type – Research paper

Keywords: Spillover effect, Liner shipping, Container throughput, Liner shipping connectivity index

1. Introduction

In 2017, more than 80% of global trade cargos by volume and more than 70% by value were shipped by sea, with the total weight of the goods reaching 10.7 billion tons. In light of these numbers, the importance of maritime transport for trade and economic development cannot be overemphasized (Hoffmann & Sirimanne, 2018). Yet only one-third of goods by volume are delivered through liner shipping, with most being industrial products with a higher value than raw materials transported by tramp shipping. Therefore, liner shipping plays an important role in the global supply chain. The scale and capacity of the shipping industry are also important factors affecting a country's competitiveness, providing more chance for economic growth (Arvis et al., 2014). Container throughput is a common indicator used to evaluate the performance of liner shipping industry in countries. Global container throughput equaled 752 million 20-foot equivalent units (TEU) in 2017. Figure 1 shows the container throughput of coastal countries.

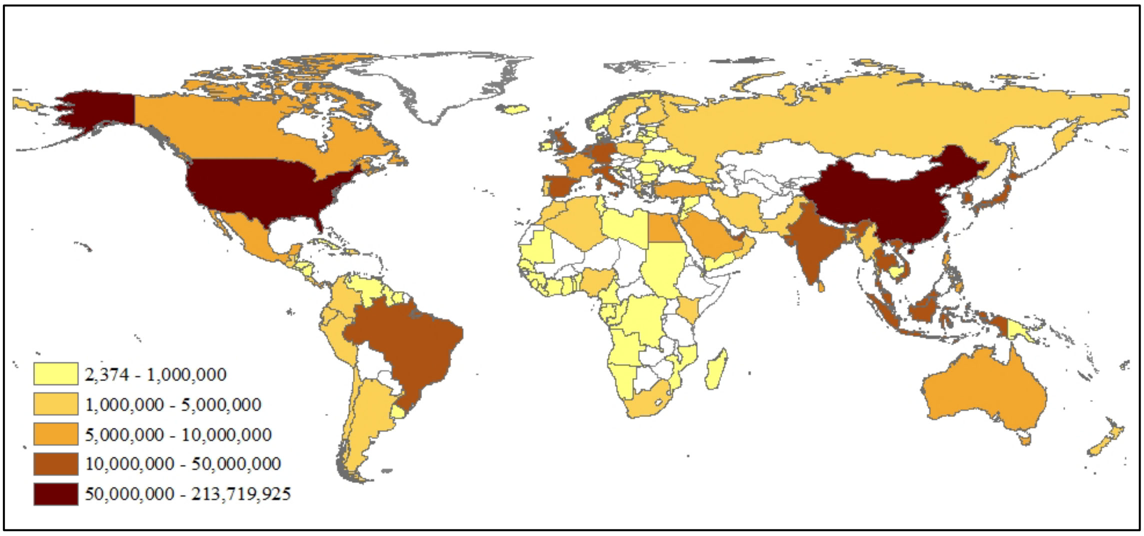

Figure 1: The Distribution of Container Throughput of Coastal Countries in 2017

Previous studies have demonstrated that GDP is a significant factor affecting throughput (Chou et al., 2008; Seabrooke et al., 2003), yet few studies have mentioned the impact of connectivity on throughput, which is a relatively new concept. Connectivity refers to the degree of connection between two nodes in a transport network. In maritime transport, it can be defined as the ability to transport cargo to other countries (Jiang et al., 2015). The Liner Shipping Connectivity Index (LSCI), proposed by Jan Hoffmann in 2005, provides credible data and is updated annually in the UNCTAD database. LSCI represents the importance of a country in the global shipping network. It can also assess the development and services scale of a country's liner shipping industry (Hoffmann, 2012). Most countries with higher LSCI are developed, export-oriented countries located near important waterways. Figure 2 depicts the LSCI of coastal countries in 2017.

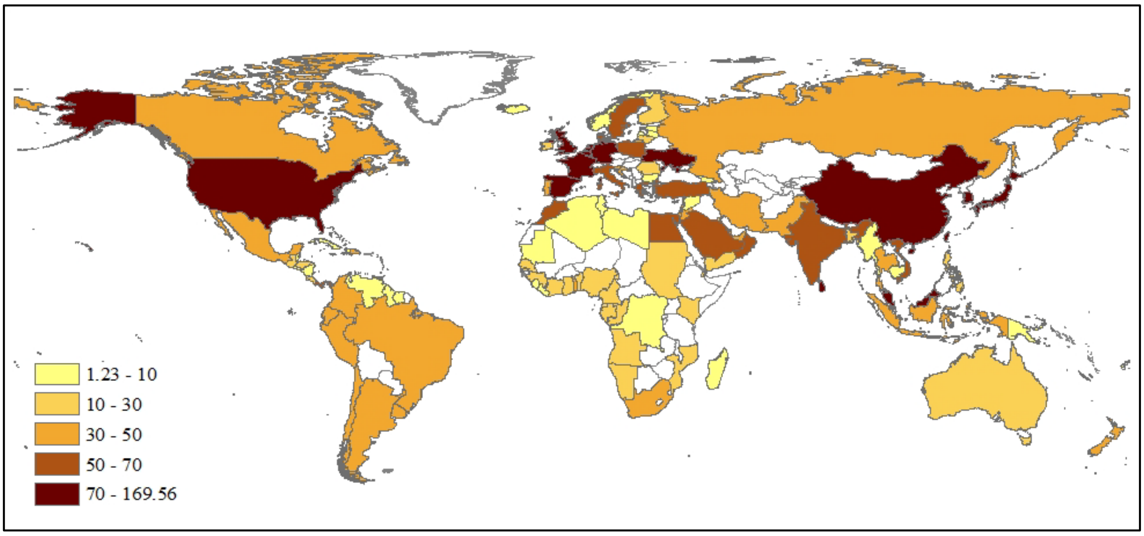

Figure 2: LSCI of 159 Coastal Countries in 2017

Research on connectivity as a determinant of international trade cargo flows has received increasing attention from academics and policy makers (Calatayud et al., 2017). Jiang et al. (2015) also pointed out that the higher the connectivity of a port, the more attractive it will be in terms of facilitating the transportation of cargo and reducing transportation cost and time, thereby resulting in it being more competitive than others. Behar and Manners (2008) said that distance should be considered to have a negative effect on transportation and exports, but good logistics performance can effectively reduce the distance between the two countries. Fugazza and Hoffmann (2017) demonstrated that liner shipping connectivity is related to the performance of containerized goods exports and that increased connectivity can promote trade growth. In addition, their study also emphasized that, if connectivity is ignored, the impact of distance on trade activity may be overestimated. LSCI is one kind of performance indicator that reflects both changes in demand and decisions taken by carriers (Hoffmann & Sirimanne, 2018). Lun and Hoffmann (2016) pointed out that characteristics of economies with excellent shipping connectivity include high throughput. Bartholdi et al. (2016) asserted that the LSCI reflects actual container throughput. Therefore, we assume that the level of the LSCI is related to the amount of container throughput. It is hypothesized that higher connectivity means that carriers expect more market demand and expand the service scale, which will bring more throughput.

In addition to discussing the relationship between throughput and LSCI, we try to explore the spillover effect of the two factors as liner shipping performance indicators. Liner shipping in the process of transporting goods involves movement between two locations in space, thereby making the spillover effect from other countries a non-negligible external influence. The rise of spatial econometric analysis has placed additional emphasis on the effects of spillover, especially in the area of transportation involving spatial movement and connectivity. Cohen and Paul (2004) mentioned that the development of transportation systems has led to higher inter-regional connectivity, thereby enabling researchers to analyze the existence of spillover effects. The spillover effect refers to the economic events in a region that transmit their effects to other regions through specific spatial associations and bring positive or negative benefits (Baumont et al., 2001). Yu et al. (2013) and Tong et al. (2013) pointed out that increasing transportation infrastructure can stimulate local economic growth, and the benefits of growth will be transmitted to neighboring regions. Bottasso et al. (2014) demonstrated that the trade activities of the top 150 ports in Europe have a positive spillover effect on GDP growth in their region. Márquez-Ramos (2016) explored the export trade performance of the first administrative regions of Spain to 45 other countries and found that it was affected by the port infrastructure of the adjacent administrative regions. Previous studies have investigated the impact of spillover effects on transport infrastructure, economic growth, and trade, but the spillover effect on freight volume is less discussed. Thus, the first purpose of this study is to examine the relationship between container throughput and LSCI; the second is to prove the spillover effect on throughput and LSCI as significant factors affecting the spatial interaction between liner shipping performance of coastal countries. The scope of this study includes 138 coastal countries with both throughput and LSCI data in 2017.

We organize the rest of the paper as follows: Section 2 establishes spatial econometrics model according to the process of the spatial analysis method. Section 3 evaluates whether the data are suitable for modeling and estimate the coefficients and analysis results of the model. Conclusions and possible directions for future research are summarized in Section 4.

2. Methodology

Spatial data analysis is used to handle data with spatial elements. Every observation contains geographical information and attribute value. For example, our data include Taiwan, which combines location ($121\ E, 23\ N$) and characteristic value ($\mathrm{LSCI} = 76.12$). The spatial data analysis includes (1) processing spatial data; (2) analyzing the characteristics of data by descriptive statistics; (3) inferring the correlation and distribution patterns between data by inferential statistics; and (4) building econometrics models to verify spatial spillover effects (O'Sullivan & Unwin, 2010). In order to transfer the abstract spatial concept into the mathematical model, the spatial relationships between observations must be quantified and presented in the form of a spatial weight matrix. The next step is to measure spatial dependence by spatial autocorrelation analysis. Spatial dependence refers to the degree of similarity between spatial units, which means that close individuals have the same feature (Cliff & Ord, 1973). If there exists spatial dependence between the attribute values of spatial units, spatial econometrics models can be established. We can calculate the spatial spillover effect if the estimation results of the models are significant.

2.1. Spatial Weight Matrix

The spatial weight matrix $\mathbf{W}$ is a $N \times N$ matrix. The diagonal of the matrix is 0, because there is no spatial relationship between a country and itself. The size of the weight value determines the degree of association between countries. $\mathbf{W}$ can be presented as in equation (1). In practice, matrices are usually standardized by row, in order to balance the scale of weight values. The conversion of row-standardized is shown as equations (2) and (3).

$$\mathbf{W} = \left[W_{ij} \right] = \begin{pmatrix} 0 & \cdots & W_{1n} \\ \vdots & \ddots & \vdots \\ W_{n1} & \cdots & 0 \end{pmatrix} \tag{1}$$

$$W_{ij} \begin{cases} = 0, i \text{ is not related to } j. \\ \neq 0, i \text{ is related to } j. \end{cases}$$

$$W_{ij}^{*} = \frac{W_{ij}}{\sum_{j=1}^{N} W_{ij}} \tag{2}$$

$$\sum_{j=1}^{N} W_{ij}^{*} = 1, i = 1, \ldots, \mathrm{N} \tag{3}$$

There are three ways to build a matrix: based on contiguity, distance or social-economic factors. Anselin et al. (2008) pointed out that the interdependence of spatial structures is related not only to geographic distances, but also to the location in the economic or social network. The concept of economic distance is increasingly used as well (Case et al., 1993; Conley & Ligon, 2002; Conley & Topa, 2002). We can compare different spillover effects by specifying various spatial weight matrices, and understand which spatial relationships have greater impact. In addition to using the maritime distance between countries, this study will also consider the relationship between countries trade relations and bilateral liner shipping connectivity.

Griffith (1995) proposed the following guidelines for specifying spatial weight matrix: (1) it is better to posit some reasonable weights matrix; (2) a relatively large number ($N > 60$) of spatial units should be employed; and (3) it is better to apply a somewhat under-specified (fewer neighbors) rather than an over-specified (extra neighbors) weights matrix. Florax and Rey (1995) also said that over-specification may reduce the power of tests. Kooijman (1976) proposed choosing **W** in order to maximize Moran's coefficient. Reinforcing this view, Openshaw (1977) selected the configuration of **W** that results in the optimal performance of the spatial model. Using the method of K nearest neighbor (KNN) to specify **W**, we found that, when K is 10, Moran's coefficient and the performance of models are optimal. In other words, for each row, we chose countries with the top 10 weight values as a neighbor.

To demonstrate the matrix of bilateral sea distance ($\mathbf{W}_{SD}$), we used data provided by Bertoli et al. (2016). They calculated the distance between the main ports of any two countries as the sea distance (km). According to Tobler (1970), everything is related to everything else, but near things are more related than distant things. We assumed that, the shorter the distance between countries, the stronger the correlation between them, which means a higher weight value. The following equation represents $\mathbf{W}_{SD}$:

$$\mathbf{W}_{SD} = [W_{ij}^{*}] = \frac{d_{ij}^{-1}}{\sum_{j=1}^{N} d_{ij}^{-1}} \tag{4}$$

where d_{ij}^{-1} is the inverse of sea distance between i and j.

To determine the matrix of bilateral trade value in 2017 ($\mathbf{W}_{TV}$), we used data from UNCTAD. Bilateral trade value is the sum of export value (US dollars) of i to j and j to i. Because liner shipping is highly correlate with international trade, we assumed that a greater trade value between countries would lead to a stronger correlation between them. The following equation represents $\mathbf{W}_{TV}$:

$$\mathbf{W}_{TV} = [W_{ij}^*] = \frac{v_{ij}}{\sum_{j=1}^{N} v_{ij}} \tag{5}$$

where v_{ij} is the trade value between i and j.

The third matrix is the liner shipping bilateral connectivity index (LSBCI) in 2017 ($\mathbf{W}_{LSBCI}$), using data from UNCTAD. The LSBCI is extended from LSCI, which includes five components. For any pair of countries i and j, the LSBCI is based on: (1) the number of transshipments required to get from i and j; (2) the number of direct connections common to both i and j; (3) the geometric mean of the number of direct connections of i and of j; (4) the level of competition on services that connect i to j; and (5) the size of the largest ships on the weakest route connecting i to j. We assumed that a higher LSBCI between countries would lead to a stronger correlation between them. The following equation represents $\mathbf{W}_{LSBCI}$:

$$\mathbf{W}_{LSBCI} = [W_{ij}^*] = \frac{LSBCI_{ij}}{\sum_{j=1}^{N} LSBCI_{ij}} \tag{6}$$

where $LSBCI_{ij}$ is LSBCI between i and j.

Finally, for the matrix of bilateral free trade agreements (BFTA) in 2017 ($\mathbf{W}_{BFTA}$), we employed data provided by WTO. We assumed that signing a BFTA is beneficial for promoting trade and cooperation. We chose the FTA in force in 2017 and built a binary weight matrix, which is presented as follows:

$$\mathbf{W}_{BFTA} = [W_{ij}^*] = \frac{W_{ij}}{\sum_{j=1}^{N} W_{ij}} \tag{7}$$

$$W_{ij} \begin{cases} = 1, \text{if } i \text{ and } j \text{ sign BFTA} \\ = 0, \text{if } i \text{ and } j \text{ do not sign BFTA} \end{cases}$$

2.2. *Spatial Autocorrelation*

The spatial autocorrelation analysis is a method for measuring spatial dependence. The main purpose is to analyze whether the attribute values of countries are similar to those of surrounding countries and then infer whether the correlation is significant or not. The formula proposed by Moran (1950) has been widely used; it is similar to the Pearson correlation coefficient, but adds the spatial weight matrix into the equation. The result of Moran's I is an index between 1 and -1. Its formula and hypotheses are below:

$$I = \frac{N}{S_0} \times \frac{\sum_{i=1}^{N}\sum_{j=1}^{N} W_{ij}\left(X_i - \bar{X}\right)\left(X_j - \bar{X}\right)}{\sum_{i=1}^{N}\left(X_i - \bar{X}\right)^2} \tag{8}$$

$$S_0 = \sum_{i=1}^{N}\sum_{j=1}^{N} W_{ij} \tag{9}$$

$H_0: I = 0$

$H_1: I \neq 0$

where X is the throughput or LSCI of a country, W_{ij} is the weight value of country i and j, $\bar{X}$ is the mean of X of all countries, and N is 138 countries. Figure 3 shows the interpretation results of Moran's I. If the p-value is less than significant level and I is greater than 0, it indicates a positive spatial autocorrelation, which means the distribution pattern of X is a cluster, meaning the adjacent countries have similar attributes in terms of throughput or LSCI. If the p-value is less than significant level and I is less than 0, it indicates a negative spatial autocorrelation, which means the distribution pattern of X is dispersed; thus, the throughput or LSCI of country is not similar with adjacent countries.

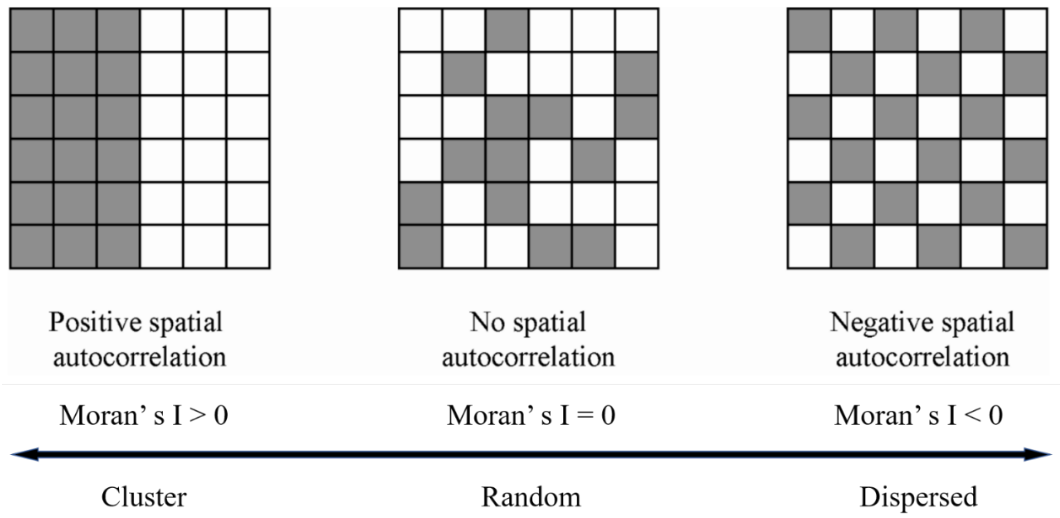

Figure 3: Result Interpretation of Moran's I

2.3. Spatial Econometrics Models

Spatial econometrics, a subfield of econometrics, was first applied in the research field of regional science and economic geography. In recent years, it has become the mainstream of econometrics, and has received great attention in theoretical development or practical application. The spatial econometrics model is an extension of the ordinary least squares (OLS) regression model; it takes the product of the spatial weight matrix and variable as an independent variable, which is called the spatial lag variable. The variable represents the influence of the attribute values of the adjacent spatial units on the dependent variable. Depending on the spatial lag variable, the spatial econometrics models can be extended to the spatial lag model (SLM), spatial lag of X model (SLX) and spatial Durbin model (SDM). If the spatial lag variable equals 0 significantly, it is an OLS model without spatial term. The relevant equations are below:

$$\text{OLS} \qquad Y_i = \beta X_i + \mu + \varepsilon, \qquad \varepsilon \sim N(0, \sigma^2 I) \tag{10}$$

$$\text{SLM} \qquad Y_i = \rho \mathbf{WY} + \beta X_i + \mu + \varepsilon, \qquad \varepsilon \sim N(0, \sigma^2 I) \tag{11}$$

$$\text{SLX} \qquad Y_i = \lambda \mathbf{WX} + \beta X_i + \mu + \varepsilon, \qquad \varepsilon \sim N(0, \sigma^2 I) \tag{12}$$

$$\text{SDM} \qquad Y_i = \rho \mathbf{WY} + \lambda \mathbf{WX} + \beta X_i + \mu + \varepsilon, \qquad \varepsilon \sim N(0, \sigma^2 I) \tag{13}$$

In these equations, Y_i is the natural logarithm of container throughput of country i, ρ and λ are spatial lag coefficients, **WY** is the spatial lag of the dependent variable, **WX** is the spatial lag of the independent variable, β is the coefficient of the independent variable, X_i is the LSCI of country i, and μ is a constant. Spatial regression models are estimated using the maximum likelihood. If ρ or λ is significant, the throughput of a coastal country will be affected by the liner shipping performance of neighboring countries, and we can calculate the spillover effect of throughput and LSCI using the following formulas:

$$\mathbf{W}_{SM} = \left[W_{ij} \right] = \left(\mathbf{I}_N - \rho \mathbf{W} \right)^{-1} or \ \left(\mathbf{I}_N - \lambda \mathbf{W} \right)^{-1} \tag{14}$$

$$\text{Spatial Spillove Effect}_{ij} = \mathrm{W}_{ij} \tag{15}$$

$$\text{Spatial Multiplier Effect}_{j} = \sum_{i=1}^{N} \mathrm{W}_{ij} \tag{16}$$

where I_N is the identity matrix, $\mathbf{W}$ is the spatial weight matrix, W_{ij} is row i and column j in the spatial multiplier matrix (indicating the spillover effect transmit from country i to j), and a countrys spatial multiplier effect is the sum of the spillover effect from other countries. Comparing the difference between spillover and multiplier effect, the former is the influence transmitted from specify country; the latter is the affect derived from all the other countries.

2.4. Data

Container throughput presents the total number of containers handled by a port, per country, expressed in TEU. A TEU represents the volume of a standard 20-foot intermodal container used for loading, unloading, repositioning and transshipment. A 40-foot intermodal container is counted as two TEUs. LSCI is comprised of liner shipping data from 159 coastal countries around the world and includes (1)the number of companies that provides services from/to a country's ports; (2) the size of the largest ship deployed to provide services from/to a country's port; (3) the number of services connecting one country's ports to other countries; (4) the total number of ships deployed on services from/to a country's ports; and (5) the total container carrying capacity of the ships that provide services from/to a country's ports. All data are from the UNCTAD database. In fact, slightly fewer countries with throughput data are exist than countries with LSCI. In order to avoid estimation errors caused by missing values, we chose 138 countries that have both throughput and LSCI data.

3. Results

This section used ArcGIS to analyze the spatial dependence of variables and map drawings; the estimation of spatial regression models was done with STATA, and we used Matlab to calculate the spatial multiplier matrix.

3.1. Ordinary Least Squares Regression Model

Table 1 presents the coefficients and summary of models derived from estimating an OLS model (equation 10) for all 138 coastal countries. The F-test and Wald test are highly significant and lead to the acceptance of the model and independent variable. The estimates of both intercept and β are significant and positive, which means a positive relationship between LSCI and container throughput. The model summary and overall fit statistics show that the adjusted R^2 of the model is 0.642, with $R^2 = 0.645$, indicating that the linear regression explains 64% of the variance in the data. Notably, the JB test is significant. When it is statistically significant, model predictions are biased. It violates the assumption that residuals should be normally distributed. Thus, there are still unexplained factors in the residual, which may be the spatial autocorrelation of the residual term. The OLS model assuming independent observations, where only LSCI matters for container throughput, ignores important features of obvious geographical clustering. It may be that the distributions of liner shipping performance share spatial clustering, which complicates this effect.

Table 1: Summary of OLS Results

Variable	Coef.	Std. Error	P value
Intercept	11.891	0.154	0
β	0.056	0.004	0
Summary			
N	138		

df.	3	

(Continued) Table 1: Summary of OLS Results

F test	246.671	0
Wald test	204.64	0
JB test	10.606	0.005
R^2	0.645	
Adj. R^2	0.642	
LIK	226.848	
AIC	0.642	

3.2. *Measuring Spatial Dependence*

In order to check the spatial dependence in LSCI, as well as the throughput and residuals of OLS, a spatial autocorrelation analysis is necessary. Table 2 presents the results of the spatial autocorrelation analysis, with both the natural logarithm of container throughput and LSCI having positive and significant Moran's I in the four kinds of spatial weight matrices. In other words, both of the liner shipping performance indexes of the 138 coastal countries are similar to their neighboring countries, main trade partners, and highly shipping-connected countries. This result gives us enough confidence to build spatial regression models with higher explanatory power. As for the residuals of OLS and the positive and significant Moran's I for just $\mathbf{W}_{SD}$ and $\mathbf{W}_{BFTA}$, we can say that the residuals of the 138 coastal countries correlate with their neighbors and trade agreement partners. Normally, the spatial autocorrelation of OLS residuals should be random—that is, Moran's I equals 0 significantly. It is strongly suggested that spatial regression models should be built to reduce the spatial dependence effect from residuals. Although Moran's I of residuals with $\mathbf{W}_{TV}$ and $\mathbf{W}_{LSBCI}$ is not significant, based on the significant Moran's I of throughput and LSCI, we still have sufficient reason to build spatial models with $\mathbf{W}_{TV}$ and $\mathbf{W}_{LSBCI}$ to get a better fit coefficient.

Table 2: Spatial Autocorrelation Analysis Results

Variable	Ln TEU			LSCI			OLS Residuals		
Weight	Moran's I	Z score	P value	Moran's I	Z score	P value	Moran's I	Z score	P value
$\mathbf{W}_{SD}$	0.479	9.963	0	0.358	7.565	0	0.259	5.473	0
$\mathbf{W}_{TV}$	0.119	3.96	0	0.158	5.222	0	-0.04	-1.036	0.3
$\mathbf{W}_{LSBCI}$	0.323	12.696	0	0.436	17.189	0	-0.021	-0.511	0.609
$\mathbf{W}_{BFTA}$	0.168	6.437	0	0.06	2.493	0.0127	0.108	4.279	0

3.3. *Models Estimation*

Table 3 presents the coefficients derived from estimating SLM, SLX, and SDM for all 138 coastal countries, with $\mathbf{W}_{SD}$, $\mathbf{W}_{TV}$, $\mathbf{W}_{LSBCI}$, and $\mathbf{W}_{BFTA}$. In spatial regression models, the log likelihood (LIK) and Akaike information criterion (AIC) are more meaningful fit statistics than R2. Briefly, the lower the LIK or AIC, the higher the models fit. The Wald tests of all models are highly significant, indicating that the independent variables are suitable for every model. The estimations of β are all significant and close to β in the OLS model; thus, the positive relationship between throughput and LSCI still make sense in spatial regression models. For SLM and SLX, the spatial lag terms ρ and λ for all spatial weight matrices are significant and greater than 0, indicating that the container throughput and LSCI of neighboring (marine distance, trade value, shipping connection, trade agreements) countries should be considered an influential factor for container throughput of all 138 coastal countries. Interestingly, for SDM, no models which have both significant ρ and λ. It seems that adding two spatial lag terms cannot lead to a model's higher performance. An insignificant spatial lag term cannot be used to calculate the spillover effect. It does not match our research purposes.

The spatial lag term is the main element for deciding the degree of spillover effects. Comparing the coefficient of spatial lag terms in SLM and SLX, when the spatial weight matrix is $\mathbf{W}_{LSBCI}$, the coefficients are the greatest, followed by $\mathbf{W}_{TV}$, $\mathbf{W}_{BFTA}$, and $\mathbf{W}_{SD}$. We can say that the container throughput of a coastal country is strongly affected by the liner shipping performance of highly shipping-connecting countries. The effects from trade and agreement partners are almost at the same level. Generally speaking, trade partners are usually the main connecting countries as well because liner shipping is highly related to international trade. The spillover effect that transmits to neighboring countries is minimal, demonstrating that the influence of geographical distance has being decaying while the importance of economic distance is ascending. Briefly, a coastal country's liner shipping performance is more related to trade partners than neighbors.

3.4. Model Selection

After estimating the models, a likelihood ratio (LR) test was used to check whether the difference between models was significant or not. Table 4 presents the results of the LR test; the null hypothesis is that there is no difference between the two models, and the degree of freedom must be different. Regarding the test between the OLS and spatial regression models with any spatial matrices, the LR statistics were all significant, indicating that spatial models are better than OLS. Generally speaking, SLM is the best model, except for $\mathbf{W}_{LSBCI}$, where SLX and SDM are close; however, most spatial lag terms in SDM are insignificant. Therefore, we decided to adopt the spatial lag terms ρ and λ from SLM and SLX. This result proved our assumption that the spatial effect should be considered an important element in our models.

Table 4: Test Results of Likelihood Ratio (LR)

Weight	$\mathbf{W}_{SD}$				$\mathbf{W}_{TV}$			
Models	OLS	SLM	SLX	SDM	OLS	SLM	SLX	SDM
OLS		25.18***	12.29***	25.87***		11.87***	11.48***	12.72***
SLM	25.18***			0.68	11.87***			0.85
SLX	12.29***			13.58***	11.48***			1.24
SDM	25.87***	0.68	13.58***		12.72***	0.85	1.24	
Weight	$\mathbf{W}_{LSBCI}$				$\mathbf{W}_{BFTA}$			
OLS		43.13***	44.05***	45.90***		13.55***	7.50***	14.05***
SLM	43.13***			2.77*	13.55***			0.5
SLX	44.05***			1.85	7.50***			6.55**
SDM	45.90***	2.77*	1.85		14.05***	0.5	6.55**	

Note: ***, ** and * denote statistical significance at the 1%, 5% and 10% level respectively

Table 3: Estimation of Models

Models	Spatial Lag Models				Spatial Lag of X Models				Spatial Durbin Models			
Weight	$\mathbf{W}_{SD}$	$\mathbf{W}_{TV}$	$\mathbf{W}_{LSBCI}$	$\mathbf{W}_{BFTA}$	$\mathbf{W}_{SD}$	$\mathbf{W}_{TV}$	$\mathbf{W}_{LSBCI}$	$\mathbf{W}_{BFTA}$	$\mathbf{W}_{SD}$	$\mathbf{W}_{TV}$	$\mathbf{W}_{LSBCI}$	$\mathbf{W}_{BFTA}$
Intercept	7.484*** (0.833)	2.727 (2.521)	0.442 (1.539)	6.381*** (1.448)	11.447*** (0.192)	9.867*** (0.603)	9.206*** (0.395)	11.065*** (0.333)	6.749*** (1.194)	5.325 (3.991)	4.697 (3.25)	5.194** (2.149)
β	0.047*** (0.004)	0.053*** (0.003)	0.044*** (0.003)	0.053*** (0.003)	0.048*** (0.004)	0.052*** (0.004)	0.039*** (0.004)	0.055*** (0.003)	0.048*** (0.004)	0.052*** (0.004)	0.04*** (0.004)	0.053*** (0.003)
ρ	0.348*** (0.065)	0.549*** (0.151)	0.732*** (0.098)	0.399*** (0.104)					0.418*** (0.105)	0.335 (0.291)	0.365 (0.261)	0.512*** (0.185)
λ					0.022*** (0.006)	0.024*** (0.007)	0.04*** (0.006)	0.024*** (0.009)	-0.008 (0.009)	0.011 (0.013)	0.022 (0.014)	-0.011 (0.015)
N	138				138				138			
df.	4				4				5			
Wald test	335.82***	288.66***	401.65***	292.9***	286.46***	283.98***	396.31***	271.99***	342.45***	288.79***	404.37***	296.76***
R^2	0.677	0.667	0.752	0.67	0.675	0.673	0.742	0.663	0.677	0.67	0.748	0.671
LIK	-214.167	-220.826	-205.193	-219.986	-220.615	-221.019	-204.733	-223.008	-213.825	-220.4	-203.809	-219.734
AIC	436.333	449.652	418.386	447.971	449.23	450.039	417.467	454.016	437.65	450.8	417.619	449.467

Note: ***, ** and * denote statistical significance at the 1%, 5% and 10% level respectively. Standard errors in parentheses

3.5. The Spillover and Multiplier Effect

We estimated eight significant coefficients of spatial lag terms in the previous section: ρ_{SD}, ρ_{TV}, ρ_{LSBCI}, ρ_{BFTA}, λ_{SD} , λ_{TV}, λ_{LSBCI}, and λ_{BFTA}. For each spatial lag coefficient, we build spatial multiplier matrices to calculate the sum of the spillover effect for each coastal country. The results are presented as maps in Figures 4 to 7. The darker the color is, the higher the spatial multiplier effect of a country is. A high spatial multiplier effect means a country's container throughput is greatly affected by the liner shipping performance of other countries. We proved that a country's container throughput will be affected by throughput and LSCI from other countries. Although the affected degree of throughput from other countries is larger than LSCI, the hot spots and distribution are similar.

Figure 4 shows that the hot spots are the Mediterranean, West Africa, Northern Europe, Central America, and Southeast Asia countries. Most of these regions are important transshipment hubs in the global shipping network or at the end of the shipping routes, suggesting that a large volume of containers flows through these areas, and the liner shipping industry often brings considerable economic benefits to countries in these regions. This result reaffirms previous findings that the positive benefits of liner shipping performance are transmitted to neighboring countries; however, our results are not just for a single region, but for the global scale.
The spatial multiplier effects of the United States and China are obviously higher than other countries in Figure 5. Because these countries are the largest merchandise traders in the world, they are also the main trade partners of most countries. Changes in other countries' trade volume will deeply affect the United States and China. As the throughput of other coastal countries increases, there may be a higher percentage of container flow generating from trading with the United States or China. It will also increase the throughput of the United States or China. This is why these countries have the highest multiplier effect.

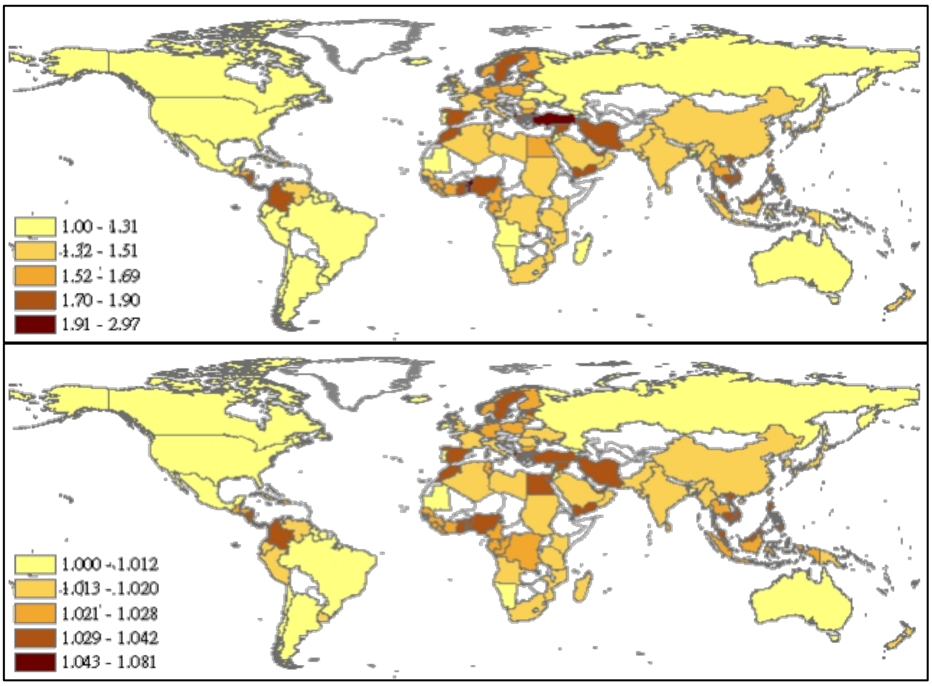

Figure 4: Spatial Multiplier Effects with W_{SD}; the Effect of ρ_{SD} on Top and the Effect of λ_{SD} Below

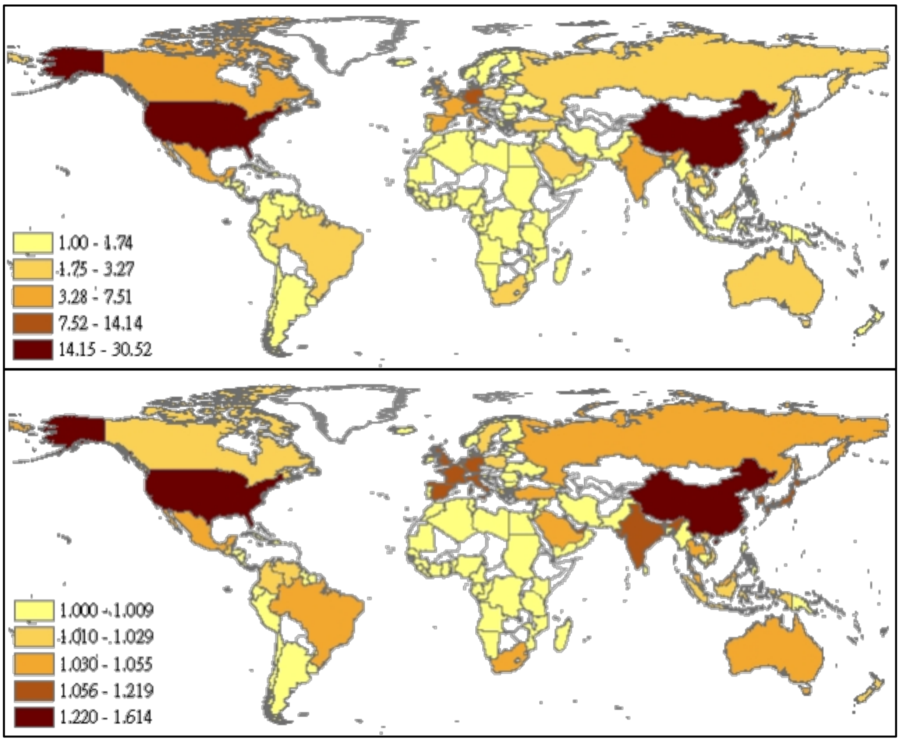

Figure 5: Spatial Multiplier Effects with $\mathbf{W}_{TV}$; the Effect of ρ_{TV} on Top and the Effect of λ_{TV} Below

The spatial lag coefficient estimated by the spatial relationship of $\mathbf{W}_{LSBCI}$ is the largest, indicating that the strong spatial spillover effect will transmit from one country to the other with its main connectivity. Figure 6 shows that the distribution of the spatial multiplier effect is similar to Figure 5, and the United States, China, and the European Union (EU) have higher multiplier effects. As the worlds three largest economies, their total trade volume and container throughput exceed 50% of the global total, and these regions are also important nodes of the three major transoceanic shipping routes in the world. Container throughput in these regions will be deeply affected by other countries due to the close connection with other countries through high-density shipping routes.

Most countries have strengthened economic cooperation by signing trade agreements with other countries. Figure 7 depicts the overall higher space multiplier effects for most countries that have signed trade agreements with others. The economic association between countries allows a countrys throughput to be affected by the liner shipping performance of its trade agreement partners. The more agreements a country signs, the higher the multiplier effect is. In particular, the EU has the highest spatial multiplier effect, in addition to high internal economic integration; it also signed agreements with many countries.

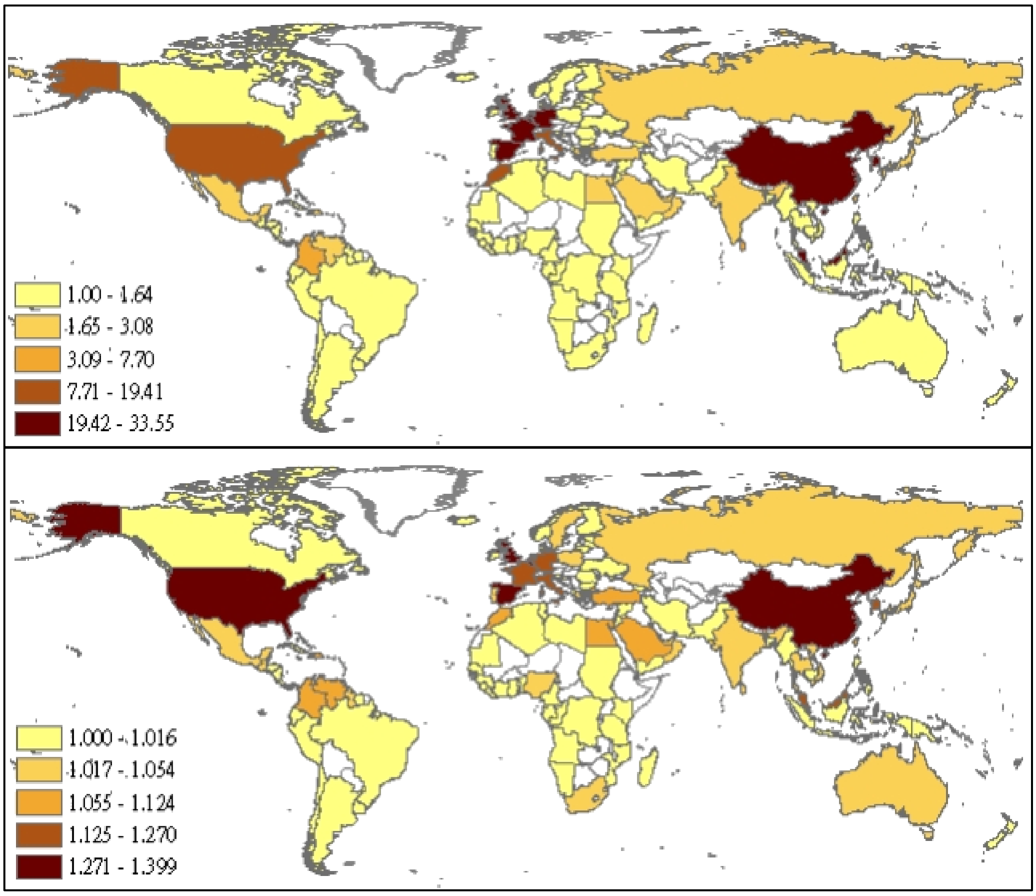

Figure 6: Spatial Multiplier Effect with W$_{LSBCI}$, Upper is Effect of ρ_{LSBCI}; Lower is λ_{LSBCI}

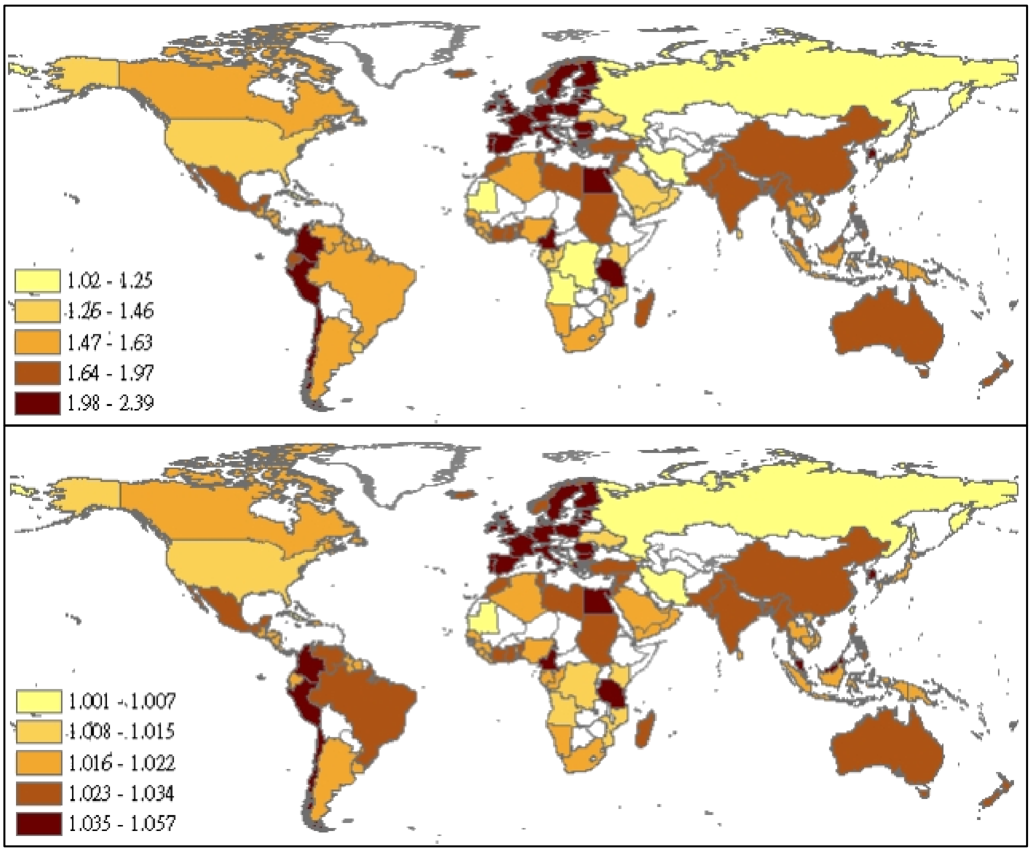

Figure 7: Spatial Multiplier Effect with W$_{BFTA}$, Upper is Effect of ρ_{BFTA}; Lower is λ_{BFTA}

4. Conclusion

We adopted spatial data analysis approaches to evaluate the spatial dependence of port container throughput and liner shipping connectivity of 138 coastal countries as well as build spatial econometrics models to examine the relationship between throughput and LSCI and estimate the coefficient of spatial lag terms to calculate the spatial spillover and multiplier effects. We found that the liner shipping performance of a country is similar to its neighboring countries, trade partners, and highly connected countries. The spatial econometrics models fit the data better than the OLS model. The models add spatial lag terms that can better explain the relationship between throughput and LSCI; moreover, the spatial models prove that there is a very close relationship between a country's liner shipping performance and that of its neighbors.

We conclude that the countrys marine freight transportation will be affected by other countr ies, and this impact will vary according to different relationships between countries. The relationships of the liner shipping industry between countries are likely to be complex and may not always be characterized only by competition. When a country's container throughput rises, the positive spillover effect will transmit to other countries and increase the throughput. We can describe this phenomenon as complementary, and our result reflects this description. In the context of globalization, this complementary relationship that spreads across regions will be seen as essential for future regional prosperity.

From a practical management and policy perspective, it is necessary to predict the future trend of container throughput and understand the relationship between shipping connectivity and cargo flows as an important basis for business and investment decision-making. The result of this study provides important information for departments related to marine transportation, including port management authority, governments, and carriers. The government should pay more attention to the shipping industrial dynamics in those regions that are highly related to us, review whether the capacity of the port facilities is sufficient or not, and optimize the allocation of existing resources to make adjustments for the long-term investment and policy of the future shipping industry, such as selecting suitable countries to develop new routes and promoting shipping connectivity to increase a countrys freight volume.

For future research, variables related to throughput or liner shipping performance can be added to the models and apply spatial econometrics models, test different spatial lag terms to increase the model fitness, or test other spatial weight matrices to compare the differences in spatial spillover effects and analyze the spatial association between spatial units. Furthermore, the concept of connectivity can be applied to other transportation systems, especially intermodal transportation. In this way, the scope of the research will no longer be limited to coastal countries, but will also contain landlocked countries, thereby resulting in a more global scale research.

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Cooperative Compensation Mechanism under the Balance of ‘Cruise-Port-City’ Benefits of Cruise Ports

Ling Sun[1],Kai-yuan Li[1,],Mei-feng Luo[2],Chen-bin Hu[1], and Ya-jun Deng[1]*

[1]College Of Transport and Communications,Shanghai Maritime University,Shanghai
[2]Department of Logistics and Maritime Studies, The Hong Kong Polytechnic University, Hong Kong
Email: [1]li309268785@163.com
[*]Corresponding Author

Abstract

Due to China's tourism consumption habits, the secondary consumption on the cruise ship is in the downturn in the Chinese market, while the Chinese people's tourism purchasing power is still in the forefront of the world, which is related to the Chinese people's like to spend on onshore tourism projects. At the same time, the reduction in the call number of cruises in China has also led to poor revenues for cruise liner port. Also, the number of tourists in onshore tourism projects, like Disneyland Park, often decreases for the seasons or other reasons, beacause tourists prefer a lovely day with never experienced scenic spot. From these aspects, we can find the cruises is in the lack of onboard secondary consumption,while the port is in the lack of berth time and call number,and the onshore tourism projects lack tourists’ time in scenic spot. So the three are indeed complementary to each other. And we also lucky to find the game theory to solve the problem of the contribution. Just think, if the cruise, port, and onshore tourism projects are integrated, by extending the cruise port time, the secondary consumption,which is on board before, will be transferred to the onshore tourism project and concentrated, and then the increased revenue will be distributed among the three according to the contribution, that is, apply the method of cooperative game theory to obtain the value of Shapley for distribution, and form a cooperative compensation mechanism to improve and balance the interests in the alliance. In the example, it can be found that the benefits of the three parties increase under this mechanism. However, in the Shapley,the port and the onshore tourism projects almost occupy the whole revenue. Under this mechanism, the port's revenue is too low, which requires an appropriate increase in port compensation to increase port participation and improve the tightness of the alliance. At last, the cruises can raise more ticket price because more scenic spot time means more total travel time for cruises. It can also come to be a source of the revenue. This paper do not consider the government into the compensation mechanism while the thought in paper can improve revenue of Scenic spots around, which means higher taxes.It is hoped that through the research in this paper, it will provide a method for the cruise ship to obtain sufficient income and stable operation in this market in China, and provide new vitality support to the port of call and the onshore economy.

Keywords: Cruise, Game, Interest balance, Compensation mechanism

1. Introduction

With the development of China's economy and the improvement of people's consumption level, cruise tourism has become a new type of consumption. After a decade of high growth of 40%-50%, there has been a slowdown in growth in 2017. In 2016, China's cruise port received 1010 cruise ships, an increase of 61% year-on-year; cruise passengers entered and left 4.5637 million people, an increase of 84% year-on-year. In 2017, the number of cruise passengers entering and leaving China was 4.955 million, an increase of 8% year-on-year, and 1,181 cruise ships were received, a year-on-year increase of 17%. In the first half of 2018, although the number of passengers entering and leaving the country increased by 9% year-on-year, only Shenzhen grew substantially, with an increase of 191%. Nearly half of the ports experienced a large negative growth, and the number of cruise ships received decreased by 16% year-on-year. This shows that China's cruise market has entered an adjustment period. China's cruise industry may usher in a turning point year, entering the critical period of the second decade. The cruise economy is a new economic growth point and an engine for regional development. In September 2018, the Ministry of Transport, the National Development and Reform Commission and other 10 ministries jointly issued the ‘Several Opinions on Promoting the Development of China's Cruise Economy’, demanding that the supply-side structural reform be promoted as the main line to expand China's cruise economic industrial chain. It clarified the nine major tasks of actively cultivating the cruise market and expanding the port service capability and so on. It is proposed that by 2035 China's cruise market will become one of the most dynamic markets in the world. Therefore, in the critical period of the development of the cruise economy in the second decade, we must adhere to the market-led, basic principles of government guidance, actively play the role of the government, coordinate and guide policies, formulate the development strategy of the cruise service industry, and change the current bad situation of governing each region and industry on his own. Carry out overall planning for coastal tourism resources, integrate cruise ship industry service supply chain tourism resources such as cruise ship enterprises, cruise ports, and tourism shore tourism projects, and establish cooperation mechanisms between government and cruise-related enterprises, regions and regions, regions and international ports to achieve multilateral win-win cooperation and promote the transformation of the cruise economy from high-speed growth to high-quality development.

Current research tends to focus on cruise ships and the port itself. In terms of cruise ships, it pay more attention in researching the interior of cruise ships. Internal research can be broadly divided into three categories, consumer habits, cruise management, and analysis of the cruise market.

In terms of consumer habits, Chua Bee-Lia et al. (2017) used a web-based survey to explore the relationship between engagement in the cruise industry and other factors, and the results indicated the critical needs to develop individuals' interest in cruise vacation with a particular cruise line. Chua Bee-Lia and Sanghyeop Lee (2019) attempted to investigate the interrelationships between quality factors, satisfaction, affective commitment, and behavioral intentions. The findings indicated that both interactional quality and outcome quality were significantly related to vacationer satisfaction.

Michael Lynn and Robert J. Kwortnik (2015) found that Carnival Cruise Line's guests rated their cruise more positively when they sailed under a voluntary-tipping policy than when automatic service charges were added to their onboard bills. Marsenka Markesel, et al. (2017) confirmed that cruise passengers' expenditures in the city ports are an important economic incentive for local tourism and related industry sectors. Li Na and Fairley Sheranne (2018) believed that mainland Chinese cruise passengers continually made cultural comparisons between Eastern and Western service, and a preference for Western service was expressed. Li Yiwei and Kwortnik Robert (2017) had revealed differences between the new cruise categories in terms of determinants that influence customer choice. Wu Hung-Che et al. used Hong Kong as a case to identify the dimensions of experiential quality and investigate the relationships among experiential quality, experiential value (emotional value and functional value), trust, corporate reputation, experiential satisfaction and behavioral intentions perceived by cruise tourists. Lyu Jiaying et al. (2017) had concluded that the cruise tourism servicescape construct was identified with six dimensions: facilities and decor, natural scenery, onshore excursions, onboard entertainment, social interactions and dining services.

In terms of cruise management, MacNeill Timothy et al. (2018) believed that in low taxation and regulation environments with an absence of community development and involvement initiatives, large cruise tourism projects can fail to provide benefits for local populations. Pesce Marco et al. (2018) believed that the rapid growth of cruise ship tourism increases the use of historic port cities as strategic hubs for cruise ship operators. Chang Young-Tae et al. (2017) believed that cruise lines were efficient at the operating stage, but varied widely in the efficiency of the non-operating stage. Ros Chaos Sergi et al. (2018) believed that it is crucial for cruise ships to have sufficient transport modes to move passengers to their inland destinations quickly, safely, and efficiently. Jamie M. Chen and Peter Nijkamp (2018) found that a cruise line's duration of stay in a port is primarily influenced by the gross tonnage of the cruise ship, the number of passengers, the sailing distance from the previous port, the sailing distance to the next port, the nature of international cruise lines, the port attraction and other factors. Tsiotas Dimitrios et al. (2018) applied complex network analysis and provided insights about the operational and geographical dynamics of the ports participating in the Mediterranean cruise network.

Whyte Lincoln James (2017) put forward opinions such as improving the cruise experience for passengers, increasing the effectiveness of targeted marketing. Jamie M. Chen et al. (2017) explored whether the cruise industry can be regarded as a two-sided market. The findings show that cruise lines might be hybrid intermediaries, selling their own ship-based products and services, while offering also a platform to enable the transaction between cruise passengers and cruise ports.

In the cruise market, recent research has focused on the new Canadian Arctic Navigation Area [Lasserre, Frédéric and Têtu, Pierre-Louis (2015), Jackie Dawson and Emma J. Stewart (2016), Asia (Chang Young-Tae et al. (2016), Wang Qian -Feng et al. (2018)and the Mediterranean region [Han Heesup, Lee Myong Jae and Kim Wansoo (2018), Jeronimo Esteve Perez and Antonio Garcia Sanchez (2018) and there are many studies on port regional cooperation, but the research on the complementary development of the port and hinterland industries in the region is rare. Wei Hairui et al. (2018) analyzed the port collaboration strategy adopted and implemented in China. It summarizes the trend of development from domestic port cooperation to provincial port groups. Dong Gang et al. (2018) quantitatively examined the effects of regional port integration in the multiport region (MPR) by applying a game theoretical approach.

In summary, as a service-oriented industry, the cruise industry pays great attention to the study of consumer habits, and consumer satisfaction has become an important indicator for evaluating cruise services. Many studies have shown that consumers are more concerned about the cost of travel and the novelty of travel. And the cruise service pays attention to efficiency.

The cruise industry also has certain social attributes, which can drive local economic development, bring about logistics, environmental protection and other related industries, and receive feedback from them.

In the developed countries such as Europe and the United States, the cruise industry is relatively leading. China is the next “sweet pastry” in the development of the cruise industry. The domestic cruise industry still has a lot of room for improvement. Domestic consumers prefer Western cruise services. The Arctic Ocean cruise industry in northern Canada can be seen as another rookie.

How can cruise port of call related companies adapt to the development needs of the cruise industry, make effective and correct strategic choices, utilize, integrate and manage the resources in the cruise ship service supply chain network, and use the multilateral compensation mechanism to optimize the cruise service supply chain. Those need support from relevant theories. At present, there is a lack of research on the distribution of profits in the cruise port service supply chain and the establishment of compensation mechanism under the balance of interests and the realization of multilateral win-win situation. The structure of the research is based on the research of cruise service supply chain, benefit distribution and multilateral compensation mechanism, and integrates these studies to analyze their relationship and roles to deepen relevant theories. According to the research results of the matured benefits distribution, focusing on the goal of improving the multilateral economic benefits, and exploring the construction of multilateral compensation mechanism under the balance of interests. This perspective has great theoretical significance in the research of cruise service supply chain, and it also provides some theoretical reference for future research.

2. Analysis of Related Enterprises in Cruise Port of Call

2.1. Analysis of the Status of Cruise Enterprises

Due to the buyout behavior of cruise by Chinese travel agencies, Chinese tourists lacked motivation for secondary consumption on cruise ships. Therefore, in the European and American markets, cruise companies that rely on the second-period profit of the ship are not operating well in the Chinese market. Chinese consumers are not like European and American consumers. They only use cruise ships as a means of transportation rather than a place for consumption and leisure. However, the onshore tour of the cruise during berthing provides a place for their spending habits.

In terms of expenditure, when cruise ships call at the port, they need to pay berthing fee and service fee to the port, as well as purchase food and other supplies, and pay other miscellaneous expenses. The berthing fee and part of service fee are related to the study in this paper. They are charged according to the length of the cruise ship's affiliated time. In terms of revenue, cruise ships charge for tickets, second consumption on board, and onshore tour items. The income from secondary consumption on board is related to this study.

Generally speaking, cruise ships often need to stop at the cruise port to replenish materials, and guide tourists to onshore tour items during the berthing. But the onshore tour time is often determined by the time required for the cruise to replenish materials or the economic berthing time. Then, tourists don't have enough time for sightseeing on the onshore tour items. The time spent in free items are certain, so the shorter the total tour time, the less time tourists spend on consumption. This leads to a reduction in average consumption. So, if you can extend the time of tourists on the onshore, that is, appropriately increase the berthing time of cruises in the cruise port, the consumption of tourists can be increased.

2.2. Analysis of the Status of Cruise Port of Call

In the past few years, the overheated cruise market has led to the construction of cruise port of call in places where conditions are available throughout the country. However, after the market cooled down, a large number of cruises withdrew from the Chinese market, and the supply of berths is greater than the demand for berths by cruises. This leads to the problem of berth idleness that must be faced today or in the future. Even in places with dense cruise lines like Shanghai, berths may be idle due to the construction of the terminals.

The revenue source of the cruise port of call is the terminal charges paid by cruise ships when they call at the port of call. In terminal charges, berthing fee and part of service fee are charged by the hour, and the other part is often related to the number of berths. Therefore, how to increase the number of cruise ship calling and prolong the time of calling is the means to increase the profit of cruise port of call. In terms of expenditure, the expenditure of the port of call is often fixed, such as dredging rivers, etc., regardless of the berthing time concerned in this paper.

If the port offers certain compensation and preferential conditions to cruise ships, it can attract more calling from cruise ships and prolong the berthing time, so as to improve the utilization rate of cruise port of call. Meanwhile, the total revenue of the port increases compared with before. For ports facing the problem of berth idleness, this compensation mechanism is beneficial to increase revenue.

2.3. Analysis of Tourism Items in the Port of Call

The profit of onshore tour items is greatly affected by the number of tourists. In terms of revenue, tourists joining the onshore tour items will bring ticket revenue and secondary income from onshore tour items. The consumption content of onshore tour items is also richer than cruise ships, which increases the choice of tourists' consumption and increases their consumption desire. That is to say, cruise ships play a bigger role in those onshore tour items, where the tourists are not enough, but the secondary consumption projects are sufficient. And the tourists on the cruise are different from ordinary individual tourists and small tour groups. As cruise travel itself is relatively expensive, tourists who choose to travel by cruise must have sufficient spending power, and they are large and dense, and they are high-quality consumers. In terms of expenditure, as it is also a fixed expenditure, it has nothing to do with this paper, so it is not discussed.

If cruise tourists spend more time on onshore tour items, the total consumption on onshore tour items will definitely increase. This benefits from tourists brought by cruise ships. Onshore tour items should give certain compensation to cruise ships to maintain the cooperative relationship between the two parties and achieve a win-win situation for both parties.

2.4. Analysis of the Revenue of the Port of Call

The crucial premise of cooperation between cruises, onshore tour items, and port is that the total revenue will increase after the cooperation. If the three parties are taken as a whole, after the cooperation, the overall increase of expenditure is the decrease of consumption of cruise tourists on board due to going onshore, and the overall increase in revenue is the increase in revenue from onshore tour items due to increased visitor time. From this, we can find that the essence is to transfer the secondary consumption on board to the onshore tour item through the cooperation of the three parties, and improve the overall benefits with the help of the secondary consumption capacity of the onshore tour item that is stronger than the cruise. At the same time, the increase in the time spent in onshore tour items will definitely lead to an increase in the total cruise tour time. Cruises can increase their fares to make up for the losses, or extend travel time to attract more visitor to increase the cruise full load rate. In short, this is an increase in income on the ship ticket.

If the increase of tickets still cannot make up for the low secondary consumption of onshore tour items, the total revenue will be reduced, and the behavior of extending berthing time of cruises will be meaningless.

3. 'Cruise-Port-City' Game Analysis and Model Establishment

3.1. Analysis of Game Relationship

The purpose of this game is to derive the value of Shapley to guide the contribution of each component and solve the problem of income distribution of the three. In this tripartite game relationship, cruise and onshore tourism projects exist as the core, that is, most of the contributions are generated by the two. The cruise ship as a dominant party has a greater active advantage over the onshore tourism project. Therefore, among the three, the weaker position is the cruise port. However, due to the single and inflexible source of port revenue, the port faces enormous pressure on the vacancy of the port berth. While, ports with less initiative will have a tendency to increase the benefits from cooperation between onshore tourism projects and cruise ship, instead of sharing participation in them. At this time, the pressure from the cruise ship is transformed into competitive pressure from other cruise ports in the same location or similar locations. For precious cruise ships call resources, if the cruise and onshore tourism projects are willing to share more of the port's benefits, the port will have a strong willingness to cooperate.

Table 1: Revenue of Top Three Cruise Line in 2017(billions of dollars)

Line Revenue	Royal Caribbea Cruises Ltd	Carnival Cruise Line	Norwegian Cruise Line
Total revenue	87.78	175.1	53.96
Ticket revenue	63.13	129.44	37.5
Secondary revenue	24.56	43.3	16.46

Source: Qianzhan Industry Research Institute

For cruises, since nearly a quarter of the revenue from cruises comes from secondary income, this portion of revenue is critical to the profitability of cruise companies. The Novartis Cruises Joy announced a loss and exited the market one year after entering the Chinese market. The reason is that Chinese tourists are not spending enough on the cruise.If the method of transferring and increasing the secondary consumption generated by cooperation with the onshore tourism project is a way to improve its own income, the cruise will not refuse to try. The cruise ship is the biggest supporter in this game. For onshore tourism projects, if the onshore tourism project tourists are saturated, the overcrowded onshore tourism project will not only affect the tourist experience of the tourists, but also lead to a decline in the evaluation of onshore tourism projects, and the congestion will cause the average consumption to reach saturation, not increase along with the rising number of people. In this case, the onshore tourism project is likely to not choose or even exclude the game alliance proposed in the text. In this case, the cooperative game is not established. In another case, the onshore tourism project is not saturated, but when the average consumption per unit time of the onshore tourism project is lower than that on the cruise, the entire alliance may refuse to cooperate with the onshore tourism project because the overall income in this case is lower than before. The last one is that the tourists on the onshore tourism project are still in an unsaturated state. In last case, due to the lack of tourists, the onshore tourism project will definitely increase the total revenue of the onshore tourism projects after a large number of tourists from the cruise. Moreover, due to the increase in tourist visit time, the average consumption per unit time of onshore tourism projects may also increase, because tourists have sufficient time to visit onshore tourism projects, and they can make rich time for secondary consumption. Under these conditions, onshore tourism projects will choose to cooperate with cruise ships.

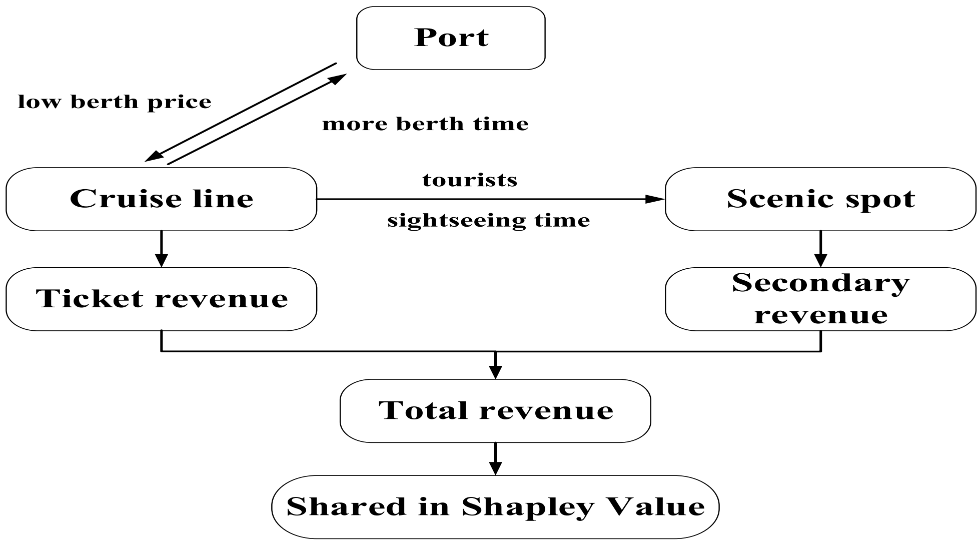

Figure 1: The Process in Game Theory

3.2. Model Establishment

Assuming that the port berths are not saturated, the increase in berthing time alone does not increase the unit cost of the port, and there is no shortage of onshore services, and there is enough time and space for tourists to play and consume.

Table 2: Model Parameters and Connotations

Element	Meaning of representation
Q	Number of people attracted by the cruise every time
P	Fares for sale by cruise
t	Increased call time
c	Port fee plus port usage fee
R	Average secondary income
k_{1i}	In the berth time of the unit, for each additional tourist, the cost that the ith port subsidizes the cruise.
k_{2j}	In the berth time of the unit, for each additional tourist, the cost that the jth onshore tourism project subsidizes the cruise
α	Assume that there are a total of α ports
β	Assume that there are a total of β onshore tourism projects

M_j	Increased income of the jth onshore tourism project for each additional unit time

When all three parties are involved in the compensation mechanism, the cruise also enjoys compensation for the port and tourist attractions.

When the port does not participate in the compensation mechanism, the port can still obtain the income due to the increase of the stop time.

When the attraction does not participate in the compensation mechanism, the cruise can increase the fare of the upstream onshore, and the attraction can still obtain the income due to the increase of the tourist time.

If the port and onshore tourism projects do not choose to participate in the economic compensation mechanism, the cruise will not choose to increase the berthing time.

Table 3: The Avenue in Types of Participation

Participation Revenue	**All in**	**Port out**	**Onshore excursion project out**	**All out**
Cruise line	$P \cdot Q - t \cdot c - t \cdot r + \sum_{i=1}^{\alpha} t \cdot k_{1i} \cdot Q + \sum_{j=1}^{\beta} t \cdot k_{2j} \cdot Q$	$P \cdot Q - t \cdot c - t \cdot r + \sum_{j=1}^{\beta} t \cdot k_{2j} \cdot Q$	$P \cdot Q - t \cdot c - t \cdot r + \sum_{i=1}^{\alpha} t \cdot k_{1i} \cdot Q$	$P \cdot Q$
Port	$t \cdot c - t \cdot k_{1i} \cdot Q$	$t \cdot c$	$t \cdot c - t \cdot k_{1i} \cdot Q$	0
Onshore excursion project	$t \cdot M_j - t \cdot k_{2j} \cdot Q$	$t \cdot M_j - t \cdot k_{2j} \cdot Q$	$t \cdot M_j$	0
Total revenue in cooperation	$P \cdot Q + t \cdot M_j - t \cdot r$	$P \cdot Q + t \cdot M_j - t \cdot r - t \cdot c$	$P \cdot Q - t \cdot r$	

If the port and onshore tourism projects do not choose to participate in the economic compensation mechanism, the cruise will not increase the berthing time to participate in the cooperative compensation mechanism, it needs to be satisfied$P \cdot Q > t \cdot c + t \cdot r$. Because the profit value can be created only when the actual operating income is greater than the cost paid, which must be met for the enterprise. When the port side chooses to participate in the economic compensation mechanism, it needs to meet:$t \cdot c - t \cdot k_{1i} \cdot Q > 0$,which is:$c > k_{1i} \cdot Q$. Port fees and port usage fees collected by the port need to be greater than the compensation paid by the port to the cruise company. In the same way, when the onshore tourism project wants to participate in the economic cooperation compensation mechanism, it needs to be satisfied: $t \cdot M_j - t \cdot k_{2j} \cdot Q > 0$,which is$M_j > k_{2j} \cdot Q$.The profits generated by the onshore tourism project will be appropriately compensated to the cruise enterprises. The increase in the income of the jth onshore tourism projects is required to be greater than the compensation for the cruise industry to the onshore tourism projects under the unit's call time.

$$v(\emptyset) = 0, \; v(\{1\}) = P \times Q, v(\{2\}) = 0, v(\{3\}) = 0 \tag{1}$$

$v(\{1,2\}) = P \times Q - t \times r$， $v(\{1,3\}) = P \times Q + t \times M_j - t \times r - t \times c, v(\{2,3\}) = 0$ (2)

$v(\{1,2,3\}) = P \times Q + t \times M_j - t \times r$ (3)

From formula for Shapley value

$\varphi_i(v) = \sum_{S \subset N\{i\}} \frac{|S|!(n-|S|-1)!}{n!} (v(S \cup \{i\}) - v(S))$ (4)

Can get the average marginal contribution of each

$\varphi_1 = P \cdot Q + \frac{1}{2}(t \cdot M_j) - \frac{2}{3}(t \cdot r) - \frac{1}{6}(t \cdot c)$ (5)

$\varphi_2 = \frac{1}{3}(t \cdot c) - \frac{1}{6}(t \cdot r)$ (6)

$\varphi_3 = \frac{1}{2}(t \cdot M_j) - \frac{1}{6}(t \cdot c) - \frac{1}{6}(t \cdot r)$ (7)

Therefore, the value of Shapley is therefore（φ_1， φ_2， φ_3）

To benefit all three parties, namelyφ_1， φ_2， φ_3Both are greater than 0,$r < 2c, c + r < 3M_j$And if the fare does not change,$c + 4r < 3M_j$

Then, the subsidy to the port should be based on the Shapley value, so

Port subsidy $t \times k_{1i} \times Q = (t \cdot c) - \varphi_2 = \frac{2}{3}(t \cdot c) + \frac{1}{6}(t \cdot r)$ (8)

Subsidy for onshore tourism projectsi

$t \times k_{2j} \times Q = (t \times M_j) - \varphi_3 = \frac{1}{2}(t \cdot M_j) + \frac{1}{6}(t \cdot c) + \frac{1}{6}(t \cdot r)$ (9)

4. Case Analysis

Interviewing relevant cruise companies and port management companies by telephone, it is known that the proportion of upstream participation is about 70%, that is to say, $\alpha = 0.7$.For example, Hong Kong Disneyland's per capita consumption in 2015 has exceeded 750 Hong Kong dollars, according to which Shanghai Disney's per capita consumption (excluding tickets) is 0.78 yuan.

The Royal Caribbean International Cruise Sea Mythology has a total tonnage of 70,000 tons. This ship type is in line with the current cruise ship type in the Chinese cruise market, and the Ocean Mythology is well operated in China and can be used as a data reference source.According to the operation of the Royal Caribbean International Cruise Sea Mythology and the published data, it is assumed that there is a Royal Caribbean International Cruise Marine Mythology port berthing at the Wusongkou International Cruise Port with a capacity of 3,500 passengers and an actual capacity of 2,000 passengers, i.e. $Q = 2000$ .According to the relevant regulations of the Ministry of Communications, the berthing fee for ships in international routes is 0.15 per hour per ton (horsepower)[25]. Other expenses are related to the net weight. After calculation, the pilotage fee is about 58,100 yuan; the tug fee is 33600 yuan per hour, the general tugboat service time at Wusongkou Wharf is 6 hours, so the tugboat cost is 201,600 yuan; the boom oil usage fee is 4,000 yuan; that is, the fixed cost is about 263700 yuan.The hourly parking fee is about 10,500 yuan, that is, r = 175 yuan per minute. According to the report of the Forward-looking database, the 2017 Royal Caribbean ticket revenue and secondary income were \$6.313 billion and \$2.465 billion, respectively, to a ratio of 2.56:1. (https://www.qianzhan.com/analyst/detail/220/181105-722ce265.html)

Assume that the price of the cruise ship sold is P. The route design and product experience of the general tour need to be guaranteed for more than 6 hours, so that visitors can fully appreciate the wonderful places of the port. According to Baidu's travel recommendation, Shanghai Disney's recommended tour time is 1~2 days.When the cruise ship, the port, and the onshore tourism project cooperate, and the onshore tourism project and the cruise ship have the same income, the game equilibrium at the time point is reached. At this time $t = \frac{P \cdot Q}{M_j + c + r}$, substituted into numerical calculations $t = \frac{2000P}{2122}$. According to the data collected by Ctrip and other travel online, the fare is generally around 800 yuan, so the time is 754 minutes. Therefore, the berth increased by 6.5 hours, and the total time t is 750 minutes.Shanghai Disney's per capita consumption (except tickets) $\frac{M_j}{Q}$ is 0.78 yuan, 70% of the ship's personnel choose onshore services.The secondary consumption on the cruise should take a lower value, because only in this case the cruise will seek onshore cooperation to increase revenue.According to the value of the Shapley value of the three parties, and the ratio of the secondary income to the total income on the cruise, in this range, take the per capita average consumption per minute on the cruise$\frac{r}{Q}$ as 0.2.

When the cruise, the port, and the onshore tourism project cooperate, when the onshore tourism project and the cruise revenue are the same, the balance at the time point is reached.At this time $t = \frac{P \cdot Q}{M_j + c + r}$, substituted into numerical calculations $t = \frac{2000P}{2122}$. According to the data collected by Ctrip and other travel online, the fare is generally around 800 yuan.

According to the above formulae, if all three parties participate in the compensation mechanism, the total increased revenue is

$$Z_{total} = P \cdot Q + t \cdot M_j - t \cdot r = 2000 \cdot P + 2000 \cdot 0.7 \cdot 0.78 \cdot 750 - 750 \cdot 2000 \cdot 0.7 \cdot 0.2 = 609000 + 2000P \tag{10}$$

Both the cruise and the port participate in the compensation mechanism, and the gain from both is

$$Z_{12} = P \cdot Q - t \cdot r = 2000 \cdot P - 750 \cdot 2000 \cdot 0.7 \cdot 0.73 = 2000P - 21000 \tag{11}$$

Both the cruise and the onshore tourism project participate in the compensation mechanism, and the gain from both is

$Z_{13} = P \cdot Q + t \cdot M_j - t \cdot r - t \cdot c = 2000 \cdot P + 2000 \cdot 0.7 \cdot 0.78 \cdot 750 - 750 \cdot 2000 \cdot 0.7 \cdot 0.73 - 750 \cdot 175 = 2000P - 341250$ (12)

$$v(\emptyset) = 0, \; v(\{1\}) = 2000P, v(\{2\}) = 0, v(\{3\}) = 0 \quad (13)$$

$$v(\{1,2\}) = 2000P - 21000, \; v(\{1,3\}) = 2000P - 341250, v(\{2,3\}) = 0 \quad (14)$$

$$v(\{1,2,3\}) = 609000 + 2000P \quad (15)$$

Average marginal contribution of each

$$\varphi_1 = P \cdot Q + \frac{1}{2}(t \cdot M_j) - \frac{2}{3}(t \cdot r) - \frac{1}{6}(t \cdot c) = 2000P + 247625 \quad (16)$$

$$\varphi_2 = \frac{1}{3}(t \cdot c) - \frac{1}{6}(t \cdot r) = 8750 \quad (17)$$

$$\varphi_3 = \frac{1}{2}(t \cdot M_j) - \frac{1}{6}(t \cdot c) - \frac{1}{6}(t \cdot r) = 352625 \quad (18)$$

Therefore, the value of Shapley is

(2000P + 247625,8750,352625） (19)

Port subsidy is

$$t \times k_{1i} \times Q = \frac{2}{3}(t \cdot c) + \frac{1}{6}(t \cdot r) = 122500 \quad (20)$$

Subsidy for onshore tourism projects is

$$t \times k_{2j} \times Q = \frac{1}{2}(t \cdot M_j) + \frac{1}{6}(t \cdot c) + \frac{1}{6}(t \cdot r) = 261625 \quad (21)$$

Table 4: The Change of Revenue through Cooperation

Cooperation revenue	**Before cooperation**	**After cooperation**	**Revenue change**
Cruise line	2000P	$2000P + 247625$	247625
Port	0	8750	8750
Onshore excursion project	0	352625	252625
Total revenue of the three	2000P	2000P+609000	609000

From the above calculations, it can be concluded that onshore tourism projects need to give a large amount of income to the cruise to compensate, but at the same time, they also use the cruise to increase the stop time to increase the tour time of the onshore tourism projects, and obtain a lot of benefits.Compared with the onshore tourism projects, the port's revenue is extremely low. From the value of Shapley, it can be seen that due to the small contribution of the port, this directly leads to the low distribution of the revenue generated by the port, and the enthusiasm of the port will be greatly affected.

It is obviously inappropriate for ports to be allocated such a low cooperative game. The role of participating in the tripartite alliance is underestimated by the increase in revenue due to time growth. The cruise ship can only go aonshore to visit the onshore tourism project. The role of the port is not taken into account as a contribution. This is the defect of the cooperative game calculated through various alliance returns. Therefore, in the income distribution, the port's income should be appropriately increased. The port revenue should be compensated by the onshore tourism project and the cruise ship on the basis of the Shapley value.At the same time, the cruise ship itself can increase the total income on the ticket, which is the ability to complement the port.

5. Conclusion

This paper establishes a model of cooperative game theory. The conditions for the increase of total revenue are clarified in the previous discussion and calculation, and then the distribution of each party in the total revenue is calculated according to the Shapley value. Since the reality is between competition and cooperation, and this model gives the game analysis only based on the benefits of various alliances, without considering the port's contribution to the onshore tour of the cruise. So, the role of ports is partially underestimated.

In general, if tourists are willing to travel to onshore for consumption to make up for the low consumption on the cruise, it is obvious that extending the berthing time of the cruise can increase the total benefits of the three parties. But if the consumption on board is enough, extending the berthing time may be less effective, and it may also need to increase the fare to increase revenue. It can be seen from the example that since the port contributes less in the whole economic circle, that is, it does not generate extra-circle benefits itself, if it is distributed according to Shapley value, the port may give up due to less interests. Taking this factor into account, onshore tour subject and cruise can properly compensate port after distribution according to Shapley value to improve the enthusiasm of the port side.

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National development and reform commission of the ministry of transport. The upper limit standard of shipping expenses on international routes .

Research on Investigation and Treatment Mechanism of Water Traffic Accidents

Xin Yang [1,2], *Jingxian Liu* [1,2,3], *Zhao Liu*[1,2],*Deng Jian*[1,2] , *and Zhi Yuan*[1,2]

[1] School of Navigation, Wuhan University of Technology, Wuhan, Hubei, China
[2] Hubei Key Laboratory of Inland Shipping Technology, Wuhan University of Technology
[3] National Engineering Research Center for Water Transport Safety, Wuhan, Hubei, P. R. China
Email: [1]1553431507@qq.com

Abstract

Maritime investigation is one of the most effective means to control water risks. It is an indispensable management link for preventing and reducing water traffic accidents, and can provide a crucial decision-making basis for improving the modernization level of governance systems and governance capabilities. Therefore, how to ensure the continuous improvement of maritime investigation capabilities has always been the subject of concern and discussion by China's transportation authorities and relevant research institutions.

Based on the actual needs of the investigation and treatment of waterborne traffic accidents in China under the new situation, this paper studies and analyzes the problems and deficiencies in the investigation and handling mechanism and procedures of waterborne traffic accidents in China at this stage, Drawing on the experience of accident investigation in developed countries such as the United States and the United Kingdom, and aiming at the present situation of investigation and treatment of water traffic accidents in China, From the aspects of water traffic accident investigation agency setting, staffing, legal norms and other aspects, the waterborne traffic accident investigation and handling mechanism suitable for China's national conditions is proposed, and the waterborne traffic accident investigation and handling procedures and regulations system are improved and improved, and the water traffic accident investigation and processing capacity is improved.

Keywords: Water traffic accident; investigation and treatment mechanism; processing procedure; regulatory system;

1. Introduction

With the rapid development of society and economy, the number and tonnage of ships have increased rapidly with the development of shipping. At the same time, problems such as crowded routes, low standardization of ships, and aging are becoming more and more serious, and the navigation environment is becoming more and more complex. The risk of water traffic safety is also on the rise. According to the Statistical Bulletin of Transportation Industry Development in 2017 (Traffic Finance and Accounting, 2018), from 2012 to 2017, a total of 1 395 maritime traffic accidents of general and above grade occurred in China, with 1404 deaths and 104 missing persons, 706 sunken ships and a direct economic loss of 1.979 billion yuanOver the past six years, although the number of accidents, deaths and disappearances, direct economic losses and shipwrecks in the national level of water traffic accidents has declined year by year, the situation of water traffic safety has been basically stable, but there are still worries, hidden dangers and risks. The "Oriental Star" accident on June 1, 2015, the "Shuanglong" accident on June 4, 2016 and the "Sangji" accident on January 6, 2018 sounded the alarm bell for China's water traffic accidents.

Maritime investigation is one of the most effective means to control water risks. It is an indispensable management link for preventing and reducing water traffic accidents, and can provide a crucial decision-making basis for improving the modernization level of governance systems and governance capabilities. By organizing accident investigation work, we can find out the root cause of the accident and announce it, and then achieve the purpose of preventing similar accidents, educating the public and improving laws and regulations. In order to standardize the investigation and handling of accidents, China has promulgated laws and regulations such as the Regulations on the Investigation and Handling of Maritime Traffic Accidents (2006) and the Regulations on the Handling of Inland River Traffic Accidents (2002), which provide a strong law for the investigation and handling of water traffic accidents. Support and security. The Central Committee of the Communist Party of China promulgated the "Opinions on Promoting the Reform and Development of the Safe Production Field" and put forward new requirements for the investigation of accidents.

According to Marine Accident Investigation Branch (2012), we understand that foreign accident investigations originated in the transportation industry and were driven by aviation and maritime development. As far as water traffic accident investigation and treatment is concerned, foreign developed countries such as Europe and the United States have many mature experiences, and established a relatively complete investigation and handling system and legal protection system.，For example, the United States established the National Transportation Safety Board in 1967, and the United Kingdom established the Maritime Accident Investigation Committee in 1989. The establishment of these professional accident investigation agencies has ensured the scientific and impartiality of accident investigations in various transportation industries in various countries.

Song Wei and Yan Hongli (2007) proposed six points of supervision advice on issues such as laws and regulations, infrastructure construction, responsibility, and execution for crew, shipping companies, and navigational environments; Yuan Zongxiang (2012) proposed a 4R (ie risk, regulation, resource and response) water traffic safety supervision model; Ma Chunxiang (2012) put forward specific countermeasures for safety management in the construction of laws and regulations, responsibility for safety production, infrastructure investment and construction, construction of law enforcement teams, and construction of traffic safety related mechanisms. However, according to Wang Shanwen (2016), compared with foreign developed countries represented by the United States, the United Kingdom, Germany and Japan, Regardless of the institutional setup and system of accident investigation, or the basic theories and methods, the investigation mechanism of water traffic accident handling in China still has some shortcomings. Research on the investigation and handling mechanism of water traffic accidents can effectively grasp the rules and characteristics of maritime investigation work, improve the scientific, predictive, initiative and creativity of work, strengthen risk pre-control and hidden dangers, and solve problems affecting China's waters. The outstanding problems and key problems of the stability of the security situation, improve the internal maritime system and industry standards, ensure the safety of shipping, and enhance the international influence of China's maritime investigation.

Based on the current situation of waterborne traffic accident investigation at home and abroad, combined with the actual needs of the investigation and treatment of waterborne traffic accidents in China under the new situation, on the basis of obtaining the existing achievements, we will learn from the good experience of foreign countries and further improve the investigation mechanism. To improve the investigation and handling capacity of water traffic accidents in China.

2. Current Status of Investigation and Treatment Mechanism of Waterborne Traffic Accidents at Home and Abroad

2.1 Current Situation of Investigation and Treatment Mechanism of Domestic Water Traffic Accidents

According to the "People's Republic of China Maritime Traffic Safety Law" (1984), in 1998, the State established the Maritime Safety Administration, which is a direct organization of the Ministry of Communications and implements a vertical management system. According to the relevant authorization, the Maritime Safety Administration is responsible for exercising the national water safety supervision and supervision, ship and offshore facilities inspection, navigation security management, prevention of ship pollution and administrative law enforcement, and fulfilling the supervision and supervision functions of the Ministry of Communications in the field of safety production. China's water accident investigation agencies and processes are shown in Figure 1：

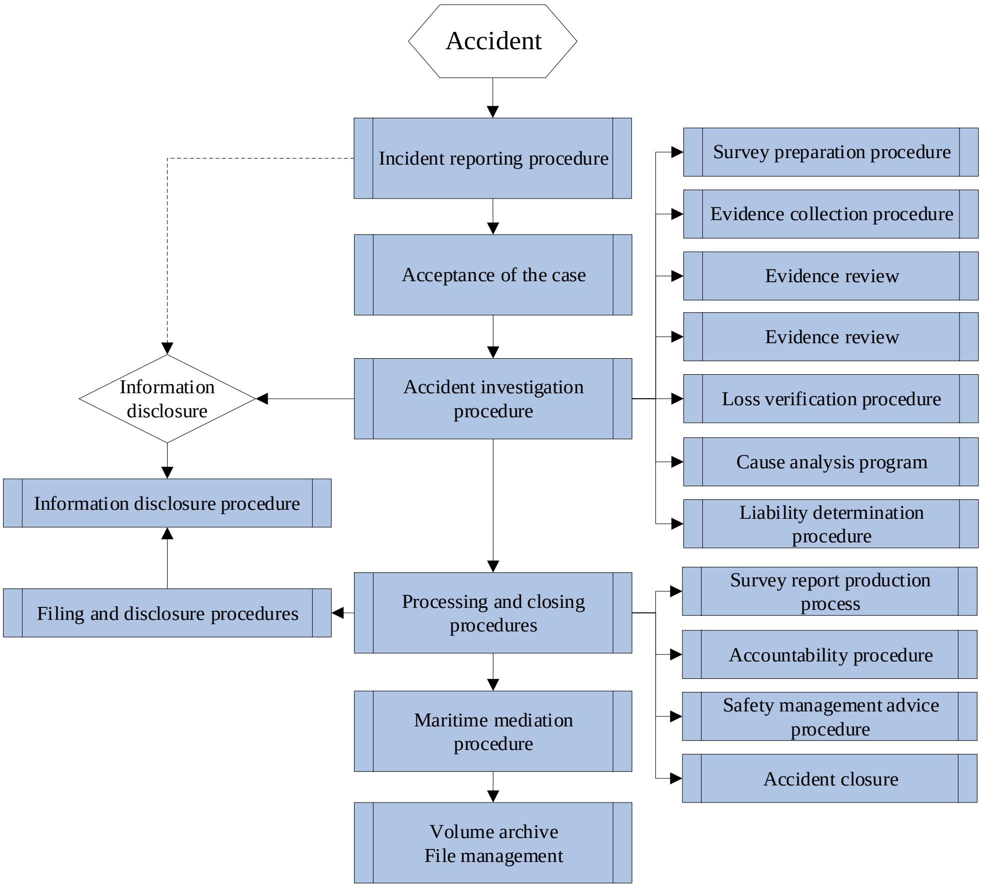

Figure 1: China Water Accident Investigation Agency and Process

2.2 Current Status of Investigation and Treatment Mechanism of Marine Traffic Accidents in the United States

The US Water Traffic Accident Survey adopts a "dual track system". The main agencies of the US water accident investigation are the United States Coast Guard (USCG) and the National Transportation Safety Board (NTSB). According to the CFR46 (Code of Federal Regulations), the National Security Transportation Committee and the Coast Guard conducted a joint investigation into the shipwreck. According to the relevant regulations, the two agencies conduct investigations on maritime affairs within their respective powers, while independently investigating and avoiding duplication as much as possible. The US National Security Transportation Committee is primarily responsible for all major maritime investigations in maritime affairs. The investigations by the US Coast Guard and the US National Security Transportation Committee are relatively independent, and each conducts investigations in accordance with relevant regulations, and each submits an investigation report. The US water accident investigation agency and process are shown in Figure 2：

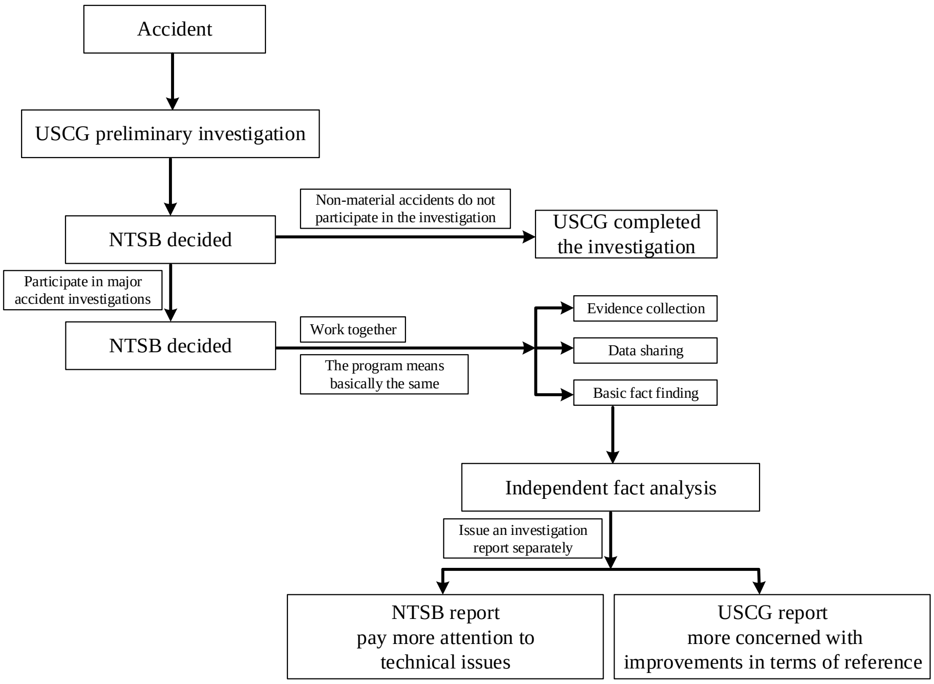

Figure 2: US Water Accident Investigation Agency and Process

2.3 Current Situation of Investigation and Treatment Mechanism of Marine Traffic Accidents in Britain

The UK Water Traffic Accident Survey uses a separation of safety investigations and administrative investigations, consisting of the Marine Accident Investigation Branch (MAIB) and the Maritime and Coastguard Agency, both of which belong to the Department of Transport. , MCA) is responsible. British water accident investigation agencies and processes, as shown in Figure 3:

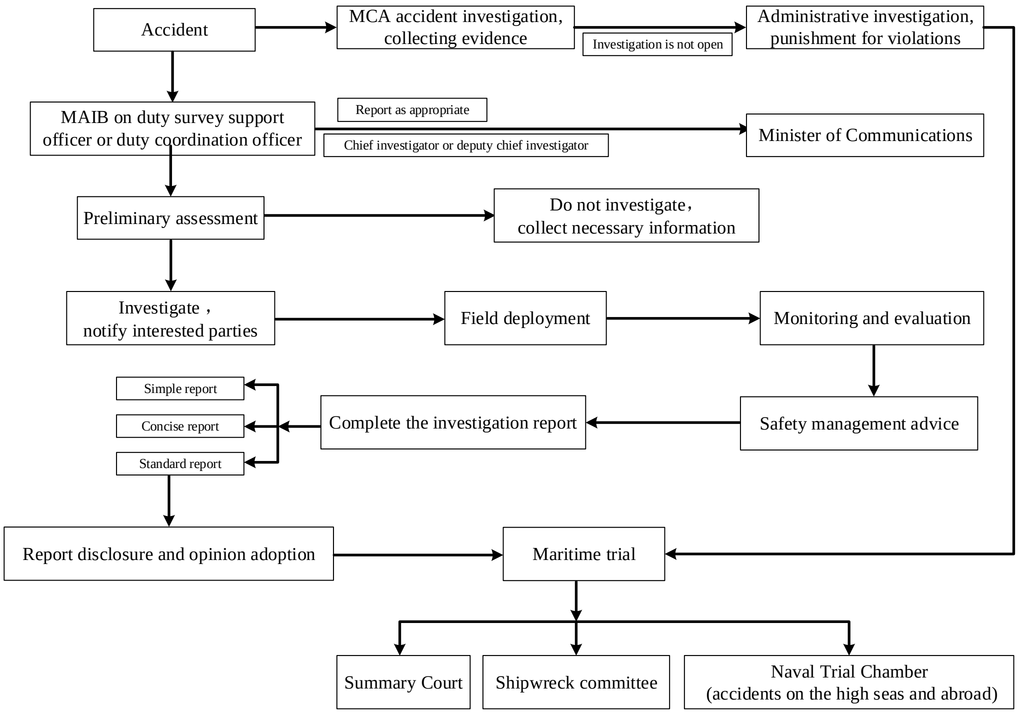

Figure 3: UK Water Accident Investigation Agency and Process

2.4 Current Situation of Investigation and Treatment Mechanism of Marine Traffic Accidents in Japan

According to the adjusted division of responsibilities of Japan's Ministry of Land and Transport, the investigation of maritime traffic accidents in Japan was carried out by the Japan Transport Safety Board (JTSB) and the Japan Marine Accident Tribunal (JMAT), mainly on the basis of the Maritime Trial Law. The former Japan Maritime Disaster Trial Office (subordinate to the Ministry of Land and Transport) was abolished on October 1, 2008, and the powers of punishment and punishment were transferred to the Maritime Disaster Trial Institute, while the investigation of the causes of accidents was transferred to the Transportation Safety Committee. The Transportation Safety Committee is mainly responsible for investigating the causes of water traffic accidents and putting forward preventive measures to prevent similar accidents from happening again. The Maritime Accident Trial Institute is responsible for punishing the persons involved in the accidents. Japan's Marine Accident Investigation Institutions and Procedures, as shown in Figure 4:

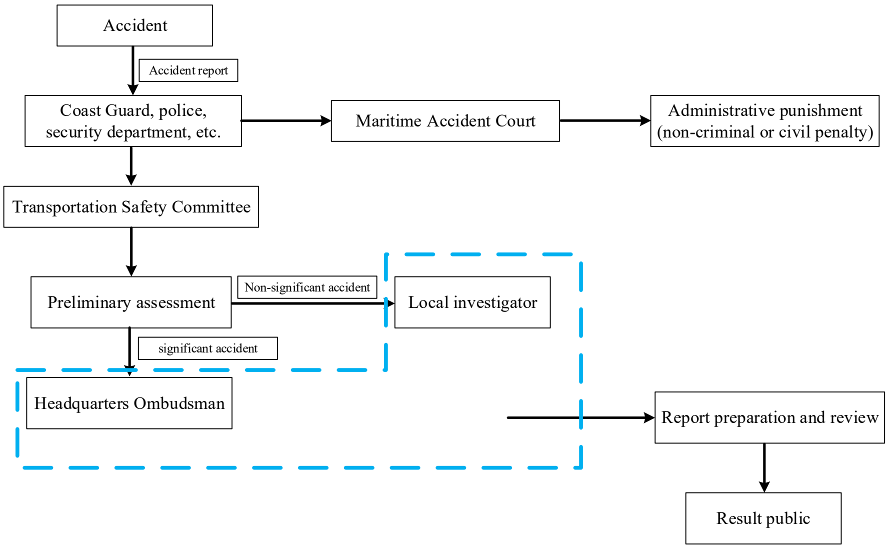

Figure 4: Japan Water Accident Investigation Agency and Process

2.5 Current Situation of Investigation and Handling Mechanism of Water Traffic Accidents in Korea

In 1963, in order to ascertain the responsibility of accidents at sea and prevent the recurrence of similar accidents at sea, South Korea established the Central Maritime Investigation Commission in accordance with the Maritime Trial Regulations promulgated in 1961. In 1971, it was renamed the Maritime Investigation Bureau. In 1999, it was renamed Korea. Maritime Court of Justice (KMST). Currently, the court is affiliated with the Korean Ministry of Marine and Fisheries. After the shipwreck accident of the "Year of the Year" on April 16, 2014, in order to improve the law enforcement system, the Korean Marine Police Agency was dissolved and a new Ministry of Public Safety and Security (MPSS) was established, Integrate the functions related to disaster management that were originally dispersed in various departments to better cope with emergencies. However, the trial court of the shipwreck is still part of the Ministry of Marine and Fisheries, and its organization has not changed.

The South Korean Maritime Court is headquartered in Seoul and has four local Maritime Courts (MST) in Mokpo, Busan, Donghae and Incheon. The local maritime trial court exercises the power of maritime investigation according to the designated area of responsibility, and has the right to investigate all kinds of ship accidents other than unilateral accidents of military vessels and government official vessels. The Korean Maritime Court of Justice adopts the same case handling system as the Administrative Court. The review process of the system is carried out in accordance with the criminal or civil court model and operates independently.

Just like Japan, South Korea divides the world's seas and is under the jurisdiction of various local shipwreck trials. Therefore, once an accident occurs in the country’s waters on the high seas or in other coastal countries, the jurisdiction is very clear. The Korean accident investigation agency and process are shown in Figure 5:

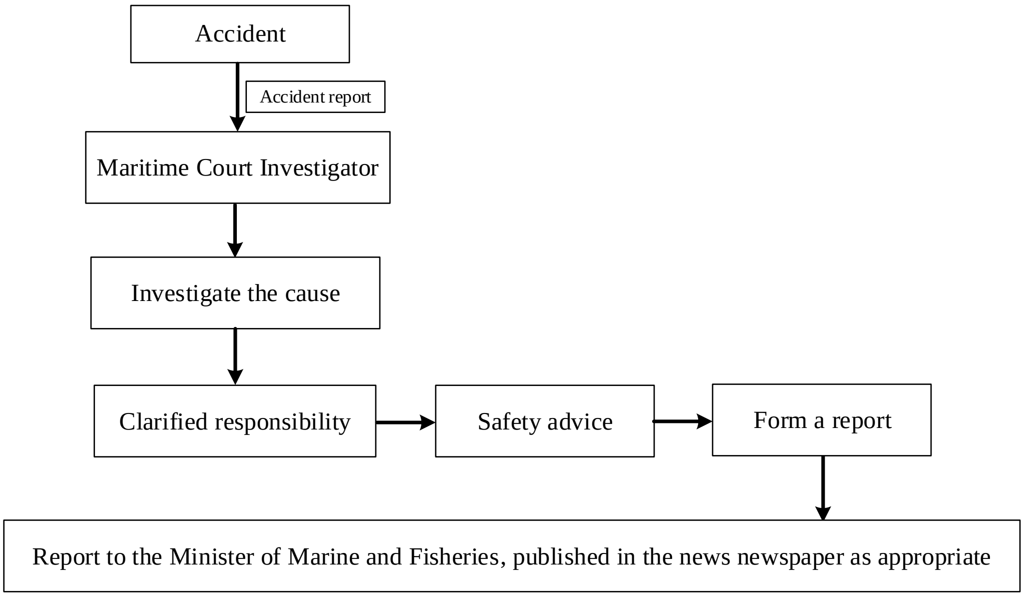

Figure 5: Korea Water Accident Investigation Agency and Process

3. Water traffic accident investigation and treatment mechanism construction

3.1 Establishment of a Perfect Mechanism for Investigating and Dealing with Maritime Traffic Accidents

Therefore, based on the existing maritime investigation and processing system, based on China's national conditions, drawing on the experience of foreign maritime investigation system and mechanism construction, establish a perfect water traffic accident investigation system, the basic structure is shown in Figure 6.

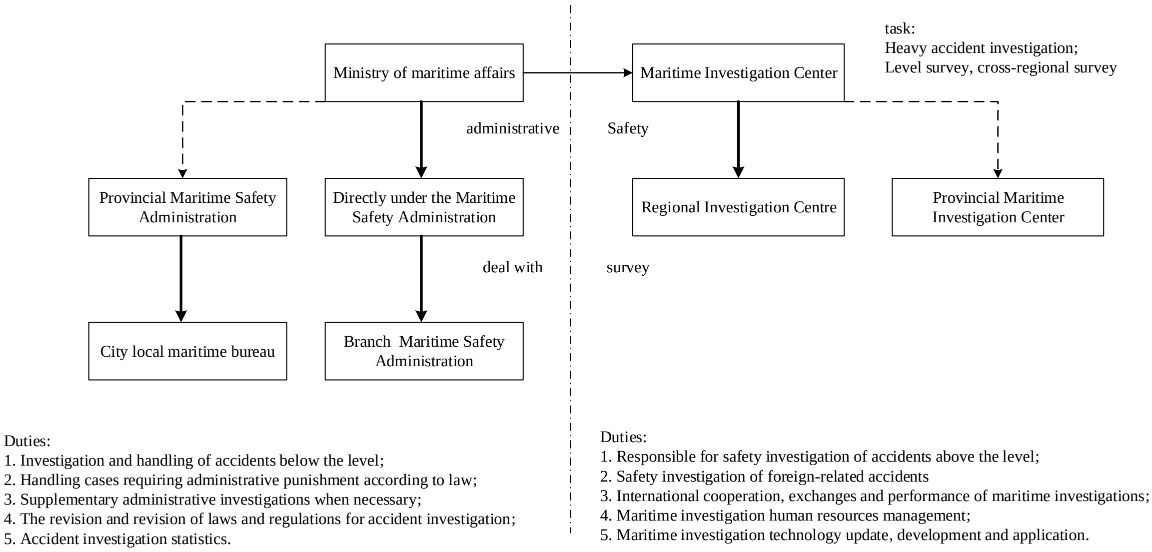

Figure 6: Inspection System Framework

(1) An independent water traffic accident investigation center was established within the Ministry of Maritime Affairs. It is responsible for the investigation of water traffic accidents in the central government waters such as the sea and the Yangtze River, Xijiang and Heilongjiang. Its duties are only responsible for the investigation of water traffic accidents, and the daily safety supervision functions are removed.

(2) Under this framework, the newly established water traffic accident investigation agency can be considered in accordance with the structure of setting up an accident investigation center and several sub-centers (such as the establishment of a water traffic accident investigation center in the ministry and relying on the direct maritime bureau, the division area setting Maritime Investigation Sub-center),responsible for the investigation of water traffic accidents and foreign-related accidents in the river waters such as the sea and the Yangtze River. At the same time, according to the IMO regulations, the investigation agency is only responsible for carrying out safety investigations, aiming to identify the cause of the accident, prevent similar accidents from happening again, and have no administrative penalty duties to meet the IMO performance requirements.

(3) Referring to the setting mode of the direct maritime system accident investigation center, the local provincial maritime management agency is established for the water traffic accidents in the inland waters of local affairs, and the corresponding provincial-level investigation center is established to be responsible for the investigation of water traffic accidents in its jurisdiction.

3.2 Defining the Scope of Investigation of Water Traffic Accidents

According to the Regulations on the Investigation and Handling of Maritime Traffic Accidents, the Regulations on the Investigation and Handling of Inland River Traffic Accidents, and the Measures for the Investigation and Administration of Water Traffic Accidents, etc. The current scope of investigation of waterborne traffic accidents in China is for ship or facility traffic accidents in coastal waters and inland river navigation waters. However, it should be noted that with the rapid development of the economy and the awakening of maritime awareness, China has become a major shipping country and a large ocean country. The scope of waterborne traffic accidents has exceeded the current regulations and needs to be improved and clarified.

Establish a new type of water traffic accident investigation system, and the scope of the accident investigation should include:

From a geographical perspective, the scope of the accident investigation should include waterborne traffic accidents on any vessel within the waters under Chinese jurisdiction, including inland rivers, inland seas, territorial seas, exclusive economic zones, etc., as well as pollution incidents outside the territorial sea that may affect the waters under our jurisdiction. In addition, it also includes accidents in any waters of Chinese ships.

From the type of accident investigated, the scope of the investigation should include the scope of the accident as determined in the “Statistical Measures for Waterborne Traffic Accidents”, including the casualties, property losses, and environmental pollution caused by the ship during navigation, berthing, and operation. Any accident that is damaged, Specifically, there are collision accidents, grounding accidents, reef accidents, touch accidents, wave damage accidents, fire and explosion accidents, wind accidents, self-sinking accidents, operational pollution accidents, and other water traffic accidents that cause casualties, direct economic losses or environmental pollution in water areas.

As far as the type of vessel is concerned, in addition to unilateral accidents between military vessels, between fishing vessels or between military vessels and fishing vessels, the investigation center has the right to investigate traffic accidents of various types of vessels and floating facilities occurring in navigable waters.

From the depth of the accident investigation, the scope of the water traffic accident safety investigation includes the correct identification of the triggering factors, which requires timely and systematic investigation, not limited to the evidence at hand, and the search for potential conditions, which may be away from the occurrence of marine accidents or sea incidents. And may cause other future marine accidents or maritime incidents. Therefore, maritime security surveys should be seen as a means of identifying not only direct triggers but also possible shortcomings throughout the chain of responsibility.

3.3 Form a High-Quality Team of Full-time Security Investigators

It is very important to improve the system of marine traffic accident investigation and establish an independent accident investigation organization with full-time safety investigators. At present, there are more than 4000 licensed maritime investigators in the National Maritime system. Based on this, in line with the principle of professionalization and elitism, the establishment of a high-quality full-time safety investigator team through selection and appointment is an important support for the construction of independent investigation institutions.

4. Suggestions on Adjusting the Investigation and Processing Mechanism of Water Traffic Accidents in China

Facing the strategic needs of a powerful transportation country under the new situation, it is necessary for China's water traffic accident investigation and treatment mechanism to comply with the requirements of the CPC Central Committee and the State Council on Promoting the Reform and Development of Safe Production. Learn and learn from the good experience of foreign countries in the same industry, and further adjust and improve the investigation work mechanism. For example, the Korea Marine Safety Court separates investigations and convictions. Accident investigations and judgments are carried out by different personnel, and the blame is done on the basis of fully listening to the opinions of the parties. Such an investigation mechanism is worth learning. It not only forms a relationship between investigation and trial and mutual restraint from the mechanism, but also improves the quality of the investigation, and can fully listen to the opinions of the parties and achieve fair judgment. For example, the UK Maritime Accident Investigation (MAIB) (According to its 1988 Merchant Shipping Law, prior to this, the British maritime investigation was conducted by relevant personnel of the Marine Department of the Ministry of Communications) and the Maritime Coast Guard (MCA) are responsible for the separation of safety investigation and administration. MAIB is mainly responsible for the safety investigation of accidents, not involving the division of responsibilities, litigation and other issues. The investigation of administrative nature is specially handed over to MCA. It can be seen that the UK has adopted two parallel investigation mechanisms, which separate the safety investigation from the administrative investigation, so as to identify the underlying causes of the accident, prevent the recurrence of similar accidents, and do not affect the relevant sanctions against the persons responsible for the accident. This kind of system design that separates the security investigation from the administrative investigation and conducts investigations by different independent institutions is also worth learning and learning.

4.1 Constructing a New Water Traffic Accident Investigation and Treatment Mechanism

Combining with the existing water traffic safety management system and drawing on the experience of foreign water traffic accident investigation system and mechanism construction, we can further improve the investigation and treatment mechanism of water traffic accidents in China from the following aspects:

（1）Focus on the construction of an independent water traffic accident investigation center, promote the revision of relevant laws and regulations, and clarify the legal status of water traffic accident investigation；

（2）It is necessary to clarify that the responsibility of the water traffic accident investigation center is to investigate the accident safety and find out the cause of the accident, not involving the division of responsibility and litigation, and to promote the construction of a new investigation and treatment mechanism that separates investigation from treatment and technical investigation from administrative punishment.

（3）Based on the separation of investigation and treatment, the investigation center is mainly responsible for the safety investigation of accidents above grade, while the cases requiring administrative punishment based on the investigation are carried out according to the existing management system, and the cases below grade are carried out according to the existing investigation mode.

（4）In the case of possible administrative penalty, administrative hearing system should be established. If the administrative counterpart has objections to the accident investigation report issued by the investigation center, the opinions of the parties should be fully listened to, and if necessary, administrative investigation should be supplemented to provide legal relief channels for the administrative counterpart.

4.2 Improving the Responsibility System of the Team Leader of the Water Traffic Accident Investigation Team

On the basis of clarifying the legal status of the water traffic accident investigation, it is clearly stated that the main body of the water traffic accident investigation is the maritime management institution, and the leader of the accident investigation team above the level is responsible for the personnel of the maritime investigation agency; the rights of the leader of the water traffic accident investigation team are determined. Responsibility and accident investigation work shall be carried out under the unified leadership of the investigation team leader; when the accident investigation team members cannot agree on the cause and nature of the accident and the handling suggestions of the accident owner, the team leader of the accident investigation team has the right to make concluding opinions; Through the improvement of relevant laws and regulations, the system responsible for the investigation team of the water traffic accident investigation team will be improved, and the duties and responsibilities of the maritime investigation officer in the investigation work will be clarified.

4.3 Formulate Water Traffic Accident Escalation Survey, Cross-regional Collaborative Investigation and Work Supervision Mechanism

Focusing on the construction of independent accident investigation centers, implementing the requirements of "Opinions", through revising relevant laws and regulations (such as Regulations on Investigation and Treatment of Marine Traffic Accidents, Regulations on Investigation and Treatment of Inland River Traffic Accidents, etc.), clarifying procedures for investigation and treatment of water traffic accidents, conditions for promotion of investigation and cross-regional collaborative investigation, and establishing a new supervision mechanism for investigation work, in order to better carry out the work. Therefore, the investigation work in order to achieve the ultimate goal of reducing the occurrence of similar accidents.

4.4 Strengthening the Rules and Regulations for the Investigation and Handling of Water Traffic Accidents, and Establish a Supervision and Reporting System for Publicity and Rectification Measures

Through the improvement of the water traffic accident handling system, the role of accident investigation and punishment in strengthening and improving safety production will be brought into full play. Strengthen the construction of accident investigation technology equipment, improve the accident investigation expert database and the sound accident investigation expert analysis system, and improve the comprehensiveness, depth, scientific and legality of the accident investigation.

The accident investigation report shall set up a special section on technical and management issues, analyze the reasons in detail and publish the full text, interpret it in a timely manner, respond to public concerns, and establish a system for rectifying and supervising the accident exposure; It is necessary to improve the post-accident assessment system and make it public to the public in a timely manner. If the performance is not effective and the rectification measures are not implemented, the relevant units and personnel shall be strictly investigated according to the regulations; For the relevant laws, regulations and standard systems for the vulnerabilities and defects found in the accident investigation, it is necessary to start the revision work in time.

4.5 Improving the Communication and Coordination Mechanism between the Maritime System and Local Governments and Relevant Departments

Due to the conflicts in relevant laws and regulations, the legal status of the water traffic accident investigation is unknown, resulting in the unclear division of the accident investigation authority (especially the inland waterborne traffic accident) directly under the maritime management agency and the local government, and the water transportation case led by the maritime management agency. The actual investigation and handling process is also inseparable from the coordination and cooperation of local governments and relevant departments. Therefore, in view of the actual problems existing in the investigation of water traffic accidents and the new requirements and new requirements, it is necessary to solve the problems by promoting the revision and improvement of relevant laws and regulations and constructing a new coordination and cooperation mechanism.

5. Conclusion

This paper combines the status quo of waterborne traffic accident investigation and treatment mechanism at home and abroad, and recognizes the insufficiency of domestic water traffic accident investigation and treatment mechanism from the aspects of water traffic accident investigation agency setting, staffing, division of duties, experience, operation methods and legal norms. The investigation and treatment mechanism of water traffic accidents suitable for China's national conditions was put forward, and the procedures and laws and regulations for the investigation and treatment of water traffic accidents in China were improved and improved, thus improving the investigation and processing capacity of water traffic accidents.

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The Moderating Role of Service Recovery on Customer Loyalty in the Context of Cruise Passengers

Ming-Ren Chiou[1], *Shih-Liang Chao*[*] *,and Hsin-Yu Hsieh* [1]

[1]Department of Shipping and Transportation Management, National Taiwan Ocean University, Keelung, Taiwan, ROC
Email: [*]alexchao@mail.ntou.edu.tw

[*]*Corresponding Author*

Abstract

The role of cruise shipping is becoming more important in the global tour industry because more customers are accepting this novel way of combining touring and hospitality for their travel. However, some service failures are unavoidable due to anthropic factors or an act of God while running this complex shipping business. Focusing on cruise carriers, this study established a model to ascertain the antecedents of customer loyalty. After that, the moderating effects of service recovery on the relationships between the antecedents and customer loyalty were tested statistically. The results of an empirical survey on Keelung Port found that, for cruise carriers, service quality and customer satisfaction both had positive impacts on the loyalty of their customers. In addition, service recovery significantly moderated the impacts of both service quality and customer satisfaction on customer loyalty.

Keywords: Cruise shipping, Tour management, Service recovery, Customer loyalty

1. Introduction

Taking cruises has become a popular option for vacation travel. In addition to enjoying the cuisine and facilities on a specially-designed large ship for a few days, various itineraries that link with land tours and air travel have further increased the scope and diversity of cruise shipping. As a result, the market has been growing dramatically, in which the Caribbean and the Mediterranean Sea are the two leading markets (Wild and Dearing 2000; Brida et al., 2013). However, two other markets, Europe and Asia, cannot be ignored because they are exhibiting high growth rates (McCarthy, 2018; CLIA, 2018). According to CLIA (2018), worldwide passengers in 2019 will total 25.32 million, which is 1.6 times that in 2013. Facing such a strong demand, cruise carriers are also actively upgrading their operational capacities by increasing operation days, routes, and the size of ships. Since cruise shipping is becoming a more important facet of tourism, a number of studies have investigated this industry from various perspectives, in which service quality and delivery (e.g. Teye and Leclerc, 1998; Chua et al., 2015; Lee et al., 2016), customer satisfaction (e.g. Zhang et al., 2013; Chang et al., 2015), and customer loyalty (Chua et al., 2015; Lee et al., 2016) are critical issues that have been empirically examined.

It's worth noting that, despite the fact that cruise operators always attempt to deliver the best service to customers, some service failures are unavoidable and may still occur due to anthropic factors or an act of God.

Since a modern cruise ship can be viewed as a complex of hotels, shopping centers, restaurants, amusement parks, and even casinos, common service failures that may occur in these places may also occur during the course of service delivery on a cruise. In addition, some service failures may occur exclusively for customers who are traveling in this manner. For example, inspections due to customs, immigration, or quarantines may also result in delays or other problems lead to passenger discontent. Another common example is that the preplanned schedule may have to be adjusted due to bad weather conditions. In some cases, cruise carriers have no choice but to cancel a port of call because of typhoons or heavy fog. The passengers who are expecting a land tour to go sightseeing or shopping may be disappointed or even dissatisfied because they are not allowed to alight from the cruise ship once the port of call is canceled.

Once a service failure occurs, most cruise operators will take specific service recovery measures. From the standpoint of a cruise operator, it is both important and necessary to understand the effect of these recovery measures. This motivated us to establish a model to empirically ascertain the effect of service recovery. It should be mentioned that, instead of defining service recovery as an external variable influencing customer loyalty directly, we made service recovery a moderating variable that may impact the relationships between other construct pairs because in terms of cruise shipping, the positive relationships between service quality and customer satisfaction have been proven in previous studies (e.g. Chua et al., 2015a). Meanwhile, a number of studies have also ascertained the positive impact that customer satisfaction has on customer loyalty (Chua et al., 2015b; Lee et al., 2016; Han and Hyun, 2018). Based on these findings, service quality and customer satisfaction were also included as two independent variables in the research model to test their impact on customer loyalty in the context of cruise shipping. Next, since service failures don't affect every customer on a cruise, we deemed service recovery efforts implemented by cruise operators to be a construct that potentially moderates the effects of service quality and customer satisfaction on customer loyalty. More specifically, the aim of this study is twofold. First, a basic model is established to ascertain the impact of service quality and customer satisfaction on customer loyalty toward cruse carriers. Afterwards, the moderating effects of service recovery on the links in the basic model were measured and tested statistically. The remainder of this paper is organized as follows: Section two reviews literature related to cruise shipping. In addition, previous studies focusing on service quality, customer satisfaction, customer loyalty, and service recovery are also reviewed in order to construct the research model. The methodology used in this study is explained in Section three. After that, Section four presents the results of an empirical study based on a questionnaire survey carried out at Keelung Port. The conclusions and implications for future research are summarized in the last section.

2. Literature Review

2.1. Cruise Shipping

Dickinson and Vladimir (1997) mentioned that the cruise industry has evolved markedly since the early days of the first passenger ships. This evolution has included excursion voyages, transatlantic travel, the post-war boom, the demise of passenger ships, and the advent of modern cruising. The industry is now growing rapidly and is one of the major areas of tourism growth at the start of the new millennium. Halmstad (2012) defined a cruise ship as a vessel regularly used for cruise activities for which the trip lasts longer than one day. Furthermore, the ship is not used in ordinary liner shipping for transporting passengers between two or more ports. Maritime tourism includes sea voyages by various kinds of ships to tourist resorts. The main sectors are cruise and ferry shipping. Cruising is a shipping service dedicated to pleasure and reconnaissance voyages. Ross K. Dowling (2006) defined a cruise as "to make a trip by sea in a liner for pleasure, usually calling at a number of ports." It is characterized by the ship being similar to a mobile resort that transports passengers from place to place. Today ships are not viewed as a means of transport but rather as floating hotels or floating resorts. According to the World Tourism Organization (WTO, 2003), the accommodation and related resort facilities comprise 75% of the ship, with the remainder devoted to its operations.

2.2. Service Quality

Parasuraman et al.(1991) defined service quality as the degree of difference between a customer's expectations and the actual experience. Han and Baek (2004) pointed out the common definition of service quality is the difference between customer expectations and service perceptions. Chakrabarty et al. (2008) defined service quality as service delivery that meets customer requirements. In research conducted by Blut (2016) on online purchasing behavior, it was pointed out that improvements in service quality are necessary to maintain the competitiveness of service industries, which helps managers confirm quality, improves customer satisfaction, and even enhances overall performance and profitability. Shahin and Samea (2010) pointed out that high service quality is not only critical but contributes to the competitiveness of service industries. According to the above literature, herein, service quality is viewed from the subjective perspective of the customer to evaluate both expected and actual acceptance of services.

2.3. Customer Loyalty

Wong and Sohal (2003) suggested that customer loyalty is typically defined as when customers repeatedly purchase goods or service over time and maintain a good attitude toward the goods or service or the company that provides them. Aksu (2006) considered customer loyalty to be one of the important factors that affect corporate revenue. An enterprise that has customer loyalty increases sales and the number of customers. Moreover, loyal customers may buy more products or service that lead to higher profits for the company, and they are likely to forgive occasional service failures and resist the attraction of competitors. Lam et al. (2004) defined customer loyalty as behavior in which attention is paid to a service provider or behavior that occurs as a reaction to the positive behavior of a service provider. Based on the above discussion, customer loyalty is defined here as confidence and trust in and dependence on the part of passengers related to the services provided by the operators under consideration.

2.4. Customer Satisfaction

Anderson et al. (1994) pointed out customer satisfaction is a customer's experience of buying a good service or product over time and evaluating the whole performance to certain particular purchase behavior based on previous experience. Satisfaction is one of the important indices by which relationship quality is measured, and it has already been proven to be a critical factor that affects customer loyalty in relevant service industry research. Kim and Park (2004) defined customer loyalty as customer reactions and judgments related to the degree of achievement of a provider. The ability to resolve customer dissatisfaction the first time a service failure occurs is highly related to customer satisfaction. Hennig-Thurau and Klee (1997) indicated that customer satisfaction with products or services are keys to company success and long-term competitiveness. Based on the above literature and considering the properties of a cruise, customer satisfaction in this study is the defined as the difference between the passenger's expectations of the cruise before taking the cruise and their feelings about the service provided by the cruise after taking the cruise.

2.5. Service Recovery

Andreassen (2001) defined service recovery as any action that an organization takes to correct a mistake. The purpose of service recovery is to transform dissatisfied customers into satisfied customers. Cambra-Fierro et al. (2011) mentioned that service recovery is proactive. The goal is not only to successfully handle complaints, but to provide a satisfactory, customer-oriented solution. Andreassen (2001) pointed out that customers who make a complaint and experience satisfactory service recovery have higher willingness to repurchase and have a more positive view of suppliers than those who are not satisfied with the service but do not complain. Maxham III (2001) indicated that an enterprise can maintain clients and loyalty through effective service recovery. Miller et al. (2000) classified service into two types, the first of which has a mental component. The recovery from the mental perspective can be divided into explanations and apologies intended to concentrate on and improve the ability to meet customer needs. It is a simple and cost-effective way to achieve service recovery, but it will increase negative emotions in customers if used improperly. The other is the physical component, where service recovery refers to actual compensation, which can be divided into service compensation and monetary compensation. It compensates for the loss or inconvenience caused by the service failure and is adds value to the service as well.

2.6. Hypotheses Development

(1) The impact of service quality on customer satisfaction

The studies related to service quality and satisfaction have been widely discussed in the past. Parasuraman et al. (1988) mentioned there is a high correlation between service quality and customer satisfaction. Antony et al. (2004) did a survey on the relationship between service quality and customer satisfaction in British hotels and found that service quality is the main determinant of customer satisfaction. Kim et al. (2004) did research on the mobile communication industry in Korea and indicated that enhancing service quality has a significant positive impact on customer satisfaction. Yeo et al. (2015) took a container terminal in Korea as an example and found that improving all areas of service quality can increase customer satisfaction. Therefore, service quality has a positive impact on customer satisfaction for cruise operators if the cruise staff has sufficient capability to determine passenger needs and resolve problems successfully, while concentrating on overall improvements in service quality. Hence, the following hypothesis is proposed:

H$_1$: Service quality has a significant positive impact on customer satisfaction with cruise operators.

(2) The impact of customer satisfaction on customer loyalty

Ganiyu et al. (2012) investigated whether customer satisfaction is an indicator of customer loyalty, and the results supported the argument that there is a strong relationship between customer satisfaction and customer loyalty. Wong and Sohal (2003) conducted research on a shopping mall in Australia and indicated that when more consumers are satisfied during the service period, there is a greater possibility of repurchase. Yang and Petterson (2004) took an internet service provider as an example and confirmed that customers will continue using a service if they are satisfied with every service the company provides. Kasiri et al. (2017) did research on three kinds of service industries, including medical, hotel, and education, and indicated that customer satisfaction has a positive impact on customer loyalty. In the cruise industry, a company that has better customer satisfaction leads to have more favorable attitude toward that company, and thus, it is easier to create loyalty. Hence, the following hypothesis is proposed:

H$_2$: Customer satisfaction has a significantly positive impact on customer loyalty toward cruise operators.

(3) The impact of service quality on customer loyalty

Parasuraman et al. (1988) pointed out that service quality has a significant effect on customer loyalty. Customer loyalty can thus be established quickly by improving service quality. Bell et al. (2005) served as an investment consultant in a study of customer loyalty and confirmed that quality of service directly affects customer intention toward repurchasing and customer switching behavior. Rasheed and Abadi (2014) took a bank in Malaysia, insurance, and telecommunications service industries as examples to investigate the impact of service quality, trust, and customer-perceived value on customer loyalty. The results indicated that service quality has a positive impact on customer loyalty. Baumann et al. (2posi017) researched the banking industry and regarded service quality and competitiveness as antecedents of customer loyalty. The results indicated that service quality has a significantly positive impact on customer loyalty. In this study, it is posited that customers will be more willing to take a cruise again if the cruise operator provides them with excellent service quality, such as a friendly frontline staff, professional knowledge, and quick response to customer questions. Meanwhile, the operator increases profits. Hence, the following hypothesis is proposed:

H$_3$: Service quality has a significant positive impact on customer loyalty toward a cruise operator.

(4) The moderating effect of service recovery

Kuo et al. (2013) pointed out that many studies have investigated service recovery, but few studies have regarded it as a moderator. However, they took tourism as an example and mentioned that service recovery is a moderator between service quality and customer satisfaction. However, if service recovery moderates the relationship between the aforementioned constructs, it seems reasonable to suggest that it may also moderate the relationship between customer satisfaction and customer loyalty. In this context, the following hypotheses are thus drawn:

H$_4$: Service recovery significantly moderates the relationship between service quality and customer satisfaction with a cruise operator.

H$_5$: Service recovery significantly moderates the relationship between service quality and customer loyalty toward a cruise operator.

H$_6$: Service recovery significantly moderates the relationship between service satisfaction and customer loyalty toward a cruise operator.

(5) Research model

The study mainly investigates the relationship between customers and service quality - customer satisfaction - customer loyalty. Constructs and relationships are set up based on relevant literature. In this context, Figure 1 represents the proposed theoretical model and hypotheses.

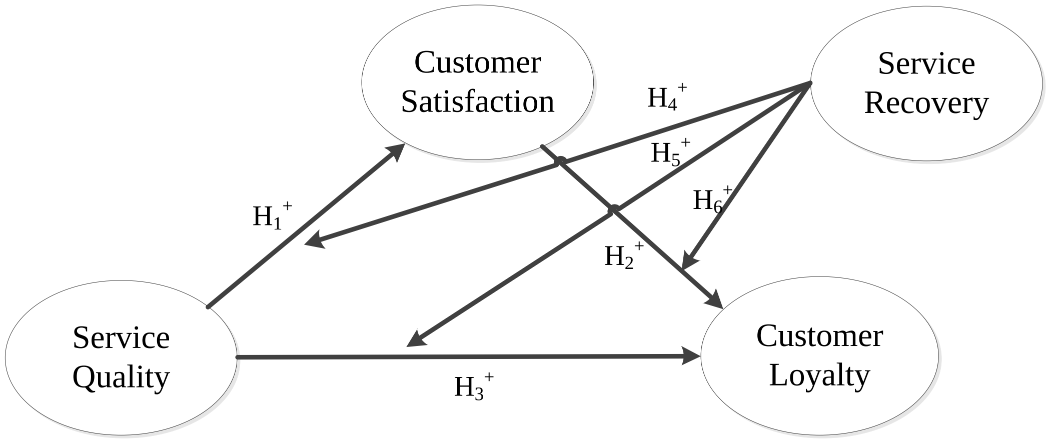

Figure 1: Research model

3. Methodology

3.1. Questionnaire Design

A questionnaire survey was conducted to collect the samples used in this study. The constructs and question items were sourced from related literature (see Table A1 in the Appendix). Each of the items was measured on a 5-point Likert scale ((1) being "strongly disagree" and (5) being "strongly agree"). The questionnaire designed in this study comprises two parts. The first part collected the passengers' experience with taking a cruise in the past, including service quality, customer satisfaction, customer loyalty, and service recovery provided by the cruise carrier. The other part collected the demographic characteristics of respondents. Before issuing the questionnaire, a pilot test was conducted during June 2018. Two professors and four practitioners were invited to review the draft of the questionnaire. The content of the questionnaire was refined based on their opinions.

With regards to the construct measures, the question items for measuring service quality were sourced from Hwang and Han (2014), which were designed to investigate the quality of the cruise exclusively. The construct for customer satisfaction was measured using items sourced from Söderlund (1998) and Casalo et al.(2008); customer loyalty, which is the dependent variable in the research model, was measured by items sourced from Söderlund (1998), Casalo et al. (2008), and Hwang and Han(2013). Lastly, service recovery, which is the moderator in the research model, was measured by items sourced from Del Río-Lanza et al. (2009). The measurement items are listed in the Appendix (see Table A1)

3.2. Sampling and Data Collection

The population in this study was passengers who embarked on cruise ships at the Keelung Port during July 2018. In total, 190 passengers were asked to fill out the questionnaires at the passenger terminals. Except for 22 invalid samples due to incompleteness, 168 valid samples were used for the analysis, which accounted for a valid returned rate of 88%. The demographic information in the returned samples is listed in the Appendix (see Table A2). As for the respondents, 46.4% were males, and 53.6% were females. In terms of age, most respondents ranged in age from 41 to 50 years-old, which accounted for the majority of all respondents. Meanwhile, 49.4% of the respondents had graduated from universities. The jobs of respondents were mainly in the field of business, accounting for 39.9% of all respondents. 25.6% of the respondents' household income fell within the range of NT$6,0001 to NT$8,0000. 35.1% and 34.5% of respondents lived in Taipei and Taichung City, respectively. 34.5% of respondents listed family trips as the trip intention. PRINCESS CRUISE and STAR CRUISE were the most frequently chosen cruise carriers, which accounted for 54.8% and 43.5% of the respondents, respectively. 67.9% of respondents were taking a cruise for the first time. Lastly, more than half of the respondents (i.e. 74.4%) were not cruise members.

3.3. SEM Analysis

In this study, the two-step procedure proposed by Anderson and Gerbing (1988) was applied to carry out an SEM analysis. The first step builds up a measurement to ensure the reliability and validity of the model. In terms of reliability, two acceptance thresholds were examined, the first of which requires the construct reliabilities (CR) of each construct to all be larger than 0.7 (Fornell and Larcker, 1981; Hair et al., 1998). The other requires that the AVE values of all constructs be greater than 0.5 (Bagozzi and Yi, 1988). After that, three validities were examined in this study. The first type, content validity, requires that the instrument used for collecting samples must precisely measure the construct that the research intends to measure. The second type of validity, which is called convergence validity, was measured by if all factor loadings of the constructs exceeded 0.5 (Kline, 1998). Thirdly, the confidence intervals (C.I.) of all coefficients between construct pairs have to be estimated using a bootstrapping method at a 0.05 level of significance. The discriminant validity of the model is endured if none of the C.I. values include one (Torkzahed et al., 2003). After the reliability and validity of the model were ensured, the second step proposed by Anderson and Gerbing (1988) was to establish a structural model to test the significance of each coefficient on the path, by which to statistically test the hypotheses proposed in this study.

4. Empirical Study

4.1. The Measurement Model

Table 1 presents the results of the measurement model analysis. The CR and AVE values of all constructs were estimated to test the reliability. As Table 1 shows, all CR values were between 0.797 and 0.914, which were all greater than the threshold (0.7) (Fornell and Larcker, 1981; Hair et al., 1998). Furthermore, the AVE values of the constructs ranged from 0.521 to 0.727, all of which were greater than 0.5 (Bagozzi and Yi, 1988).

The reliability of our model was ensured based on these two measures. In addition, the convergent validity and discriminant validity were also examined. As can be seen in Table 1, the standard factor loading for all of the constructs was larger than 0.5, which ensured the convergent validity of our model (Kline, 1998). Afterwards, the discriminant validity had to be tested by using a bootstrap method to estimate the coefficients between construct pairs by 1000 times repeatedly under a 95% C.I. Discriminant validity existed if 1 was not included in any of the C.I. values. As Table 2 demonstrates, none of them included 1. That is, discriminant validity existed among the four constructs. Lastly, Table 3 shows that all seven Goodness-of-fit indexes exceeded the acceptance thresholds (Hayduck, 1987; Doll et al., 1994; Scott, 1994; Bagozzi and Yi, 1988; Jöreskog and Sörbom, 1989; Jarvenpaa et al., 2000; Ullman, 2001), which meant that the fitness between the collected valid samples and the measurement model in this study was acceptable.

Table 1: The Results of the Measurement Model Analysis

Construct	Observation Variable	Standard factor loading	Standard error	Construct reliability (CR)	Average variance extracted (AVE)
Service quality	SQ2	0.707		0.867	0.521
	SQ3	0.702	0.096		
	SQ4	0.715	0.154		
	SQ5	0.746	0.148		
	SQ6	0.736	0.146		
	SQ8	0.724	0.146		
Customer satisfaction	SA1	0.700	0.092	0.880	0.648
	SA2	0.877	0.082		
	SA3	0.848	0.094		
	SA4	0.783			
Customer loyalty	CL1	0.853	0.078	0.914	0.727
	CL2	0.892	0.081		
	CL3	0.876	0.083		
	CL4	0.785			
Service recovery	SR1	0.784	0.129	0.797	0.568
	SR2	0.783	0.118		
	SR3	0.691			

Table 2: The Results for Estimating the Confidence Interval of All Construct Pairs

Construct pair	Estimate	Lower bound	Upper bound	p-value
Service quality and Customer satisfaction	0.195	0.103	0.371	0.001
Service quality and Service recovery	0.178	0.096	0.357	0.001
Service quality and Customer loyalty	0.184	0.097	0.357	0.001
Customer satisfaction and Service recovery	0.251	0.145	0.397	0.001
Customer satisfaction and Customer loyalty	0.250	0.158	0.413	0.001
Service recovery and Customer loyalty	0.214	0.118	0.385	0.001

Table 3: Goodness-of-fit Measures of the Measurement Model

Goodness-of-fit measure	Recommended value	Value of this study
χ^2/degree of freedom	≤3.00	1.934
Goodness-of-fit index (GFI)	≥0.80	0.859
Adjusted Goodness-of-fit index (AGFI)	≥0.80	0.807
Normed fit index (NFI)	≥0.80	0.891
Comparative fit index (CFI)	≥0.90	0.943
Standardized root mean square residual (SRMR)	≤0.05	0.031
Root mean square error of approximation (RMSEA)	≤0.08	0.075

4.2. The Structural Model

The results of structural model analysis were mainly used to examine the relationship between latent constructs. According to Table 4, the results of the seven Goodness-of-fit indexes met the acceptance threshold (Hayduck, 1987; Doll et al., 1994; Scott, 1994; Bagozzi and Yi, 1988; Jöreskog and Sörbom, 1989; Jarvenpaa et al., 2000; Ullman, 2001), showing good fitness between the collected data and the structural model. The critical value, one of the measures obtained from AMOS software, was used to examine the path coefficient between constructs, which was deemed significant if the absolute value of a critical value was greater than 1.96. Table 5 presents path the coefficients and critical values. It was found that the critical value of each construct was greater than 1.96, which meant the hypotheses proposed in the study were supported.

Table 4: Goodness-of-fit Measures of the Structural Model

Goodness-of-fit measure	Recommended value	Value of this study
χ^2/degree of freedom	≤3.00	1.957
Goodness-of-fit index (GFI)	≥0.80	0.887
Adjusted Goodness-of-fit index (AGFI)	≥0.80	0.833
Normed fit index (NFI)	≥0.80	0.915
Comparative fit index (CFI)	≥0.90	0.956
Root mean square residual (RMR)	≤0.05	0.027
Root mean square error of approximation (RMSEA)	≤0.08	0.076

Table 5: Path Coefficients and Critical Ratios (H_1 to H_3)

Hypotheses	Variables	Estimates	S.E.[a]	C.R.[b]
H_1	Service quality→Customer satisfaction	0.800	0.120	6.644
H_2	Customer satisfaction→ Customer loyalty	0.314	0.155	2.032
H_3	Service quality→Customer satisfaction	0.568	0.167	3.393

[a] S.E. stands for standard error [b]; C.R. stands for critical ratio.

[b] CR did not exceed 1.96 at the 0.05 level of significance.

The results of the structural model analysis, which explains the coefficient of determination (R^2) and path relationships between service quality, customer satisfaction and customer loyalty, are shown in Figure 2. The R^2 value of customer loyalty was 0.523, which meant both service quality and customer satisfaction explained 52.3% of the total variations in loyalty. The R^2 value of customer satisfaction was 0.631, which meant that service quality explained 63.1% of the total variations in customer satisfaction. In general, the results of the structural model analysis demonstrated that the explanatory power of the model was acceptable because the R^2 value of customer loyalty reached 0.523.

Lastly, the three moderating effects from service recovery were tested using ROCESS software. First, the moderating effect of service recovery on the relationship between service quality and customer satisfaction was tested. As Table 7 indicates, the lower and upper levels for C.I. of the estimated interaction variable included 0, which meant that the moderating effects of service recovery on the relationship between service quality and customer satisfaction were not significant. Second, the moderating effect from service recovery on the relationship between service quality and customer loyalty was tested. The result is listed in Table 6, which indicates that the moderating effect of service recovery on the relationship between service quality and customer loyalty was significant because all estimated C.I. values did not include 0. Finally, the results of the hypotheses tests are summarized in Table 7.

Table 6: The Results for the Moderating Effect of Service Recovery

	coefficient	Standard error	t-value	p-value	LLCI*	ULCI**
Service quality	0.442	0.078	5.652	0.000	0.288	0.597
Service recovery	0.495	0.071	6.944	0.000	0.354	0.636
Customer satisfaction	0.399	0.101	3.953	0.000	0.200	0.598
Service quality	0.221	0.107	2.059	0.041	0.009	0.433
Service recovery	0.206	0.098	2.099	0.037	0.012	0.400
Interaction 1***	0.018	0.047	0.382	0.703	-0.074	0.110
Interaction 2	0.393	0.117	3.367	0.001	0.163	0.624
Interaction 3	-0.435	0.128	-3.406	0.001	-0.687	-0.183

* LLCI: lower level for confidence interval.

** ULCI: upper level for confidence interval.

*** insignificant.

Table 7: The Test Results of Proposed Hypotheses (H_4 to H_6)

Hypotheses	LLCI*	ULCI**	Result
H_4: Service recovery significantly moderates the relationship between service quality and customer satisfaction with cruise carriers.	-0.074	0.110	Not supported
H_5: Service recovery significantly moderates the relationship between service quality and customer loyalty toward cruise carriers.	0.163	0.624	Supported
H_6: Service recovery significantly moderates the relationship between service satisfaction and customer loyalty toward cruise carriers.	-0.687	-0.183	supported

* LLCI: lower level for confidence interval.

** ULCI: upper level for confidence interval.

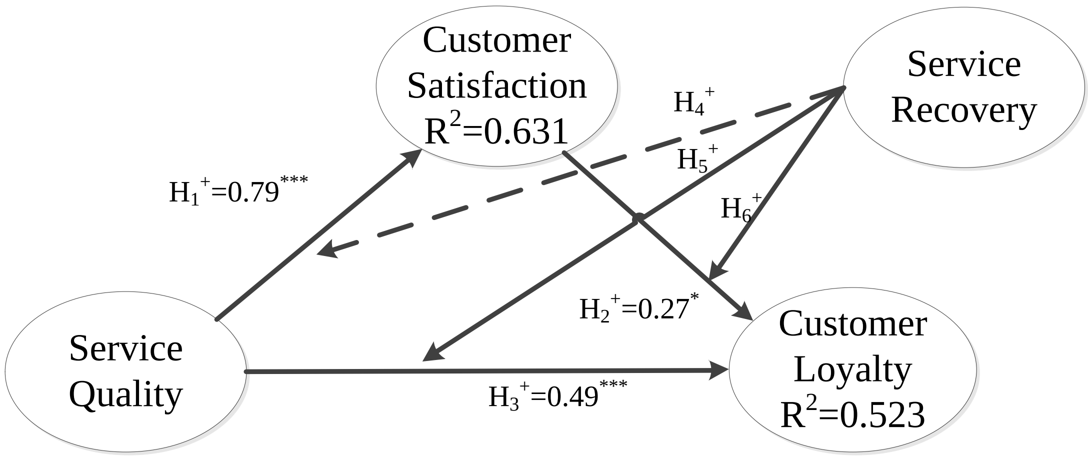

Figure 2: Results of the Structural Model Analysis

5. Conclusions and Managerial Implications

The role of cruise shipping is becoming more important in the global tour industry because more customers are accepting this novel way to combine touring and hospitality when planning their travels. In this study, we proposed a model to ascertain the antecedents of customer loyalty in the context of cruise carriers. Meanwhile, the moderating effects of service recovery on the relationship between service quality and customer satisfaction and the relationship between customer satisfaction and customer loyalty were also examined statistically. An empirical survey was carried out at the Keelung Port to collect samples from cruise passengers. Some findings and managerial implications that contribute to the literature and practice can be drawn from the results of the empirical study, which are summarized as follows: First, ascertaining the antecedents of customer loyalty has been a vital issue for cruise shipping relevant literature (e.g. Hwang and Han, 2014; Chua et al., 2015). In this study, by taking account the interaction among the cruise ship staff, facilities, and land tours, we proved that service quality has significant positive impacts on both customer satisfaction and customer loyalty. This result implies that cruise carriers should try their best to ensure the quality of their service in order to increase the satisfaction and loyalty of their customers. Essentially, service quality is the difference between customer expectations and their perceptions of the services provided (Parasuraman et al., 1991; Han and Baek, 2004). In the present empirical study, a majority of the respondents were taking a cruise for the first time. Therefore, cruise carriers should try to narrow the gap between customer expectations and the service they actually perceived as having. Namely, cruise carriers should avoid exaggerating their advertisements and ensure quality while delivering the service they intend to provide. Second, in terms of the three significant direct impacts proven in this study, the impact of customer satisfaction on customer loyalty (i.e. H_2) was much lower than that from service quality on the other two constructs (i.e. H_1 and H_3). This finding implies that even though customer satisfaction could be increased by improving the service offered from a cruise carrier (i.e. H_1), the significant effect of customer satisfaction towards loyalty was quite weak. In other words, because most carriers are trying to satisfy their customers in the competitive cruise shipping market, those customers with high satisfaction might still be interested in the services offered by other carriers. Therefore, cruise companies should pay attention to developing auxiliary measures to enhance the loyalty of customers with high satisfaction while running their businesses. Extending this idea, the third conclusion of this study is related to the moderating role of service recovery. According to our findings, service recovery will positively moderate the effect of customer satisfaction on customer loyalty. That is, once a service failure occurs, cruise carriers should try their best to provide good service recovery because it can significantly enhance the positive impact of customer satisfaction on loyalty. Similarly, the positive impact pf service quality on customer loyalty could also be strengthened once service recovery is performed appropriately. Since service failures are unavoidable when running a cruise ship, which is a complex business combining shipping, hospitality, and touring, we suggest that cruise carriers pay attention to service recovery when a service failure occurs in order to increase the effects of service quality and satisfaction on customer loyalty. Fourth, extending the findings of Kuo et al. (2013), this study is the first to prove the significant moderating effects of service recovery on the relationship between service quality and customer loyalty and the relationship between customer satisfaction and customer loyalty. These findings contribute to the literature investigating customer loyalty in the service industry. Since service failures may occur during the service delivery process, practitioners and researchers may want to take into account these two effects when addressing issues related to service quality, customer satisfaction, and customer loyalty in the service industry.

6. Limitations and Directions for Future Research

Lastly, some limitations and directions for future research are given as follows: First, the results of this study were based on an empirical study carried out at Keelung Port. Even though this port was ranked the third largest cruise port in Asia in 2018 with 322 port calls, these results reflected only the opinions of passengers who started and ended their cruise journeys at Keelung Port. Future researchers may want to collect samples from other important cruise ports to carry out a comprehensive investigation on the effect of service recovery by comparing the results obtained from different sample groups. Second, instead of investigating only a single moderating effect of each exogenous variable (e.g. Kuo et al., 2013), more recent studies (e.g. Lee et al., 2016; Kamran-Disfani et al., 217) have incorporated multiple moderating effects of an exogenous variable simultaneously to explore more managerial implications. In terms relevant studies on cruise shipping, Lee et al. (2016) established a model to test five hypothesized moderating effects of affective commitment simultaneously, three of which were proven significant by an empirical survey of cruise passengers. Similarly, two of three hypothesized moderating effects of service recovery were found to be significant in this study, revealing that service recovery moderates the impacts of service quality and customer satisfaction on customer loyalty. Because an exogenous variable might moderate multiple relationships in a research model, future research could establish hypotheses to test the multiple moderating effects of an exogenous variable and could include this in the model design. Third, to increase the novelty and attraction of cruise tours, many diversified ways for enjoying cruise tours have been designed and carried out. The so-called fly cruise is a good example of such diversity. When going on a fly cruise, passengers arrange to fly to a destination for a land tour for a few days. After that, they continue their tour by taking a cruise. More combinations to adjust the connections of flights, land tours, and cruise travel are available because cruise carriers have to meet the various demands of their customers. Future studies may want to include such diversified activities when investigating the products or services provided by cruise carriers because they indeed comprise a portion of the elements that make a cruise trip enjoyable.

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Using the Kano Model to Investigate the Quality of a Pharmaceutical Logistics Service: A Study of Taiwanese Health Insurance Pharmacies

Shih-Liang Chao[1] , Chin-Ping Chuang[1] , and Hsuan-Yun Lin[1]

[1]Department of Shipping and Transportation Management, National Taiwan Ocean University, Keelung, Taiwan, ROC

Abstract

The distribution of pharmaceutical products has become more complicated because the supply chain has been extending globally by various transportation systems. During the process of medicine distribution and sales crossing states or countries, some uncontrollable factors may lead to a potential risk of deterioration of medicines. Therefore, the Good Distribution Practice (GDP) has been implemented as a norm to ensure consistent quality of the medicinal products shipped from Good Manufacturing Practice (GMP)-certified manufactories to hospitals, pharmacies, and clinics. This study analyzed the service quality of medical product suppliers for National Health Insurance (NHI)-appointed pharmacies. An empirical survey was conducted using a questionnaire designed using a two-dimensional Kano model. The purpose was to classify the service items of the medical product logistics service from the perspective of pharmacists who work at NHI-appointed pharmacies. The results of our empirical study provide directions for pharmaceutical products logistics service providers to improve their service quality.

Keywords: Good Distribution Practice (GDP), Kano model, pharmaceutical logistics

1. Introduction

Any national of the Republic of China who meets the requirements of an act by the National Health Insurance Administration Ministry (NHI) can become the beneficiary of health insurance. Chronic patients are considered as those who need to take the same drugs continuously over a six month period, but controlled drugs are only available by prescription from doctors. In accordance with the need for a continuous prescription, chronic patients may get their medicine easily from NHI-appointed pharmacies, which will save the cost of registering at a hospital or clinic, as well the time spent in traffic to obtain these medicines. Therefore, it is more convenient to refill prescriptions for chronic disease treatment at NHI-appointed pharmacies. In order to prevent the distribution and sale of pseudo-drugs, it is important to follow the standards established by the NHI to ensure the safety of medication sources while implementing logistics services for pharmaceutical suppliers. In Taiwan, pharmaceutical logistics can be divided into three sectors: medicine industries, large pharmaceutical logistics companies, and middle and small size pharmaceutical distributors. This study was aimed at investigating the logistics services of NHI-appointed pharmacies. Firstly, we took NHI-appointed pharmacies as the research object and used a two-dimensional Kano model to categorize the service quality and customer satisfaction with drug suppliers. After that, we verified the results, explored the properties of various quality items, and analyzed customer satisfaction and dissatisfaction indexes.

2. Literature Review

2.1. The Process of Filling Prescription Medicine

The procedure for obtaining prescription drugs in Taiwan is shown in Figure 1. The patients in a hospital or clinic have to see a doctor and get the first prescription dispensed, after which they get the medicine at a pharmacy in the hospital or clinic. Stable patients with chronic diseases, in addition to the regular return visit, can take the prescription directly to NHI-appointed pharmacies to save time and reduce inconvenience. As a result, a large number of patients are obtaining their medicines from NHI-appointed pharmacies, which comprise the research object in this study in an effort to investigate the logistics quality.

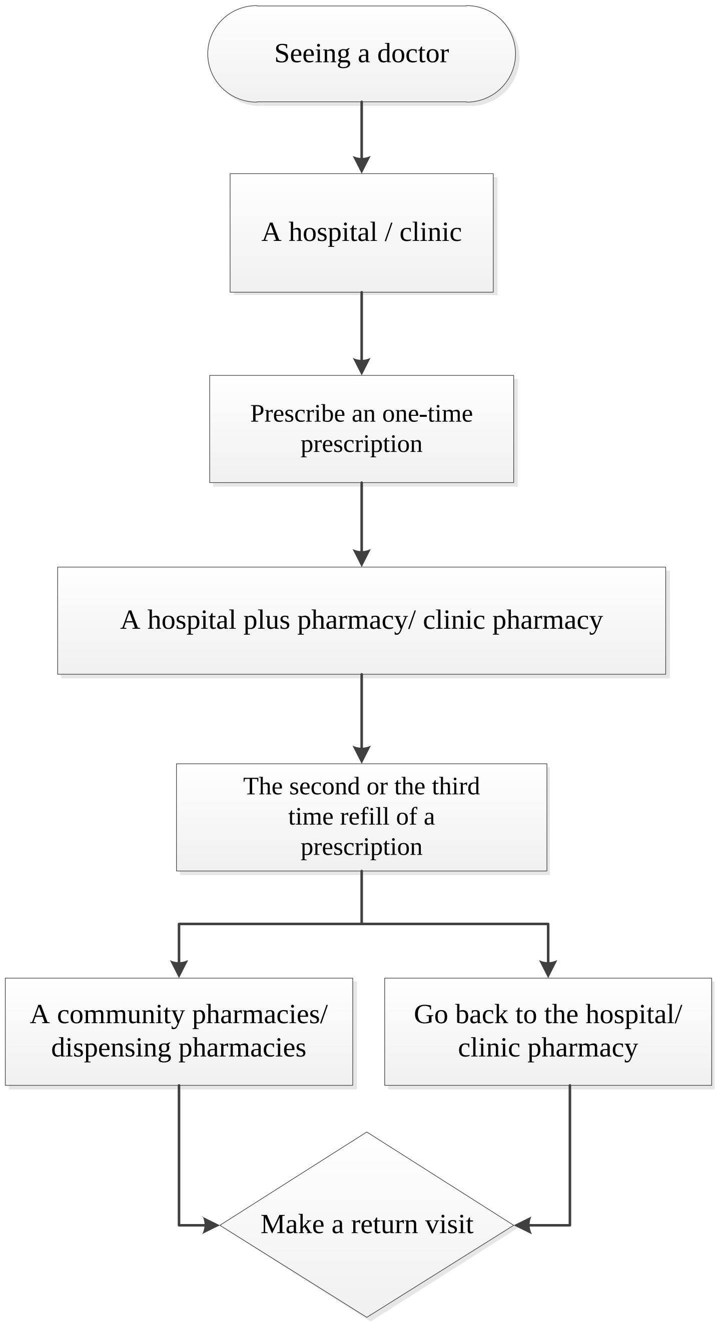

Figure 1: The Process of Filling Prescription Medicine

2.2. The Kano Model

The concept of a two-dimensional quality model is that not all quality characteristics are satisfactory. Based on the theory of Herzberg et al. (1959), Kano and Takahashi (1979) developed a concept of two-dimensional quality, based on the idea that quality is not a one-dimensional concept. Kano et al. (1984) proposed a two-way model of quality (see Figure 2) based on customers' perceptions and experiences. The horizontal axis shows the amount of quality elements, where the right-hand side has a sufficient amount, and the left-hand side has an insufficient amount. The vertical axis indicates customer satisfaction, where the upper axis indicates high satisfaction, and the lower axis indicates low satisfaction.

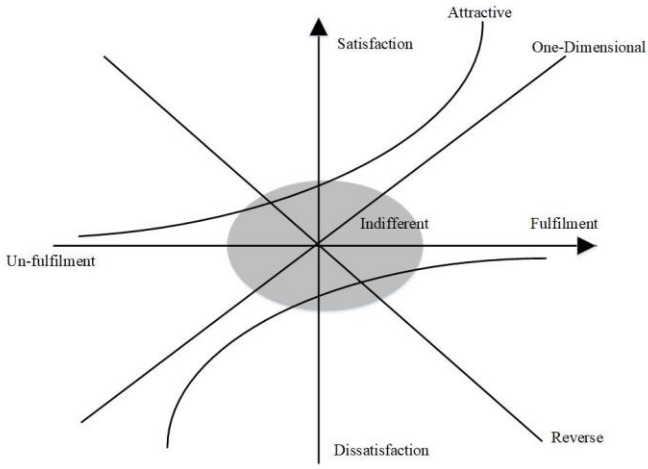

Figure 2: Kano's Two-way Model of Quality

Source: Kano et al. (1984)

Based on these axes, quality can be classified into the following five categories:

(1) Attractive quality: When it is offered, customers will be satisfied. However, when it is not offered, customers will not be dissatisfied. The corresponding element in Herzberg et al. (1959) is the motivator factor.

(2) One-dimensional quality: When it is offered, customers will be satisfied. It varies in a liner way. That is, the higher the quality, the higher the level of satisfaction, and vice versa. It has to be noted that, however, when it is not offered, customers will be dissatisfied.

(3) Must-be quality: Customers believe that this quality is a necessity. When it is not offered, customers will be dissatisfied. However, customer satisfaction will not be increased when this service is offered. The corresponding element in Herzberg et al. (1959) is the hygiene factor.

(4) Indifferent quality: Customer satisfaction and dissatisfaction will not be changed whether this service is offered or not.

(5) Reverse quality: When it is offered, customers will be dissatisfied, and vice versa.

3. Research Methodology

3.1. Categorizing the Service Items Using a Kano Model

By combining the two answers in the Kano evaluation table (Table 1), the quality of pharmaceutical logistics service items can be classified into six categories: i.e. attractive quality (A), one-dimensional quality (O), must-be quality (M), indifferent quality (I), reverse quality (R), or questionable result (Q). Category Q indicates that there is a contradiction in the customer's answers to the questions. The attribute of each service item in the Kano classification scheme is determined by the category that receives the highest response frequency. If two or more Kano categories are tied for a given service item, we categorized it using the following order (M>O>A>I), as suggested by Matzler et al. (1996),

Table 1: Kano Evaluation Table

Customer requirements → ↓		Dysfunctional (negative) question				
		1. like	2. must-be	3. neutral	4. live with	5. dislike
Functional (positive) question	1. like	Q	A	A	A	O
	2. must-be	R	I	I	I	M
	3. neutral	R	I	I	I	M
	4. live with	R	I	I	I	M
	5. dislike	R	R	R	R	Q

Notes: A: Attractive; O: One-dimensional; M: Must-be; I: Indifferent; R: Reverse; Q: Questionable

Source: Matzler and Henterhuber (1998)

3.2. Determining the degree of contribution of each service item

Berger et al. (1993) developed a customer satisfaction index that indicates whether satisfaction can be increased by providing a quality attribute, or whether fulfilling a quality attribute only can prevent the customer from being dissatisfied. Based on a satisfaction increment index (SII) and dissatisfaction decrement index (DDI), service providers can determine what service items should be increased and what service items should be removed to optimize the overall outcome as perceived by their customers. SII refers to the degree of satisfaction that can be increased after a customer is satisfied with a certain service item, while DDI refers to the degree of customer dissatisfaction that can be reduced after removing a certain service item. The calculation formula of SII and DDI are explained by Eq. (1) and (2).

$$SII = (A+O)/(A+O+M+I) \tag{1}$$

$$DDI = -(O+M)/(A+O+M+I) \tag{2}$$

When the SII was obtained from Eq. (1), if the value is close to zero, it means that the effect is low. Oppositely, if the value is close to 1, this means that the item has a positive effect on increasing customer satisfaction. In terms of DDI, when the value is close to -1, this means that the element can decrease customer dissatisfaction more significantly. In addition, Hu et al. (2009) proposed that the difference between SII and DDI indexes could represent overall satisfaction with a service item. Accordingly, they defined the degree of contribution of a service item as a satisfaction contribution index (SCI) by Eq. (3). In order to facilitate the subsequent analysis, each SCI index is divided by the maximum value to be normalized so that the value of any SCI index is always between zero and 1.

$$SCI = (SII - DDI)/MAX(SII - DDI) \tag{3}$$

4. Empirical Study

4.1. Sampling and Data Collection

In this study, a questionnaire based on the Kano two-dimensional scheme was designed and issued to 180 NHI-appointed pharmacies that were customers of the largest medical product logistics service provider in Taiwan (hereafter called firm A) from January to March in 2018. In total, 146 samples were returned of which 46 samples were deemed invalid due to incompleteness. The 100 valid samples accounted for a valid returned rate of 68.4%. By analyzing the basic information in the returned samples listed in the Appendix (see Table A1). It was found that 71% of the respondents had a bachelors' degree and above. 46% of the pharmacists had been working for more than ten years, of which those who have more than 16 years of experience accounted for 15%. 50% of the pharmacies have been in operation for more than ten years, of which 25% were founded more than

16 years prior to this study. According to the above data, the respondents are professional and experienced and have worked for a reasonable period of time, showing that the results of our empirical study were reliable.

4.2. Results of Categorization

In total, 30 service items relevant to medical product logistics offered by firm A were categorized according to the service attributes defined by the Kano model scheme. The categorization results are shown in Table 2. As Table 2 demonstrates, none of the 30 logistics service items were categorized as a reverse quality, indicating that the respondents would not be dissatisfied with the logistics service items listed in Table 2. Service items that were labeled with an indifferent quality attribute included “logistics staffs have a neat appearance,” “the place for keeping drugs is equipped with advanced electronic devices,” and “supporting customers by providing certificates when they are being audited by the government.” That is, customer satisfaction would not be affected regardless of whether or not these service items were provided. In addition, seven items in Table 2 were categorized as attractive quality because the satisfaction of customers could be increased when they were offered. However, customers would not be dissatisfied if these items were not offered by firm A. The result of the attractive quality attribute analysis showed that if firm A could provide additional information and customization, satisfaction would increase with the degree of satisfaction with the attributes. Although the satisfaction of customers would not drop without these items, medical product logistics providers could still enhance their competitiveness by providing these items to their customers. Different from the attractive quality, the must-be quality plays a core role while implementing the medical product logistics because pharmacies would be less satisfied if service items belonging to this attribute are not well provided. Of the 30 items we surveyed, 33.33% were categorized as must-be quality (see Table 2). Items belonging to this attribute mainly included quick response, problem-solving skills, and meeting the regulations required by the public sector. Therefore, medical product logistics firms should pay attention to these basic requirements when servicing the pharmacies to reduce customer dissatisfaction. Lastly, among the 30 attributes, the proportion of one-dimensional quality was 36.66%, which was the highest among all of the attributes. These items mainly included “handling returned goods quickly and replacing the goods correctly,” “providing an online cargo tracking system,” “delivering the goods timely and correctly,” and “providing online transaction inquiry systems.” It was found that services related to reverse logistics and inventory management were of great importance. In addition, the increasingly strict regulations for supervising drugs have made reverse logistics a vital concern for medical product logistics. Therefore, medical product logistics service providers should try to improve or enhance the qualities related to reverse logistics and logistics timeliness to create better satisfaction and to reduce the dissatisfaction of their customers.

Table 2: Results of Medical Product Logistics Service Item Categorization Using the Kano Model

Service items	Classification agreement (%)						Category	SII	DDI	SCI
	A	O	M	I	R	Q				
Providing an electronic order platform.	28	25	26	18	0	3	A	0.55	-0.53	0.866
Orders can be received on a timely basis and processed instantly and correctly.	31	22	23	20	0	4	A	0.55	-0.47	0.825
Accepting small, customized orders.	31	29	17	20	0	3	A	0.62	-0.47	0.883
Delivering the goods according to a customized time window.	32	19	24	21	0	4	A	0.53	-0.45	0.791
Providing recycling services.	28	20	23	25	0	4	A	0.50	-0.45	0.766
Providing the latest information related to medication from the public sector (e.g. regulation updating).	28	23	24	22	0	3	A	0.53	-0.48	0.816

(Continued) Table 2: Results of Medical Product Logistics Service Item Categorization Using the Kano Model

Service items	Classification agreement (%)						Category	SII	DDI	SCI
	A	O	M	I	R	Q				
Providing the latest information related to medication from the private sector (e.g. changes in prices or packaging).	30	25	25	17	0	3	A	0.57	-0.52	0.875
Logistics staffs have a neat appearance.	19	19	26	34	0	2	I	0.39	-0.46	0.684
The place for keeping drugs is equipped with advanced electronic devices.	19	17	27	34	0	3	I	0.37	-0.45	0.666
Supporting customers by providing certificates when they are being audited by the government.	19	19	28	33	0	1	I	0.38	-0.47	0.694
Warehousing process is in compliance with the standards required in the GDP regulations.	27	23	38	9	0	3	M	0.52	-0.63	0.925
The temperature and humidity records of drugs can be traced on a timely and accurate basis.	19	26	34	20	0	1	M	0.45	-0.61	0.857
The place for keeping drugs is equipped with backup power supply system.	21	23	32	20	0	3	M	0.46	-0.57	0.833
The staff of the logistics service provider are quite professional.	16	28	33	21	0	2	M	0.45	-0.62	0.866
Offering suggestions on inventory management based on historical records.	26	21	30	20	0	3	M	0.48	-0.53	0.816
Offering a quick notification mechanism in case an adverse drug reaction occurred.	17	30	32	20	0	1	M	0.47	-0.63	0.890
Handling customer complaints in a timely and effective manner.	18	30	32	17	0	3	M	0.49	-0.64	0.916
Quick response to emergency events.	17	29	33	19	0	2	M	0.47	-0.63	0.890
Delivering the goods by the next day after receiving the order.	24	32	25	17	0	2	O	0.57	-0.58	0.932
Providing an online cargo tracking system.	18	39	23	17	0	3	O	0.59	-0.64	0.991
Handling returned goods quickly and replacing the goods correctly.	17	40	23	17	0	3	O	0.59	-0.65	1.00
Notifying customers in advance when some drugs are expected to be out of stock.	18	33	29	16	0	4	O	0.53	-0.65	0.951
Providing online transaction inquiry systems.	20	37	22	17	0	4	O	0.59	-0.61	0.976
Delivering the goods timely and correctly.	16	38	26	18	0	2	O	0.55	-0.65	0.973

(Continued) Table 2: Results of Medical Product Logistics Service Item Categorization Using the Kano Model

Service items	Classification agreement (%)						Category	SII	DDI	SCI
	A	O	M	I	R	Q				
Offering a single contact window to address customer problems.	26	33	19	18	0	4	O	0.61	-0.54	0.934
Being able to fulfill urgent or revised orders from customers.	19	34	25	19	0	3	O	0.55	-0.61	0.933
Goods are well packaged during the course of the logistics process with clear names, batch numbers, and expiration dates.	19	32	30	18	0	1	O	0.52	-0.63	0.922
Notifying customers in advance when a shipment is expected to be delayed.	16	33	30	18	0	3	O	0.51	-0.65	0.933
The service staff is kind and courteous.	18	35	27	17	0	3	O	0.55	-0.64	0.958

4.3. Results of Satisfaction and Dissatisfaction Indexes Analysis

After all service items were categorized according to the Kano model scheme, we further calculated the three indexes defined in Section 3 to examine the degree for increasing the satisfaction and reducing the dissatisfaction of each item. The SII scores for each item were obtained one by one using Eq. (1), as listed in Table 2. Items with high SII scores included “accepting small, customized orders,” “offering a single contact window to address customer problems,” “providing an online cargo tracking system,” “handling returned goods quickly and replacing the goods correctly,” and “providing online transaction inquiry systems.” This result reflected that customized, real-time, professional management services could effectively increase the satisfaction with pharmacies in terms of logistics operations. On the other hand, the DDI scores for each item were also calculated one by one with Eq. (2) (see Table 2), which indicated the degree for reducing customer dissatisfaction with each item. Items that obtained high DDI scores were “handling returned goods quickly and replacing the goods correctly,” “notifying customers in advance when some drugs are expected to be out of stock,” “delivering the goods timely and correctly,” “notifying customers in advance when a shipment is expected to be delayed.” It can be found that it should be a priority to improve the professionalism, immediacy, and rationality of the service provided by logistics operators to reduce customer dissatisfaction. Lastly, the SCI index of each item, which provides the degree of contribution of each item to both increasing satisfaction and reducing dissatisfaction, were solved using Eq. (3). The results showed that three items obtained high SCI scores, including “handling returned goods quickly and replacing the goods correctly,” “providing an online cargo tracking system,” and “providing online transaction inquiry systems.” Like the DDI scores, reverse logistics processing still obtained the highest SCI score because the pharmacies were asked to act in line with the Pharmaceutical Inspection Co-operation Scheme (PICS), which made reverse logistics a concern for pharmacies in terms of selecting their logistics operators. Overall, the SCI score rankings were similar to those of the SII and DDI scores, indicating that respondents attached similar importance to the overall logistics services of medical products.

5. Conclusions and Suggestions

In this study, an empirical survey was carried out based on the customers of the largest medical products logistics operator in Taiwan. Thirty common service items related to medical product logistics were categorized according to the Kano two-dimensional quality scheme. The results showed that most items were categorized into one-dimensional quality and must-be quality. In terms of the must-be quality items, most were processes that could be implemented in compliance with the regulations. This result suggests that most pharmacies in Taiwan are following the regulations to ensure the quality of medical products. Therefore, their logistics operators are required to act in line with these regulations during the course of transportation and warehousing operations. As for the one-dimensional quality, the main service items with this attribute focused on information delivery and reverse logistics operation. Based on the infrastructure of information and internet technologies, these items reflected the generality of service quality that a logistics operator should be able to offer in the contemporary business environment. That is, delivering precise information promptly while operating pharmaceutical logistics and rapid processing of reverse logistics for inventory management should be a concern and should be well implemented when servicing contemporary pharmacies. According to the results of the SII analysis, NHI-appointed pharmacies expressed a desire for their logistics operators to provide customized delivery of small orders because they have to service a lot of patients with various demands. In addition, it's important to deliver the orders punctually and accurately because medicines for long-term chronic patients cannot be delayed or mistaken. Due to the strict regulations on the resale of returned products in the pharmaceutical industry in Taiwan, it is important to ensure that the items and quantities of drugs are correct when implementing logistics and reverse logistics. In recent years, the integrated drug history platform in the cloud launched by the Food and Drug Administration of Taiwan has become the infrastructure of drug counseling for many chronic patients. Therefore, if pharmacies and their logistics operators can combine their drug distribution information with this cloud-integrated platform, it would be more easy to control the medicine distribution process and provide drugs to patients more accurately.

In terms of the characteristics of the drug supply chain, the relationship between NHI-appointed pharmacies and drug suppliers is Business to Business (B2B), while the relationship between NHI-appointed pharmacies and chronic prescription patients is Business to Consumers (B2C). Based on the results of this study, it can be concluded that the demands of chronic patients will feedback to NHI-appointed pharmacies, which will then affect the level of service quality provided by the NHI-appointed pharmacies to their suppliers and logistics operators. Therefore, we suggest that future researchers may want to survey the service quality of the entire drug logistics services industry based on the feedback of consumers by integrating the feedback from the bottom end with the opinions of the NHI-appointed pharmacies.

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System Impulse Modeling of the Green Shipping Policies

Lixian Fan[1], and Jingbo Yin[2,]*

[1]School of Management, Shanghai University, 599 Shangda Rd., Shanghai 200444, China.
[2]Department of International Shipping, State Key Laboratory of Ocean Engineering, School of Naval Architecture, Ocean and Civil Engineering, Centre for Polar and Deep Ocean Development, Shanghai Jiaotong University, 800 Dongchuan Rd., Shanghai 200240, China.
Email: [1]lixianfan@shu.edu.cn
[2]jingboyin@sjtu.edu.cn

[*] Corresponding Author

Abstract:

Shipping emissions has aroused significant attention along with the rapid growth of the international maritime transportation. There are plenty of policies and measures in practice in regulating the shipping emission and a lot of studies have investigated the significance and impacts of these policies and measures to the shipping industry. It is obvious that they are inter-determined. However, previous studies have analyzed these emission abatement measures separately instead of in a systematical way. Therefore, this study tries to investigate the shipping emission abatement polices and measures in a system model in which each polices and measures are correlated with others. When there is a change in a certain policy or measure, the impact will transmit to other polices and measures. Hence, we can analyze the dynamic movement of the system by imposing an impulse to certain polices or measures. By introducing the definition of the pulse process and its stability, this study discusses the evolvement and adjustment of the shipping emission system in detail. The dynamics of the system is then discussed when there is a pulse in each of the variable. The results suggest that the slow steaming practice of ships may decrease emissions under certain circumstances; it actually increases the total emissions in the shipping industry. It also suggests that although the implementation of the EEDI policy can promote the adoption of the EEOI policy, the EEOI actually relieve the demanding for the EEDI policy. It also reveals that the effect of bunker price on emission reduction is larger than other measures.

Keywords: Shipping emission, System impulse modeling, EEDI, EEOI, MBMs

1. Introduction

The shipping transportation is one of the most environmentally friendly modes in terms of energy efficiency (IMO, 2012), which carries over 80% of the global trade volume (UNCTAD, 2017). However, due to the huge trade volume carried and the large number of vessels sailing around the world, substantial quantities of emissions are produced from the shipping industry (Psaraftis & Kontovas, 2013; Sun, Yan, Wu, & Song, 2013; Yang, Lu, Haider, & Marlow, 2013). According to the 2009 GHG (Green House Gas) study by International Maritime Organization (IMO)(IMO, 2009a), carbon dioxide (CO2) emissions from shipping transport accounts for 3% of the global CO2 emissions. It is estimated that the emissions would increase by 150-250% by 2050 if there is no active countermeasure to control the amount of emissions(IMO, 2009a). For this reason, the IMO established a goal to reduce the amount of CO2 emissions by 20-50% by 2050 from existing vessels (IMO, 2009a).

Since ships move between different jurisdictions, there is a need for the IMO, a specialized agency of the United Nations, to be responsible for regulations on the prevention of maritime pollution by ships (Fagerholt, Gausel, Rakke, & Psaraftis, 2015). Therefore, the Energy Efficiency Operational Indicator (EEOI) and Energy Efficiency Design Index (EEDI) are developed for existing and new vessels separately (IMO, 2009, 2009a, 2010) to restrict emissions in which three strategies are suggested: vessel size enlargement, voyage speed reduction, and new technologies application. In addition to the operation and technical measures, various Market-based Measures (MBMs) have also been introducing such as a carbon tax and Emissions Trading Scheme (ETS)(Miola, Marra, & Ciuffo, 2011; Wang, Fu, & Luo, 2015). It aims to motivate industrial organizations to use up-to-date technological, operational and managerial practices in emission reduction (European_Commission, 2013; IMO, 2009a).

Among the above three types of polices in emission reduction, speed is a key variable in maritime transportation (Psaraftis & Kontovas, 2013). In general, ships travel slower than other modes and it usually lasts 1-2 months for long-distance trips. Therefore high speed is significant during boom periods as it entails the economic added value of faster delivery of goods, lower inventory costs and increased trade throughput (Psaraftis & Kontovas, 2013). However, slow steaming and optimizing ship speed are receiving increased emphasis these days because of increasing fuel prices, depressed market conditions and environmental issues of air emissions.

Figure 1 illustrates the bunker price trends from 1973 to May, 2018 for 180st, 380cst, Gas Oil, Marine Diesel Oil (MDO) and Marine Gas Oil (MGO) from different locations. The bunker price has witnessed a remarkable increase from the early 2000s and the price during 2010 to 2013 is almost six times higher than ten years ago. Currently, although there is a sharp decrease in 2014, it is still three times higher than that in1990s. As discussed by Stopford (2009) and Ferrari, Parola, and Tei (2015), the fuel cost accounts for almost half of the overall operational costs of a ship. In addition, the impact of speed on fuel consumption is nonlinear, i.e., a ship goes faster will emit much more than the same ship going slower.

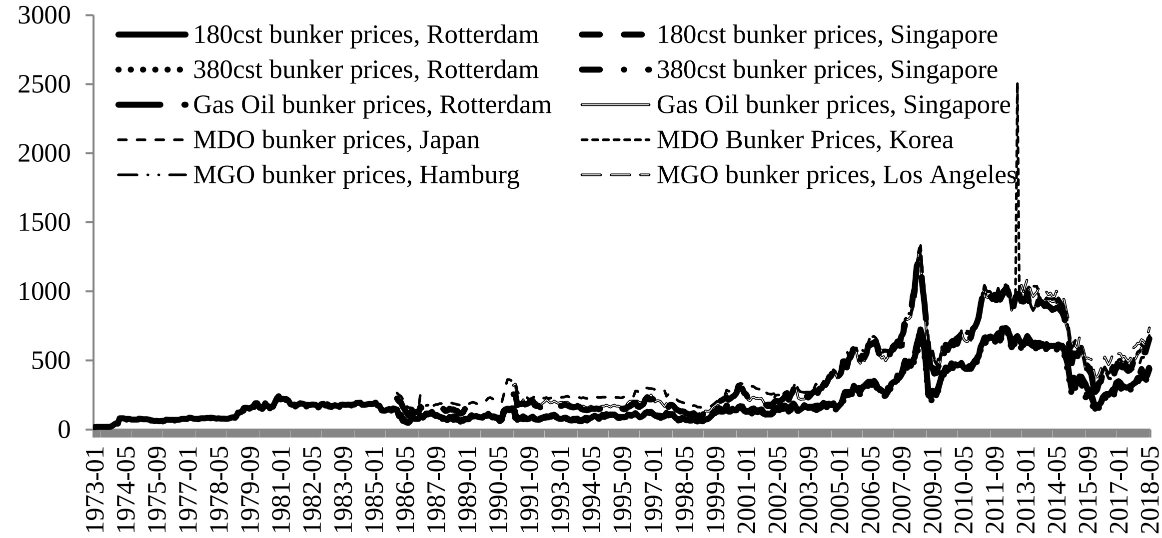

Figure 1. Trend in fuel prices (US$/tonne)
Source: Clarksons Shipping Intelligence Network (Clarksons, 2018).

As mentioned above, the technical, operational, and market based policies and the ship speed and fuel price measures all impact the shipping emissions. It is obvious that they are inter-determined. There are many studies discussed the EEDI and EEOI policies in restraining emissions (Acomi & Acomi, 2014; Ančićn & Šestan, 2015). Meanwhile, lots of studies investigated the feasibility of implementing the market-based polices (Heitmann & Khalilian, 2011; Lee, Chang, & Lee, 2013; Miola et al., 2011; Shi, 2016; Wang et al., 2015). In addition to these, plethora of studies have analyzed the role of slow steaming in emission abatement and discussed the optimal ship speed for different types of ships or routes under different scenarios (Corbett, Wang, & Winebrake, 2009; Doudnikoff & Lacoste, 2014; Fagerholt et al., 2015; Ferrari et al., 2015; Woo & Moon, 2013). However, these emission abatement measures are analyzed separately instead of systematically. A systematic analysis is significant as there are mountains of strategies in emission abatement in the shipping industry and most of them are inter-correlated. For example, the implement of the EEOI policy will lead to slow steaming which in turn will decrease emissions. Meanwhile the EEOI policy will also motivate the implement of the EEDI strategy, which also results in speed reduction.

Therefore, this study tries to investigate the shipping emission abatement polices and measures in a system model in which each polices and measures are correlated with others. When there is a change in a certain policy or measures, the impact will transmit to other polices and measures. Hence, we can analyze the dynamic movement of the system by imposing an impulse to certain polices or measures.

The remains of this study are arranged as follows. Section 2 presents the systematic model of emission polices. Section 3 illustrates the systematic model of the pulse process. Section 4 discusses the dynamics of the pulse process. Section 5concludes the study.

2. System Modeling of Emission Polices and Measures

Since we are aiming to investigate the structural inter-correlations among various emission abatement policies and measures, the bivariate correlations are used as inputs to the systematic model (Figure 2). In practice, there are dozens of polices or measures restricting shipping emissions. We just focused on seven key measures that are discussed a lot recently.

As the focus of the systematic model is to restrict emissions from the shipping industry, we denote V_1 as the shipping emission volume, which is put in the middle of the system diagram. Since shipping emission is serious concerned by the public, we include the environmental quality as variable V_2. It is obvious that V_1 impacts V_2 negatively. So, there is a "-" sign on the line from V_1 to V_2.

As mentioned above, shipping speed is one of the most important measures to reduce emissions (Corbett et al., 2009; Doudnikoff & Lacoste, 2014; Fagerholt et al., 2015; Woo & Moon, 2013), especially under the current depressed economic situation. Therefore, many shipping companies have chosen to slow down their shipping speed instead of laying up some of the vessels. In Figure 2, the slow steaming measure is denoted as V_3. It is obvious that the current emission situation has motivated the shipping company to slow down ship speed. Therefore V_1V_3 is positive. This down slowing ship speed can help improve the environmental quality in turn. So, V_3V_2 is positive.

Currently, the most discussed polices in shipping emission restriction are the EEDI and EEOI, which are denoted as V_4 and V_5 separately. As they are designed to reduce emissions, the paths of V_4V_1 and V_5V_1 are both negative. Meanwhile, they are also connected with other factors. It is obvious that the slow steaming activities can facilitate the implementation of the EEOI requirements (V_3V_4 is positive). Meanwhile, the implement of EEOI will lead to a condition improvement for the implement of EEDI, so V_4V_5 is positive.

As bunker consumption is one of the most important parts in operating a vessel. Bunker price is also considered in this model, which is denoted as V_6. It is naturally derived that the bunker price negatively impacts shipping emissions according to economics theory. So, V_6V_1 is negative. It is naturally derived that the increase of the bunker price will positively motivate the enforcement of the EEDI as which can be achieved by decreasing the fuel consumption of the engine in the ship building period. Therefore, V_6V_5 is positive.

Finally, although there is no consensus on how to carry out the MBMs policy yet, many researchers agreed on the significance of MPMs policy on emission abatement (Heitmann & Khalilian, 2011; Lee et al., 2013; Shi, 2016; Wang et al., 2015). Then V_7V_1 is negative. It is also revealed that a MBM is necessary for the shipping industry as the adopted technical and operational measures alone would not be sufficient in achieving absolute emissions reduction (Shi, 2016). Therefore, we propose a negative impact of environmental quality on the implement of the MBMs policy (V_2V_7 is negative), i.e., the keep deteriorating of the environment will urge various institutions and governments to compromise on the adoption of the most suitable MBMs to make its proportionate contribution to addressing global climate change.

Figure 2 is an illustration of the structural direct connections between various policies and measures, which is used as an input to the impulse analysis in the next section.

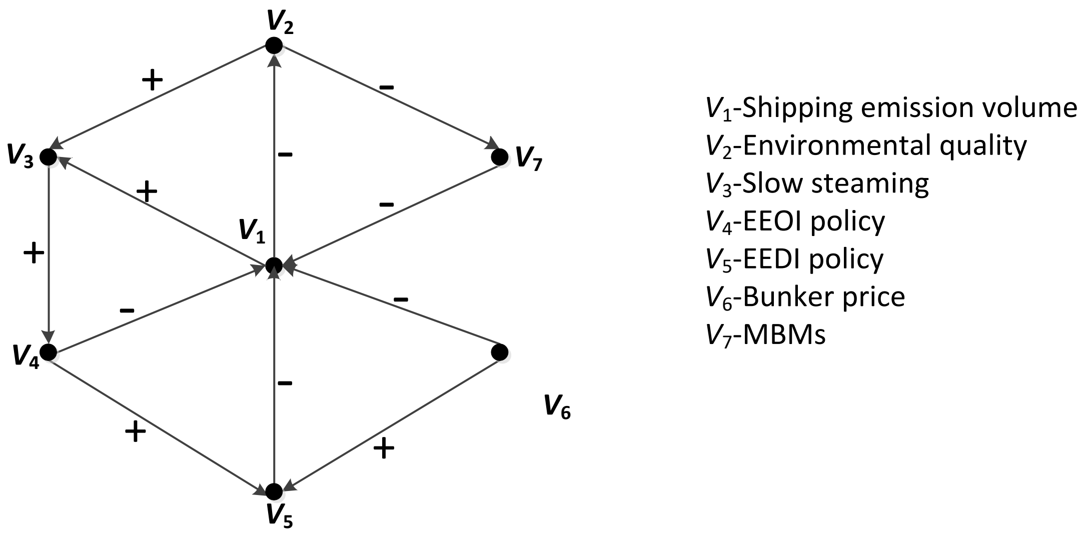

Figure 2: Structural connections of measures impacting shipping emissions.

3. Impulse Analysis of the System and Discussion

To analyze the inter-correlations between variables, we denote matrix A==(a_{ij}) as:

$$a_{ij} = \begin{Bmatrix} 1, & if\ V_iV_j\ is\ positive \\ -1, & if\ V_iV_j\ is\ negative \\ 0, & if\ V_iV_j\ is\ zero \end{Bmatrix} \qquad (1)$$

Then the adjacency matrix of Figure 2 can be represented by the matrix in Equation 1. Actually, it will be more significant if we can calculate the actual effect of each variable on other variables. For example, V_1V_3=0.1 suggests a 10% (or 1 unite) decrease of the ship speed if the emission increase 1% (or 1 unit). However, the effect values are relatively difficult to obtain currently. So, we just focus on the directional adjacency matrix, A, in this study.

$$A = \begin{vmatrix} 0 & -1 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & -1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 1 & 0 & 0 \\ -1 & 0 & 0 & 0 & 0 & 0 & 0 \\ -1 & 0 & 0 & 0 & 0 & 1 & 0 \\ -1 & 0 & 0 & 0 & 0 & 0 & 0 \\ -1 & 0 & 0 & 0 & 0 & 1 & 0 \end{vmatrix} \qquad (2)$$

3.1 The Pulse Process

To investigate the impact of a variable's sudden change on the dynamic evolvement of the system, $V_i(t)$ is denoted as the value of variable V_i at time t, and $P_i(t)$ is denoted as the change of V_i at time period t, which is called a **pulse**. It is obvious that,

$$V_i(t+1) = V_i(t) + P_i(t+1),\ i = 1,2,\dots,7,\ \ t = 0,1,2,\dots \qquad (3)$$

$$P_j(t+1) = \sum_{i=1}^{8} A_{ij}P_i(t)\,,\ j = 1,2,\dots,7,\ \ t = 0,1,2,\dots \qquad (4)$$

Denote $V(t)=(V_1(t),V_2(t),\ldots,V_n(t))$ and $P(t)=(P_1(t),P_2(t),\ldots,P_n(t))$, then Equation (3) and (4) can be illustrated as,

$$V(t+1) = V(t) + P(t) \quad (5)$$

$$P(t+1) = P(t)A,\ t = 0,1,2,\ldots \quad (6)$$

Without loss of generality, we suppose

$$V(0)=P(0) \quad (7)$$

If we impose a pulse at the initial time, the values of $P(t)$ and $V(t)$ at any t can be calculated using Equation (5) to (7). This system evolvement caused by imposing one or more pulses at the beginning is called a **Pulse Process**. It is called **Simple Pulse Process** if there is only one variable is 1 (or -1) in $P(0)$.

3.2 Stability of the Pulse Process

As discussed in Jiang, Xie, and Ye (2013), when there is a pulse at t=0 (a variable is changed), if all the values of the variables in the system do not increase (or decrease) infinitely at any time, the pulse process is stable. More precisely, for all the i (variables) at any time t, if $|P_i(t)|$ is finite, it is called **Pulse Stable,** and if $|V_i(t)|$ is finite, it is called **Value Stable**.

Because $P(t)$ and $V(t)$ are calculated by Equation (5) and (6), it is obvious that the stability of the system is determined by the eigenvalue (λ) of matrix A. Lucas (1996) has proposed the following theorems to ensure the stability of the pulse process.

Theorem 1: the necessary condition for the pulse process to be pulse stable is $|\lambda| \leq 1$.

Theorem 2: the sufficient condition for the pulse process to be pulse stable is $|\lambda| \leq 1$ and the characteristic roots are all single roots.

Theorem 3: the necessary and sufficient condition for the pulse process to be value stable is that the process is pulse stable and $\lambda \neq 1$.

Then, the characteristic polynomial for matrix A can be derived:

$$f(\lambda) = \lambda^4(\lambda^3 + 2) \quad (8)$$

Because $f(-1)=1$, $f(-2)=-96$, there is a root within (-2,-1). According to Theorem 1, there must be an instable pulse in some certain simple pulse process.

3.3 Adjustment of the Pulse Process

To convert an unstable process to a stable one so that it satisfies Theorem 1 and 2, the values in matrix A must be adjusted. Although there is no general conclusion to help transform an adjacent matrix system to a stable pulse process, there are some methods that can be applied to some special matrix systems. Among them, one is called **Advanced Rosette**, in which there are bi-directional connections in a diagram and a central vertex exits on all closed circuits just like the diagram in Figure 2. Here, a closed circuit is a path from a vertex to other points along their directional edges without repeating and finally goes back to the starting vertex.

In Figure 2, V_1 is the vertex, V_1V_2, V_2V_7 and V_7V_1 comprised a closed circuit, $V_1V_2V_7V_1$. The number of the directed edges is called the **length** of the closed circuit. So, the length of closed circuit, $V_1V_2V_7V_1$, is 3. If the number of negative directed edges is an odd number, then the **sign** of this closed circuit is -1, otherwise it is +1. Let us denote a_k as the summation of all the k-edges closed circuits. Then, r is the largest number that satisfies $a_r \neq 0$. Therefore, the stability of an advanced rosette diagram can be determined by $\{a_1, a_2,\ldots, a_r\}$ with the following theorem (Lucas, 1996):

Theorem 4: the necessary condition for an advanced rosette diagram system to be pulse stable is

$$a_r = \mp 1 \quad (9)$$

$$a_k = -a_r a_{r-k}, \quad k = 1,2, \ldots, r-1. \quad (10)$$

Theorem 5: the necessary and sufficient condition for an advanced rosette diagram system to be value stable is

$$\sum_{k=1}^{r} a_k \neq 1 \quad (11)$$

Theorem 4 can be used to find the violations in the system, so that the unstable system can be transformed to a stable one. Seeing from Figure 2, there is no circuit with one and two edged paths, so a_1=0 and a_2=0. There are two 3-edges closed circuits, which are $V_1V_3V_4V_1$ and $V_1V_2 V_7V_1$. As the signs of these two circuits are both –1, so a_3=-2. Similarly, there is one 4-edges closed circuits, which are $V_1V_3 V_4 V_5V_1$. Since the sign this closed path is -1, so a_4=-1. Because a_k=0 for all the k>4, so r=4. We finally get the serial of {a_1, a_2, a_3, a_4}={0, 0, -2, -1}.

According to Equation (9) and (10), it must satisfies the following equations to be stable:

$$a_1 = -a_4 a_3 \quad (12)$$

$$a_2 = -a_4 a_2 \quad (13)$$

$$a_1 = -a_4 a_3 \quad (14)$$

Obviously, Equation (13) is satisfied. To meet the requirements of Equation (12) and (14), we can only change a_3 to 0. Seeing from Figure 2, the signs along the 3-edges closed circuit of $V_1V_2 V_7V_1$ cannot be changed. Similarly, the signs of paths V_1V_3 and V_4V_1 are determined according to reality. The only path we can change is V_3V_4. A negative impact of slowing steaming on the implementation of EEOI is more reasonable, as it will motivate public agencies to consider of the enforcement of EEOI if the ship speed cannot be slow down. Then, a_3 is 0 now. Since the sign of the path from V_3 to V_4 has been changed, the sign of the 4-edges circuit is also change to +1, i.e., a_4=1. The serial of {a_1, a_2, a_3, a_4} is changed to {0, 0, 0, 0, 1} and Equation (12) and (14) are all satisfied.

Above analysis can only ensure this advanced rosette diagram system to be pulse stable. According to Theorem 5, the summation of the a_is should not equal to 1 for the system to be value stable. Seeing from Figure 2, there is only one 4-edges closed circuits, which is $V_1V_3V_4V_5V_1$. The only path that can be changed is V_4V_5 without influencing the system too much. By changing the positive sign from V_4V_5 to negative, the serial of a_i changes to {0, 0, 0, -1} and all the Theorems are satisfied.

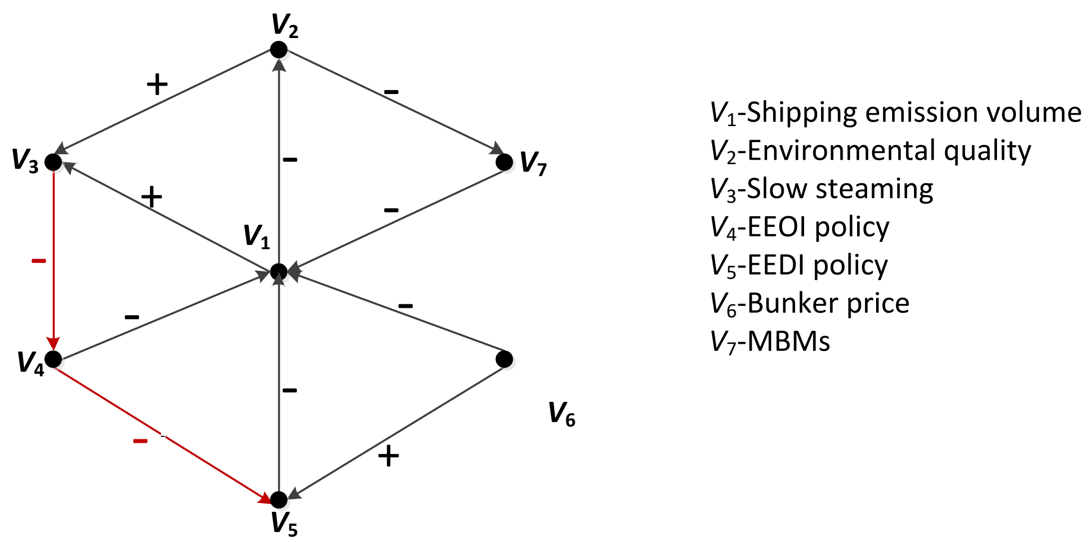

Figure 3: Adjusted structural connections of measures affecting shipping emissions.

According to above Theorems, the shipping emission system illustrated in Figure 3 is a stable pulse process, i.e., under any sudden changes of any variables in the system, the values changes of all the variables in the following periods are finite.

4. Discussion of the Pulse Process

To illustrate the evolvement of the variables in the system, we draw the variables at different periods when there is a simple pulse in each of the variables (Figure 4-9). Figure 4 is the pulse process of V_2 (Environmental quality). When the environmental quality deteriorates in time 0 ($P_2(0) = -1$), it will bring some pressure to the implement of the MBMs policy directly, which will reduce the shipping emission in turn. The pulse will then transmit to the implementation of slow steaming, EEDI and EEOI gradually. Finally, all the variables will be stable at 1 or -1. The pressure on the implementation of the MBMs and EEOI policies are stable at 1, while, the value of emission, slow steaming, environmental quality and EEDI will be stable at -1. The bunker price will not be impacted under this pulse.

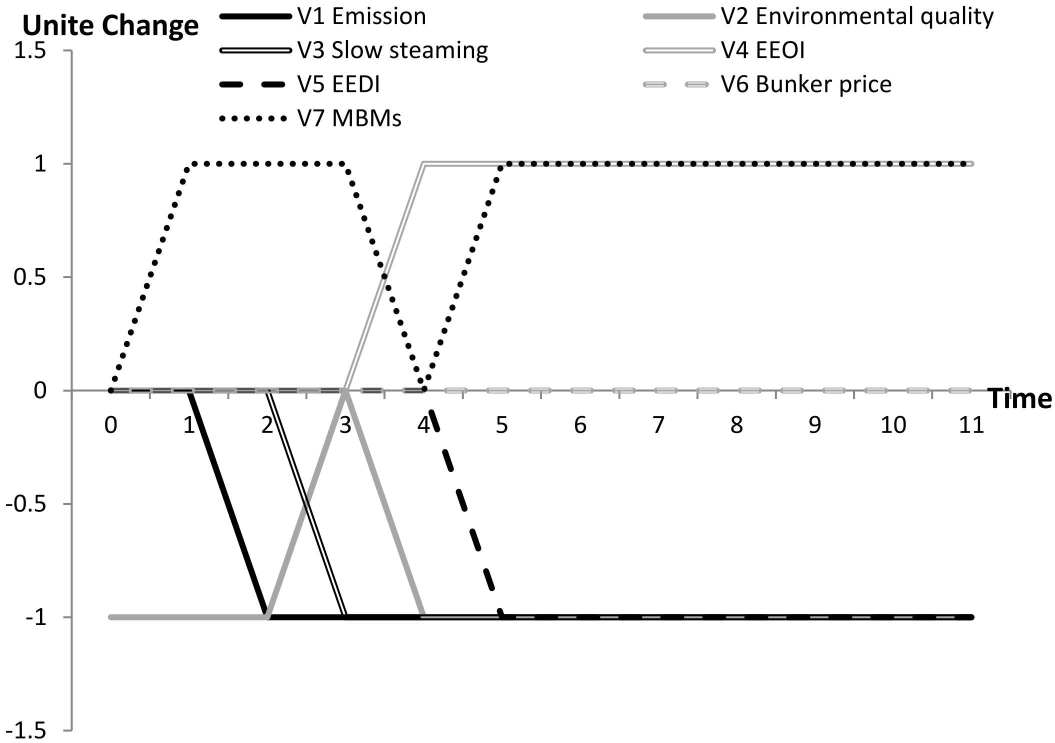

Figure 4: System evolvement with a pulse in V_2 (Environmental quality).

When there is a pulse in V_3 (slow steaming), the system will move dynamically as illustrated in Figure 5. As analyzed above, the active slow steaming practice may relieve the pressure on imposing the EEOI policy and it in turn impact the implementation of the MBMs policy negatively. On the other hand, it positively impacts the implementation the EEDI policy and the environmental quality. It is worth noting that, under current shipping transportation scales, this slow steaming practice actually increases the shipping emission volume. This result is similar to the results in Doudnikoff and Lacoste (2014), where the authors found that the total emissions are increased through slowing down within SECA and speeding up outside SECA for shipping companies to maintain a fixed service frequency.

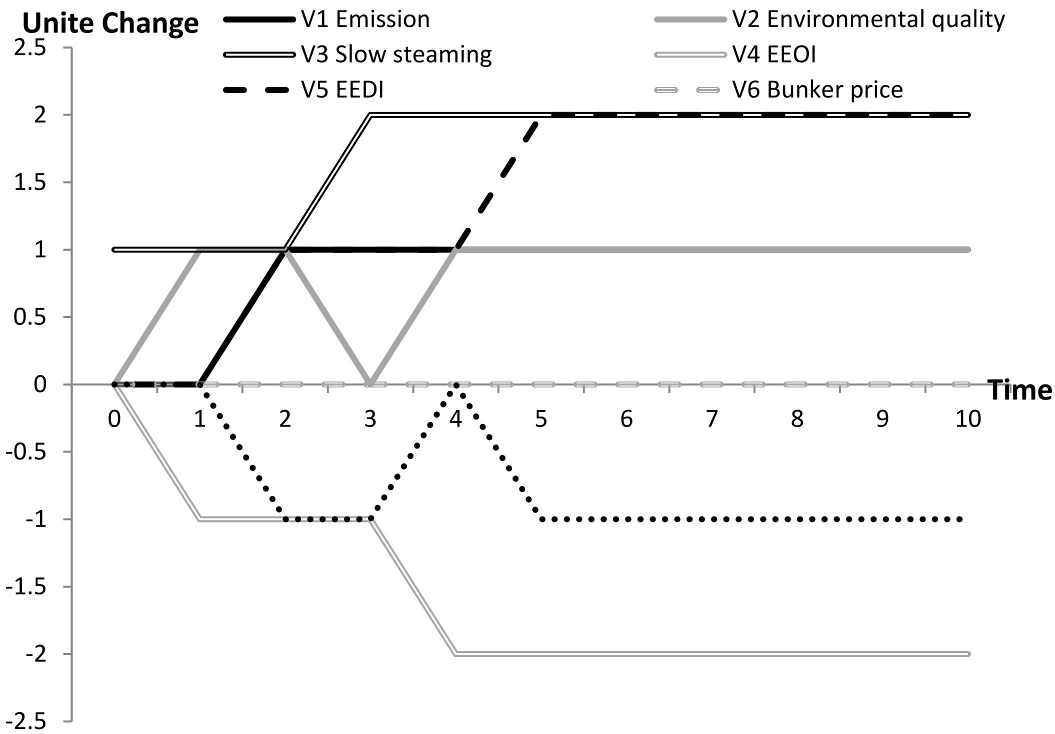

Figure 5: System evolvement with a pulse in V_3 (Slow steaming).

The dynamics of the system variables with a pulse in the EEOI (V_4) policy are different (illustrated in Figure 6). The implementations of the EEOI policy will negatively influence the practice of the EEDI policy as discussed previous. Although it impacts the emissions, environmental quality, slow steaming and MBMs policies shortly, in the long-run, the effects return to 0, i.e., these variables return to their initial level. This suggests the ineffectiveness of the EEOI policy if it is implemented alone.

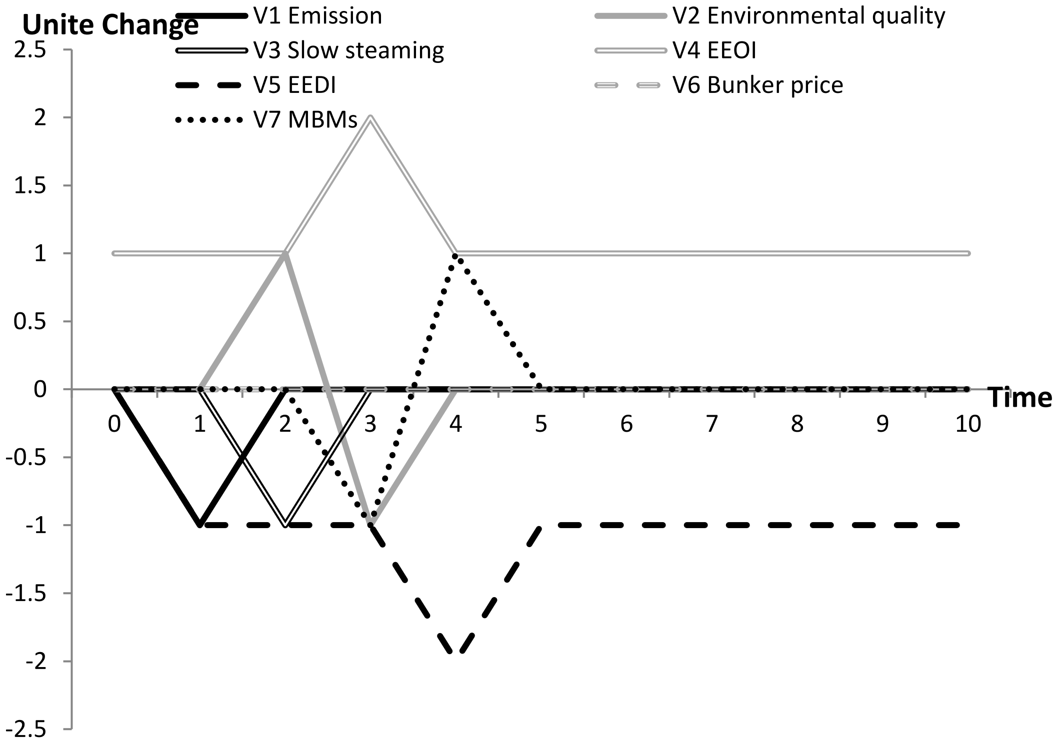

Figure 6: System evolvement with a pulse in V_4 (EEOI).

Figure 7 illustrates the dynamics of the system when there is a pulse in the EEDI policy. It will decrease the emission level at the first period and which will be kept in a stable level in the following periods. However, the improved shipbuilding technology motivated by the imposed EEDI policy will relax the demand for slow steaming. This is indicated by the lowered stable level of slow steaming variable. Similar to this, the improvement in shipbuilding will improve the operation of the ship and smooth the implementation of the EEOI policy. Different with these, the impacts of carrying on the EEDI on the environmental quality and MBMs are short-term. They will return to their original level after several periods because of the complicated dynamic system.

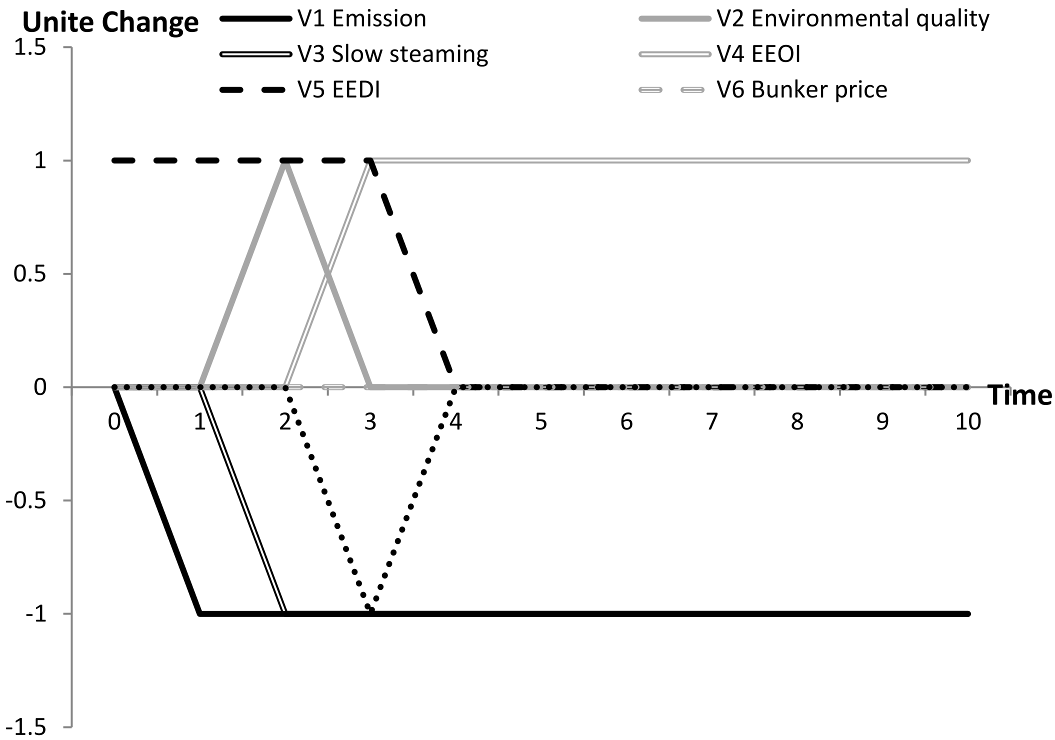

Figure 7: System evolvement with a pulse in V_5 (EEDI).

When there is a pulse in V_6 (bunker price), the dynamics of the system is more significant than other variables, which is drew in Figure 8. First, it decreases the shipping emissions gradually in the first two periods and keeps in this lower emission level afterwards. Before period 4, this increased bunker price motivates the progress in shipbuilding technology as suggested by the increased value of EEDI. However, its impact on the EEOI starts at period 2 and which gradually increases to a stable higher level. After period 4, the impact on EEDI decreases to a negative level. Different with our perception, the increased bunker price lowers down the demand for slowing steaming as which has been digested by impacting the implementation of the EEDI and EEOI policies.

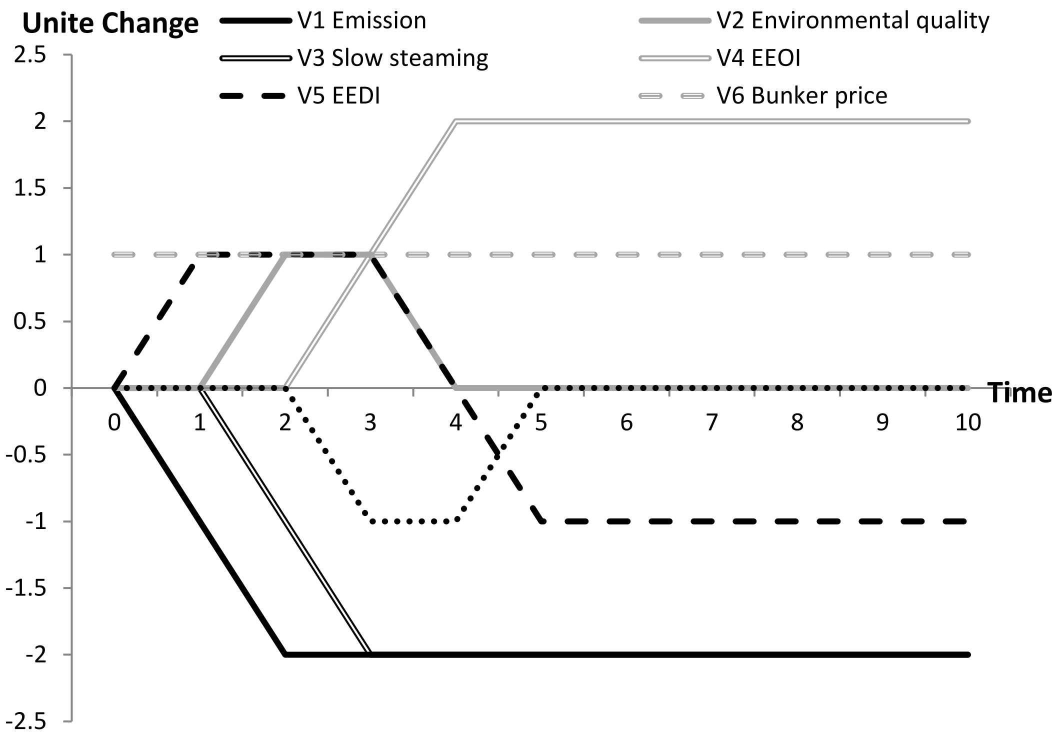

Figure 8: System evolvement with a pulse in V_6 (Bunker price).

The effects of an impulse in the MBMs policy are illustrated in Figure 9. First of all, it decreases the shipping emission and which is kept stable afterwards. Similar with other pulses, the impacts on the EEDI and EEOI policies are opposite. The effect on slow steaming is also negative.

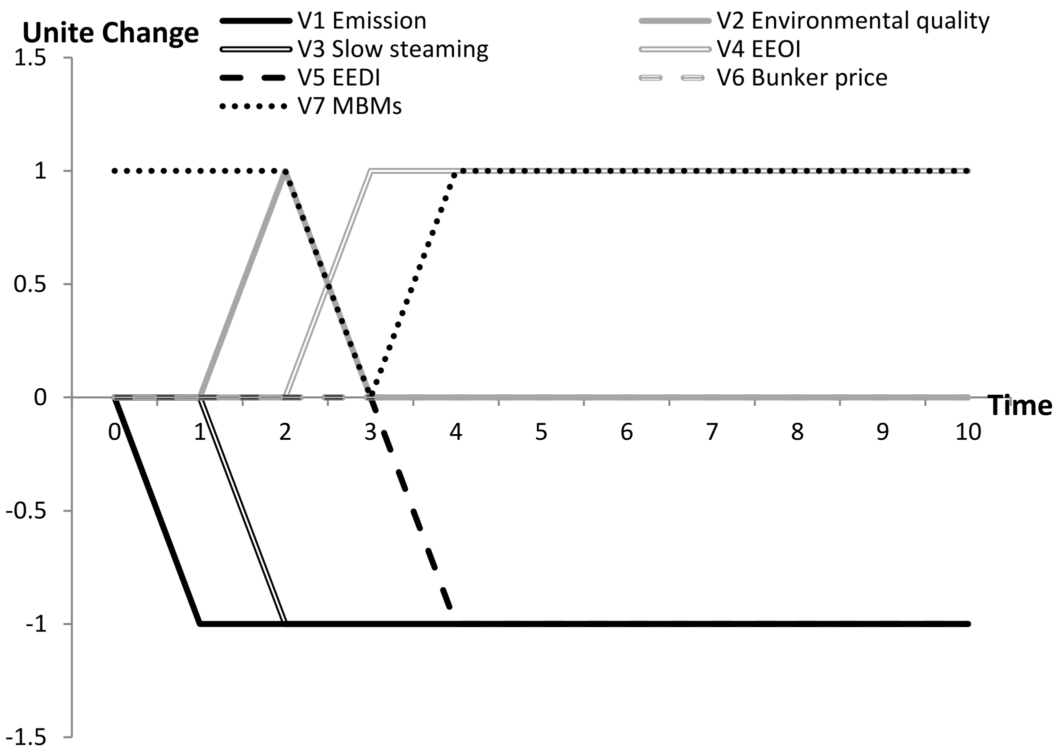

Figure 9: System evolvement with a pulse in V_7 (MBMs).

To summarize, we draw the emissions from each pulse in Figure 10. It is obvious that all the pulses have positive influence on shipping emissions except the slow steaming practice and the EEOI policy. The increase of bunker price has the biggest impact on decreasing emissions.

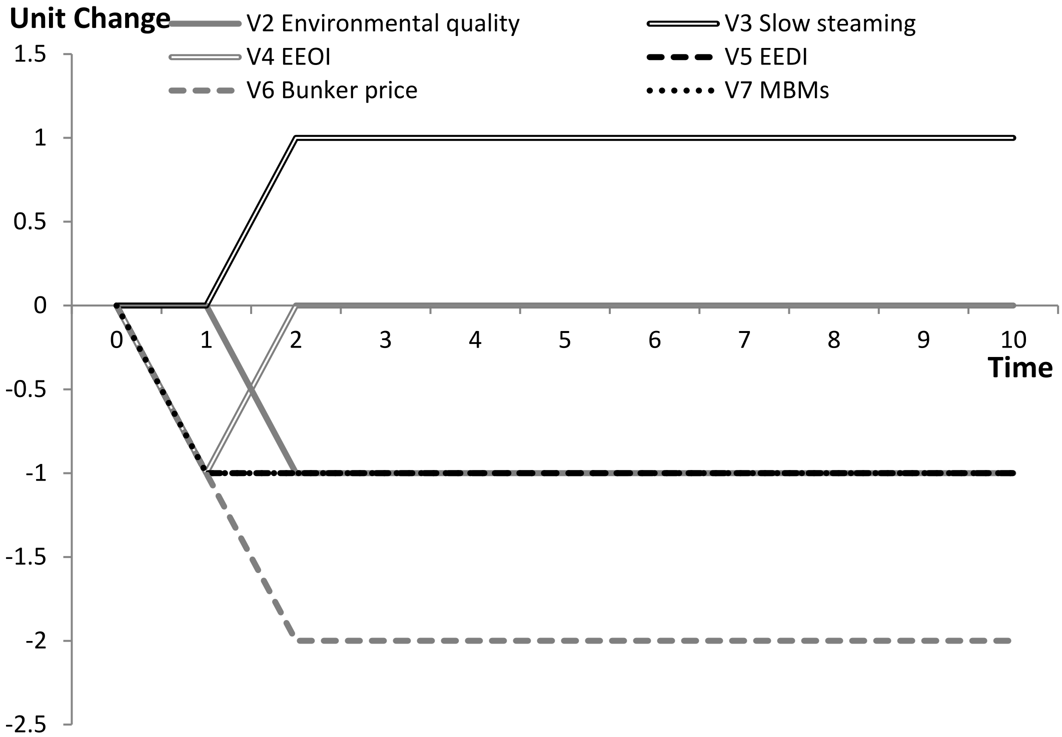

Figure 10: Emission dynamics under various pulses.

5. Conclusion

With the rapid growth of the international maritime transportation, the shipping emission has aroused a significant attention from international communities, maritime authorities, trade associations and academic scholars recently. Broadly saying, there are two types of policies and measures in the shipping industry. The most important one relates to policies issued by IMO, such as the several amendments of MARPOL 73/78/97 (IMO, 1997). It was revised again in 2008 with some specified approaches and phases to stringently control shipping emissions in the revised Annex IV (IMO, 2008). The IMO also established a goal of reducing the amount of CO2 emissions by 20-50% by 2050 (IMO, 2009a). The other type of policies and measures are those issued by port authorities or related associations. Such as the requirements of using shore power facilities for berthing ships.

As a result, there are plenty of policies and measure in practice in regulating the shipping emission and a lot of studies have investigated the significance and impacts of these policies and measures to the industry (Acomi & Acomi, 2014; Ančićn & Šestan, 2015; Corbett et al., 2009; Doudnikoff & Lacoste, 2014; Fagerholt et al., 2015; Ferrari et al., 2015; Lee et al., 2013; Miola et al., 2011; Shi, 2016; Wang et al., 2015; Woo & Moon, 2013). However, all of these policies and measures are analyzed separately without considering the mutual effects among them. Therefore, this study tries to investigate the inter-correlation of the emission abatement policies and measures in a systematic model by considering their structural correlations. By introducing the definition of the pulse process and its stability, this study discusses the adjustment of the shipping emission system in detail in section 3. Finally, the dynamics of the system is then discussed when there is a pulse in each of the variable. The results suggest: 1) the slow steaming practice of ships may decrease emissions under certain circumstances, it actually increases the total emissions in the shipping industry. 2) although the implementation of the EEDI policy can promote the adoption of the EEOI policy, the EEOI actually relieve the demanding for the EEDI policy. 3) the effect of bunker price on emission reduction is larger than other measures.

Acknowledgements

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Climate Change Adaptation for Airports by a Climate Change Risk Indicator (CCRI) Framework

Mark Ching-Pong Poo[1]*, Zaili Yang*[1,2,]**, Delia Dimitriu*[3] *, Zhuohua Qu*[4]*, Paul Tae-Woo Lee*[2]*, and Xuehao Feng*[2]

[1] Liverpool Logistics, Offshore and Marine Research Institute, Liverpool John Moores University, the UK
[2] Ocean College, Zhejiang University, China
[3] Ecology and Environment Research Centre, Manchester Metropolitan University, the UK
[4] Liverpool Business School, Liverpool John Moores University, the UK
Email: [1]Z.Yang@ljmu.ac.uk

[*] Corresponding Author

Abstract

The study is to develop a Climate Change Risk Indicator (CCRI) framework for airport adaptation to climate change. This paper firstly describes the results of a literature review of the studies by international and professional bodies on climate change adaptation for transportation systems, with a focus on the aviation sector. Secondly, a Fuzzy Evidential Reasoning (FER) method is employed to develop a new CCRI framework to evaluate the climate risks of airports. Finally, six airports in the United Kingdom (UK) are selected as the real cases to demonstrate the feasibility of using the proposed CCRI framework.

Keywords: Climate change adaptation; Climate vulnerabilities assessment; Climate change risk indicators; Airport resilience; Climate resilience

1. Introduction

Over the past few years, the focus on climate change studies has switched from solo mitigation to both mitigation and adaptation (California Institute of Technology, 2018). As global warming is still unstoppable and it brings more extreme climate events, the relevant risks become serious. Moreover, economic losses due to fatalities become more severe (Lurie, 2015). In the past two decades, severe climate events caused highly significant economic damages. For instance, in 2018, Typhoon Mangkhut crashed Asian countries by bringing high winds and storm surges to the coastal cities (Wallemacq et al., 2018). Airport authorities need to be altered to climate risks (International Airport Review, 2018). Appropriate climate risk control and adaptation measures become necessary with urgency (Burbidge, 2016).

There are various studies for different climate change vulnerabilities and increasing trend in climate change adaptation areas (Poo et al., 2018). We observe a growing number of climate risk assessment studies for critical infrastructures, including cyclones (Lam et al., 2017, Hoshino et al., 2016) and heatwave (Schubert et al., 2014). Also, there are some data-driven studies for visualising climate resilience (Stamos et al., 2015) and the escalation of extreme climate impacts (Forzieri et al., 2018). They have built up the data models by yearly data. Stamos et al. (2015) compare the climate impacts by the number of extreme weather events (EWE), wind gusts, snowfall, blizzard, heavy precipitation, heatwaves, and coldwaves. Forzieri et al. (2018) also reveal climate sensitivities by literature reviews, expert surveys, vulnerabilities for GIS data collection, and hazard projections for hazards. Poo et al. (2018a) set up a Climate Change Risk Indicator (CCRI) framework for seaports using the monthly data collected from different authorities. Conducting a climate risk study for airports will provide useful insights for cross-fertilisation between seaports and airports.

The Intergovernmental Panel on Climate Change (IPCC) is an international body for assessing the science related to climate change. Climate change adaptation is one of the critical studies by the IPCC working group

II in the fifth Assessment Report (Field et al., 2014). Field et al. has undertaken thorough reviews on transport infrastructures and stated that transportation systems would face enormous challenges by the environment in the near future (2030-2040) and the long future (2080-2100), especially in developed cities. They have also indicated climate-related drivers of impacts for coastal zone systems and transportation systems, including extreme high temperature, extreme precipitation, snow cover, damaging cyclone, sea level rise, and flooding. Furthermore, Field et al. find a changing climate leads to changes of EWEs in different sectors, including frequency, intensity, spatial extent, duration, and timing. It can result in unprecedented extreme weather and climate events (Field et al., 2012).

In the climate adaptation area, several studies have been conducted from the perspectives of risk assessments and operation strategies for airports. Keokhumcheng et al. have undertaken a flood risk assessment in the region surrounding the Bangkok Suvarnabhumi Airport (Keokhumcheng et al., 2012). Herath et al. have utilised both temporal downscaling and spatial approaches to develop intensity–duration–frequency (IDF) relations for sub-daily rainfall extremes in the Perth airport area (Herath et al., 2016). Also, Kuok et al. have done a similar assessment in Kuching city (Kuok et al., 2015). Besides, Coffel et al. find that the rising temperature affected the airport operations by lowering the aircraft takeoff performance (Coffel et al., 2017). These studies prove that climate risks threaten airport safety and operations. Dunn and Wilkinson stated that it is possible to build up an adaptive air traffic network to increase the resilience of airport operations (Dunn and Wilkinson, 2016). In 2016, EUROCONTROL, who works to achieve safe and seamless air traffic management across Europe, has clarified the expected climate impacts for airports and provided further insights and directions for building aviation climate resilience (Burbidge, 2016).

A CCRI framework is critical to assess and compare the climate risks between different time frames and scales. By implementing a CCRI framework, adaptation measures can be effectively allocated, and airports can be cooperated in disaster management to build up climate resilience, including emergency takeoff and landing. To build up a comprehensive framework, reasoning techniques are also essential apart from climate data. Reasoning techniques are also essential to build up a CCRI framework apart from climate data.

2. Identification of CCRIs

By the literature review on airport climate adaptation reports (Abertis Infraestructuras S.A., 2011, Birmingham Airport Holdings Ltd, 2011, Gatwick Airport Ltd., 2011, London Luton Airport Ltd., 2011, Maclachlan, 2011, Manchester Airports Group plc, 2011, Associated British Ports, 2011, Heathrow Airport Limited, 2011) and IPCC findings, we observe EWEs can be a reference for observing the climate risks for airports. CCRIs for observing and analysing EWEs are selected from Met Office (Met Office, 2018), Climate Projection (UK Climate Projection, 2018), EU Floods Directive (Environment Agency, 2018), and British Oceanographic Data Centre (BODC) (British Oceanographic Data Centre, 2018). All monthly variables are selected from Met Office, and then some of the risks without monthly data are further chosen from EU Floods Directive and BODC.

Met Office data is collected from UK Climate Projections in 2009 (UKCP09) gridded observation datasets. The historical dataset spans the period 1910–2016 and covers the UK at 5 x 5 km resolution. It is used to observe the current risks and set up the grades of the CCRIs for analysis. The definition and time zone of climate indices are shown below:

Table 1: Definition and time zone of CCRIs

Climate index	Definition	Time frame
Maximum temperature	Average of daily maximum air temperature (ºC)	1910 – 2016
Minimum temperature	Average of daily minimum air temperature (ºC)	1910 – 2016
Mean temperature	Average of daily mean air temperature (ºC)	1910 – 2016
Precipitation	Total precipitation amount (mm)	1910 – 2016
Mean wind speed	Average of hourly mean wind speed at a height of 10 m above ground level (knots)	1969 – 2014
Mean sea level pressure	Average of hourly mean sea level pressure (hPa)	1961 – 2014
Mean relative humidity	Average of hourly relative humidity (%)	1961 – 2014
Mean vapour pressure	Average of hourly vapour pressure (hPa)	1961 – 2014
Mean cloud cover	Average of hourly total cloud cover (%)	1961 – 2006
Days of air frost	Count of days when the minimum air temperature is below 0 ºC (days)	1961 – 2016
Days of ground frost	Count of days when the grass minimum temperature is below 0 ºC (days)	1961 – 2016
Days of rain >= 1 mm	Count of days with >= 1mm precipitation (0900-0900 UTC) (days)	1961 – 2016
Days of rain >= 10 mm	Count of days with >= 10mm precipitation (0900-0900 UTC) (days)	1961 – 2016
Days of sleet or snow falling	Count of days with sleet or snow falling (days)	1971 – 2011
Days of snow lying	Count of days with greater than 50% of the ground covered by snow at 0900 UTC (days)	1971 – 2011

"Long-term flood risk map" is chosen as a CCRI for observing the probabilities of flooding events by rivers and sea. We will consider the whole airports including the outer connections on the webpage (https://flood-warning-information.service.gov.uk/long-term-flood-risk/map) and they come with four levels classified by the UK Environment Agency:

- High risk means that each year this area has a chance of flooding of greater than 3.3%. This takes into account the effect of any flood defenses in the area. These defenses reduce but do not completely stop the chance of flooding as they can be overtopped, or fail.
- Medium risk means that each year this area has a chance of flooding of between 1% and 3.3%. This takes into account the effect of any flood defenses in the area. These defenses reduce but do not completely stop the chance of flooding as they can be overtopped, or fail.
- Low risk means that each year this area has a chance of flooding of between 0.1% and 1%. This takes into account the effect of any flood defenses in the area. These defenses reduce but do not completely stop the chance of flooding as they can be overtopped, or fail.
- Very low risk means that each year this area has a chance of flooding of less than 0.1%. This takes into account the effect of any flood defenses in the area. These defenses reduce but do not completely stop the chance of flooding as they can be overtopped, or fail.

Finally, ten maximum sea level records and ten maximum skew surge records are collected from 45 UK seaports from BODC. It is for observing the risks of flooding due to sea-level rise. Average values of two types of records have been calculated for each seaport. Afterwards, tidal levels collected by National Tidal and Sea Level Facility (NTSLF) are given as a height above chart datum. The heights of chart datum relative to ordnance datum at Newlyn. The relative maximum sea level records have been calculated for a valid comparison between different locations. As some of the airports in the UK are built by the coast, Aberdeen Airport (ABZ) has been chosen, as an example, to evaluate in the study.

3. Fuzzy Evidence Reasoning (FER) of its fitness in CCRI

A CCRI framework requires the construction of a hierarchical structure accommodating risks from different climate threats. Corresponding CCRIs have been selected to assess each climate threat independently. In such a hierarchical structure, it is usually the case that the risk indicators at a higher level are also making use of the information produced at the lower levels. It is therefore essential to synthesise the risk performance against individual indicators from the lowest level to the top. An ER method is well matched to undertake modelling quantitative and qualitative values within one framework. The kernel of this approach is an ER algorithm developed on the concept of the Dempster–Shafer (D–S) theory, which requires modelling the hypothesis set with the requirements and limitations of the accumulation of evidence. The most substantial strength of ER is its ability to deal with vague and incomplete data. As some of the climate parameters, such as "Days of air frost", are lacking forecasting data. Therefore, an ER approach is suitable to develop a CCRI framework for assessing and comparing the present and future climate risks.

Five assessment grades are determined by using a fuzzy expression (i.e. "Low risk", "Moderately low risk", "Medium risk", "Moderately high risk", "High risk"). Nevertheless, the risk levels of climate threats also represent by a fuzzy set. Five assessment grades are set up for CCRIs collected from Met Office and BODC and four assessment grades are originally designated to CCRIs by the UK Environmental Agency. To connect CCRIs from the UK Environmental Agency with corresponding climate threats, utility mapping is used and the specific rules are mentioned in Section 4.2.

By connecting all input information and undertake analysis, it is possible to convert different types of CCRIs into CCRI index. FER has been used in CCRI assessment (Yang et al., 2018) and performance measurement (Ha et al., 2017). The newest ER algorithm has been integrated by the following equations.

A represent the set with five linguistic assessment grades {L_1 "Low risk", L_2 "Moderately low risk", L_3 "Medium risk", L_4 "Moderately high risk", L_5 "High risk"}, which has been combined from two subsets A_1 and A_2 based on two different CCRIs. Let α represents degrees of belief attaching to different linguistic terms and ω represents normalised relative weights of the CCRIs.

$$A = \{\alpha_1 L_1, \alpha_2 L_2, \alpha_3 L_3, \alpha_4 L_4, \alpha_5 L_5\}\text{, where } \sum_{m=1}^{5} \alpha_m \le 1 \quad (1)$$

$$A_k = \{\alpha_{1,k} L_1, \alpha_{2,k} L_2, \alpha_{3,k} L_3, \alpha_{4,k} L_4, \alpha_{5,k} L_5\}\text{, where } \sum_{m=1}^{5} \alpha_{m,k} \le 1 \text{ and } k = 1, 2 \quad (2)$$

$$\sum_{k=1}^{2} \omega_k = 1 \quad (3)$$

$$M_{m,k} = \omega_1 \alpha_{m,k}\text{, where } m = 1, 2, 3, 4, 5 \text{ and } k = 1, 2 \quad (4)$$

Equation (1) represents the set with five linguistic assessment grades and equation (2) represents the corresponding CCRIs fuzzy sets from two subsets. By the total normalised relative weights are given in equation (3), and individual relative weight is obtained, the individual degrees, M can be obtained by equation (4).

$$H_k = \bar{H}_k + \tilde{H}_k \text{, where } k = 1, 2 \tag{5}$$

$$\bar{H}_k = 1 - \omega_k \text{, where } k = 1, 2 \tag{6}$$

$$\tilde{H}_k = \omega_k \left(1 - \sum_{m=1}^{5} \alpha_{m,k} \right) \text{, where } k = 1, 2 \tag{7}$$

Equations (5) to (7) represent the remaining belief values (H) unassigned for $M_{m,1}$ and $M_{m,2}$, where $m = 1, 2, 3, 4, 5$. $\bar{H}$ represents the degree to which other CCRIs can play a role in the assessment and $\tilde{H}$ is attributable to the possible incompleteness in the subsets A_1 and A_2 .

$$a'_m = K\left(M_{m,1}M_{m,2} + M_{m,1}H_2 + H_1M_{m,2}\right) \text{, where } m = 1, 2, 3, 4, 5 \tag{8}$$

$$\bar{H}'_U = K\left(\bar{H}_1\bar{H}_2\right) \tag{9}$$

$$K = \left(1 \text{-} \sum_{T=1}^{5} \sum_{\substack{R=1 \\ R \neq T}}^{5} M_{T,1}M_{R,2} \right)^{-1} \tag{10}$$

Let a'_m be the non-normalized degree to which the synthesised evaluation is confirmed to the five linguistic grafess and $\bar{H}'_U$ the non-normalised remaining belief unassigned after the commitment of belief to the five linguistic grades. They work together as the result of the synthesis of the risk degrees. After the above 10 equations, the final two equations mean the calculation of the combined degrees a_m . They are generated by putting $\bar{H}'_U$ back to the five expressions using the following normalisation process and H_U means the normalised remaining belief unassigned in the synthesised set.

$$a_m = a'_m / \left(1 - \bar{H}'_U\right) \text{, where } m = 1, 2, 3, 4, 5 \tag{11}$$

$$H_U = \tilde{H}_U / \left(1 - \bar{H}'_U\right) \tag{12}$$

The above equations give the process of combining two CCRI fuzzy sets. If three CCRI fuzzy sets are required to be combined, the result obtained from the combination of any two sets can be further synthesised with the third one using the above algorithm. Similarly, climate threat fuzzy sets can also be combined to a CCRI index fuzzy set by the same algorithm, and a final index can be obtained from the CCRI index fuzzy set. Furthermore, some of the climate threats have been addressed by airports, including “Seasonal changes of fog events”, “Seasonal changes of lighting events”, “Seasonal changes to weather pattern”, and “Seasonal changes to wind speed and direction”. However, no suitable CCRIs can be found, and expert judgements are required to be a part of the framework in the next stage. Therefore, FER is suitable for the future development of the CCRI framework as FER can integrate different expert judgments based on scientific assessments.

4. CCRI Framework

4.1 Defining the problem

By gathering data from Met Office, the UK Environment Agency, and BODC, we can summarise the CCRI framework by the Table 2. 25 x 25 km monthly gridded forecasting datasets are collected from UKCP09, and we can find some forecasting data to compare the existing risks and future risks. The future period is set to 2050s (2040-2069), and the emission scenario is medium. 50th percentile data in the 2050s with medium emission scenario is taken as the reference for analysis as they had made a probabilistic projection for every variable. Heat stress is projected to increase by many climate model ensembles and generations, largely driven by temperature increases and humidity declines (Baker and Grant, 2018) . Therefore, "Warming trend/ Extreme temperature/ Drought" is defined by combining the warming and drying trend and the whole framework is shown below:

Table 2: Summary of CCRI framework

Climate threat	EWE	CCRI	UB/ LB	Source	Monthly data	Forecast data
Warming trend/ Extreme temperature/ Drought	Heatwave Drought Wildfires	Maximum temperature (ºC)	UB	Met Office	Yes	Yes
		Mean temperature (ºC)	UB	Met Office	Yes	Yes
		Minimum temperature (ºC)	UB	Met Office	Yes	Yes
		Relative humidity (%)	LB	Met Office	Yes	Yes
		Rainfall (mm)	LB	Met Office	Yes	Yes
		Cloud cover (%)	LB	Met Office	Yes	Yes
Extreme precipitation	Flooding	Rainfall (mm)	UB	Met Office	Yes	Yes
		Days of rain >= 1.0 mm (days)	UB	Met Office	Yes	No
		Days of rain >= 10.0 mm (days)	UB	Met Office	Yes	No
		Long-term flood risk	N/A	The UK Environment Agency	No	Yes
Snow cover	Coldwave/ Snow events	Days of air frost (days)	UB	Met Office	Yes	No
		Days of ground frost (days)	UB	Met Office	Yes	No
		Days of sleet and snow falling (days)	UB	Met Office	Yes	No
		Days of snowlying (days)	UB	Met Office	Yes	No
		Maximum temperature (ºC)	LB	Met Office	Yes	Yes
		Mean temperature (ºC)	LB	Met Office	Yes	Yes
		Minimum temperature (ºC)	LB	Met Office	Yes	Yes
Damaging cyclone	Wind gust/ Storminess	Rainfall (mm)	UB	Met Office	Yes	Yes
		Vapour pressure (hPa)	LB	Met Office	Yes	No
		Mean seal level pressure (hPa)	LB	Met Office	Yes	Yes
		Mean wind speed (knots)	UB	Met Office	Yes	Yes
Sea-level rise	Flooding	Maximum relative sea level record (m)	N/A	BODC/ Met Office	No	Yes
		Maximum skew surge record (m)	N/A	BODC/ Met Office	No	Yes
		Long-term flood risk	N/A	The UK Environment Agency	No	Yes

4.2 Setting the criterion grades

Task Team on Definitions of Extreme Weather and Climate Events (TT-DEWCE) from World Meteorological Organization (WMO) has stated that there are fixed and well known the extreme events and their thresholds differ from location to location (TT-DEWCE, 2016). So, extreme values can be defined by obtaining extreme percentile ranks. For Met Office, 5 x 5 km monthly gridded observational datasets of the whole United Kingdom are collected. Then, 80th, 90th, 95th and 99th percentile values are used to divide the upper bound (UB) assessment grades in five and 20th, 10th, 5th and 1st percentile values are used to classify the lower bound (LB) assessment grades in five. Therefore, all datasets can fit the set with five linguistic assessment grades {L_1 "Low risk", L_2 "Moderately low risk", L_3 "Medium risk", L_4 "Moderately high risk", L_5 "High risk"}, which are mentioned in Section 3. Based on the classification of disaster types on critical infrastructure stated by Forzieri et al., climate variables are categorised, and the values used as defining grades are shown in Table 10 (Forzieri et al., 2018):

Table 3: Marginal values of CCRIs from Met Office for defining grades

Climate threats	CCRI	LB/ UB	Percentile			
			20th/80th	10th/90th	5th/95th	1st/99th
Warming trend/ Extreme temperature/ Drought	Maximum temperature (°C)	UB	17.24	19.17	20.52	22.91
	Mean temperature (°C)	UB	13.19	14.78	15.86	17.64
	Minimum temperature (°C)	UB	9.2	10.59	11.48	12.86
	Relative humidity (%)	LB	78.54	76.31	74.47	70.7
	Rainfall (mm)	LB	40	27.05	18.59	7.44
	Cloud cover (%)	LB	64.9	60.64	56.71	48.57
Extreme precipitation	Rainfall (mm)	UB	130.5	174.68	222.65	346.63
	Days of rain >= 1.0 mm (days)	UB	17.66	20.54	23.04	27.24
	Days of rain >= 10.0 mm (days)	UB	4.38	6.24	8.22	12.78
Snow cover	Days of air frost (days)	UB	9.15	13.52	17.17	24.23
	Days of ground frost (days)	UB	16.88	20.38	23.06	27.68
	Days of sleet and snow falling (days)	UB	3.4	6.3	9.17	15.18
	Days of snowlying (days)	UB	1.53	4.37	8.01	18.35
	Maximum temperature (°C)	LB	2.02	4.37	5.63	7.22
	Mean temperature (°C)	LB	-0.58	1.72	2.88	4.32
	Minimum temperature (°C)	LB	-3.32	-1.07	0.02	1.32
Damaging cyclone	Rainfall (mm)	UB	130.5	174.68	222.65	346.63
	Vapour pressure (hPa)	LB	7.26	6.63	6.14	5.21
	Mean sea level pressure (hPa)	LB	1009.21	1006.02	1003.08	997.9
	Mean wind speed (knots)	UB	12.2	14.36	16.44	21.04

As the maximum sea level records and maximum skew surge records from BODC are extreme data already, we tried to separate them into five groups by four values at 20th, 40th, 60th, and 80th percentiles of records from all 45 ports data (Zhang et al., 2013). For forecasting, we used the UKCP09 values, the long-term linear trend in skew surge (1951-2099) for return level of 10 years (mm/yr) and sea-level change (m), to foresee the sea-level and storm surge changes.

Table 4: Marginal values of CCRI from BODC for defining grades

CCRI	Percentile			
	20th	40th	60th	80th
Maximum sea level record (m)	2.79	3.28	3.6	5.33
Maximum skew surge record (m)	0.75	0.87	1.04	1.22

Datasets from Met Office and BODC have been divided into five assessment grades by four percentiles. By considering the "Long-term flood risk" levels directly from the website, all assessment grades have been selected and shown below:

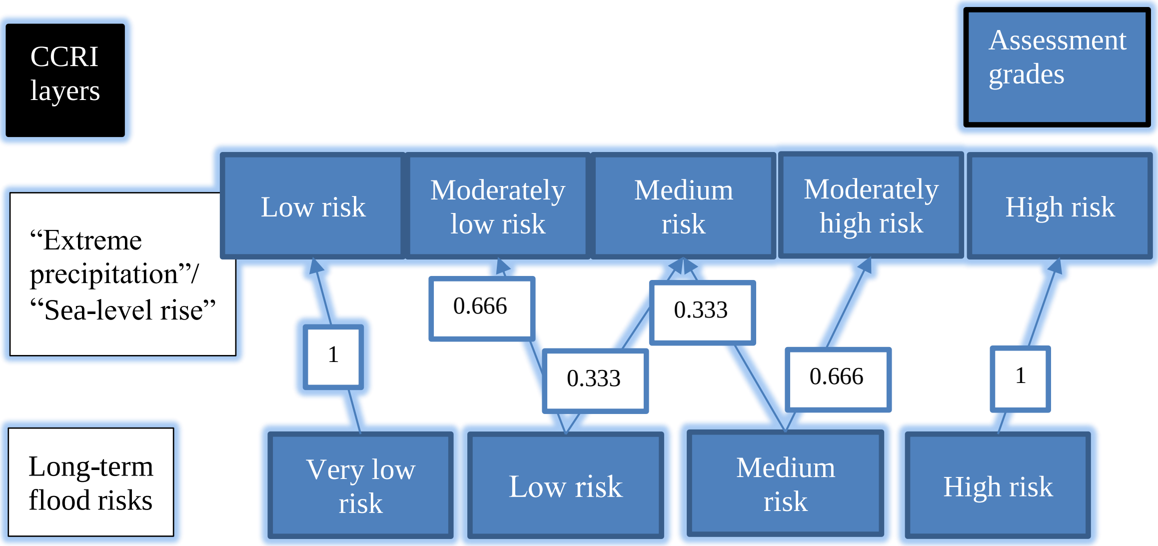
Table 5: Assessment grades of CCRIs

Source	**Assessment Grade**				
Met Office	Low risk	Moderately low risk	Medium risk	Moderately high risk	High risk
UB Percentile	*<=80*	*80.1 – 90*	*90.1 - 95*	*95.1 - 99*	*99.1 - 100*
LB Percentile	*>=20*	*10 – 19.9*	*5 – 9.9*	*1 – 4.9*	*0 – 0.9*
Environment Agency	Very low risk	Low risk	Medium risk		High risk
BODC	Low risk	Moderately low risk	Medium risk	Moderately high risk	High risk
Percentile	*<=20*	*20.1 – 40*	*40.1 - 60*	*60.1 - 80*	*80.1 - 100*

Figure 11: CCRI Framework

By gathering all CCRIs and the assessment grades, CCRI framework can be set up with three levels, and it is shown in Figure 1. Except "Long-term flood risks" from Environment Agency with four assessment grades, they are all with five assessment grades, {L_1 "Low risk", L_2 "Moderately low risk", L_3 "Medium risk", L_4 "Moderately high risk", L_5 "High risk"}. Therefore, there have special utility mapping rules for connection all linguistic assessment grades. The specific rules for connecting to an upper level, "Extreme precipitation" and "Sea-level rise", are set up as Figure 2 and statements below:

Figure 12: Utility Mapping between "Long-term flood risks" and "Extreme precipitation"/"Sea-level rise"



- 1 of "Very low risk" of "Long-term flood risks" to 1 of "Low risk" of "Extreme precipitation"/ "Sea-level rise";
- 1 of "Low risk" of "Long-term flood risks" to 0.666 of "Moderately low risk" and 0.333 of "Medium risk" of "Extreme precipitation"/ "Sea-level rise";
- 1 of "Medium risk" of "Long-term flood risks" to 0.333 of "Medium risk" and 0.666 of "Moderately high risk" or "Extreme precipitation"/ "Sea-level rise"; and
- 1 of "High risk" of "Long-term flood risks" to 1 of "High risk" of "Extreme precipitation"/ "Sea-level rise".

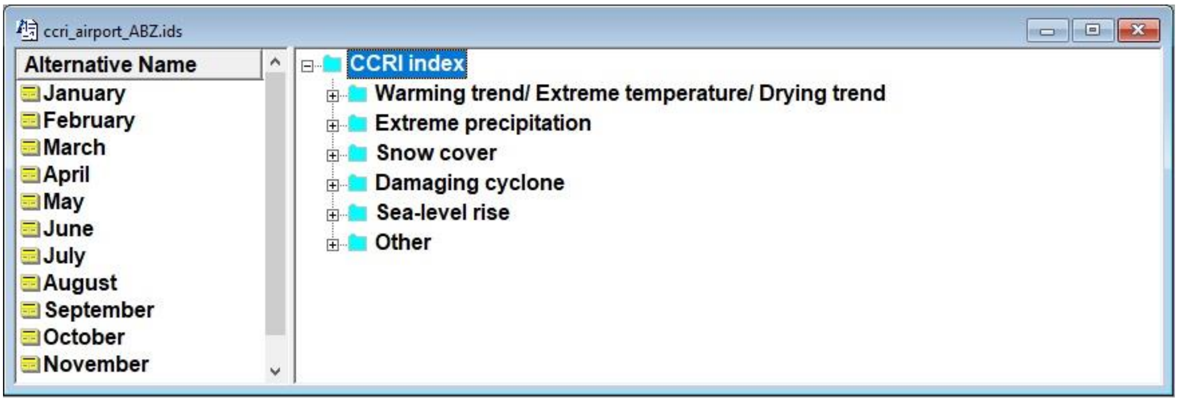
4.3. Evaluating airports using climate data from the lowest level to top level criteria

By assessing the dataset of the airports, we can distinguish the grading of each criterion. Two airports, "Heathrow Airport (LHR)", and "Aberdeen Airport (ABZ)", are chosen for a demonstration as they are from different regions of the UK. The CCRI framework consists of three layers: "Climate Change Risk Indicators index", "Climate threats", and "Climate Change Risk Indicators". For "Climate Change Risk Indicators", all attributes have equal weights. For "Climate threats", the weight assignment come from a sensitivity study for different critical infrastructures in Europe (Forzieri et al., 2018): "Warming trend/ Extreme temperature/ Drying Trend" as 29.78; "Extreme precipitation" as 19.11; "Snow cover" as 25.56; "Damaging cyclone" as 25.56; and "Sea-level rise" as 19.11. Therefore, we can get a CCRI index for each airport at the highest level.

4.4 Synthesizing all evaluations using the ER algorithm

By implying ER equations mentioned in Section 3, CCRI index of each airport can be evaluated from the lowest level to the top level. Calculation software IDS is used for facilitating the calculation as shown in Figure 3. The assessment grades are given their corresponding values as the set of [0, 0.25, 0.5, 0.75, 1] for ["Low risk", "Moderately low risk", "Medium risk", "Moderately high risk", "High risk"]. The software IDS uses the concept of a utility interval to characterise the unassigned degree of belief (unknown percentage). The ER algorithm produces a utility interval which is enclosed by the two extreme cases where the unassigned belief moves either to "Slightly preferred with a minimum utility value" or to "Greatly preferred with a maximum utility value".

Figure 13: Screen capture of IDS



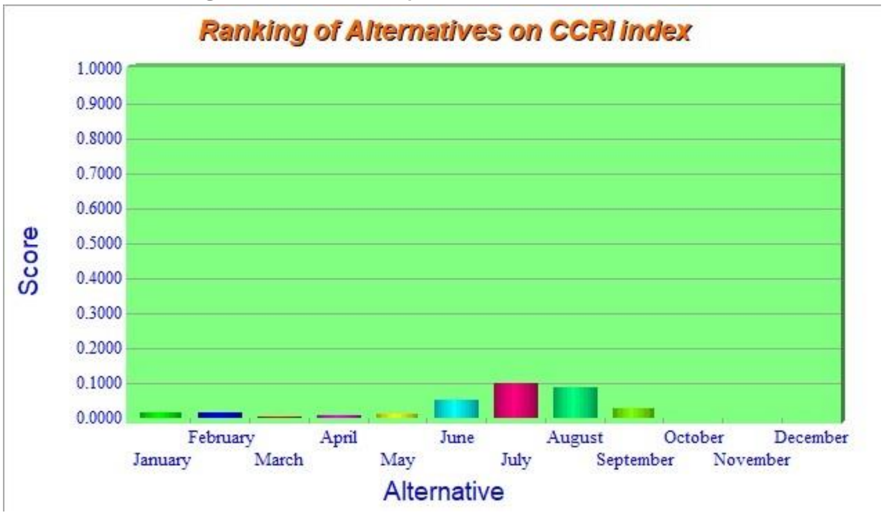
5. Demonstration by two selected airports

By assessing CCRI indexes of two airports, comparisons are between ports and months. Also, now and future, as known as historical and forecasting, are compared for observing the climate change impacts.

5.1 Comparison between months

Figure 14: Monthly CCRI indexes of ABZ

Figure 15: Monthly CCRI indexes of LHR



By comparing CCRI indexes between different months, we can find the climate risk levels in different seasons. ABZ and LHR are taken places in Figure 4 and 5. For ABZ, we can see that there two crests. The bigger crest in from December to February and the smaller one is from July to August. By Table 6, Monthly CCRI indexes are presented and ranks are based on the comparison on CCRI indexes of different months in the same airport. For LHR, we can observe the only peak from June to August. The month with the highest CCRI index in ABZ is January, and the month with the highest CCRI index in LHR is July.

Table 6: Monthly CCRI indexes of two the UK airports

Airport/ Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
ABZ	0.166	0.132	0.093	0.072	0.068	0.068	0.102	0.102	0.068	0.068	0.086	0.141
Rank	1	3	6	8	9	9	4	4	9	9	7	2
LHR	0.131	0.131	0.121	0.121	0.129	0.159	0.189	0.172	0.140	0.121	0.121	0.125
Rank	6	5	9	8	7	3	1	2	4	11	11	10

5.2 Comparison between now and future

The other analysis is to compare the now and future data. Figures 6 to 9 are used to observe the changes of CCRI indexes of January and July in two different airports, ABZ and LHR. The comparison is shown in Table 7. Due to the missing of a part of future CCRIs, the deviation of between the best and the worst scenarios of CCRI indexes in the future is higher than that of now. Average indexes are used for analysis in this section. CCRI index of ABZ in January slightly increases from 0.1664 to 0.1958, and that in July increases drastically from 0.1015 to 0.2085 in the future. CCRI index of LHR in January slightly increases from 0.0184 to 0.0554, and CCRI index of LHR in July increases nearly in a double from 0.1009 to 0.2083. We can find that hot summer weather will threaten the airports more frequently and severely, but the winter weather threats remain at the same level from the results.

Figure 16 & 17: CCRI indexes of ABZ in January and July

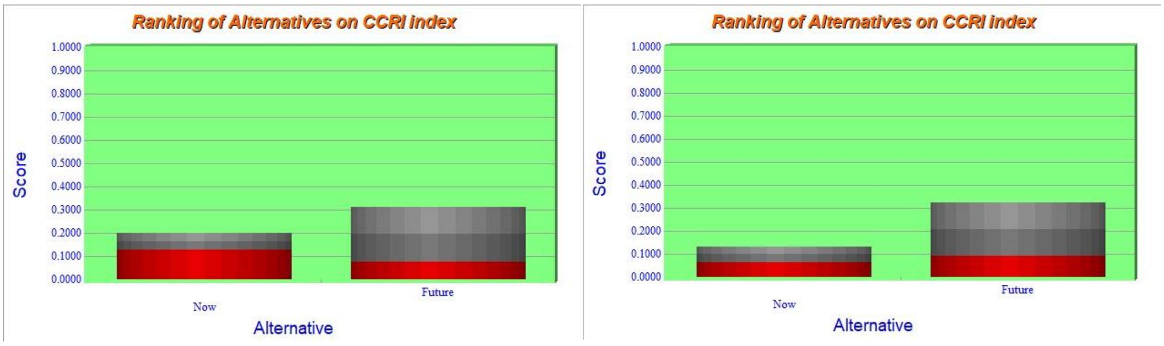


Figure 18 & 19: CCRI indexes of LHR in January and July

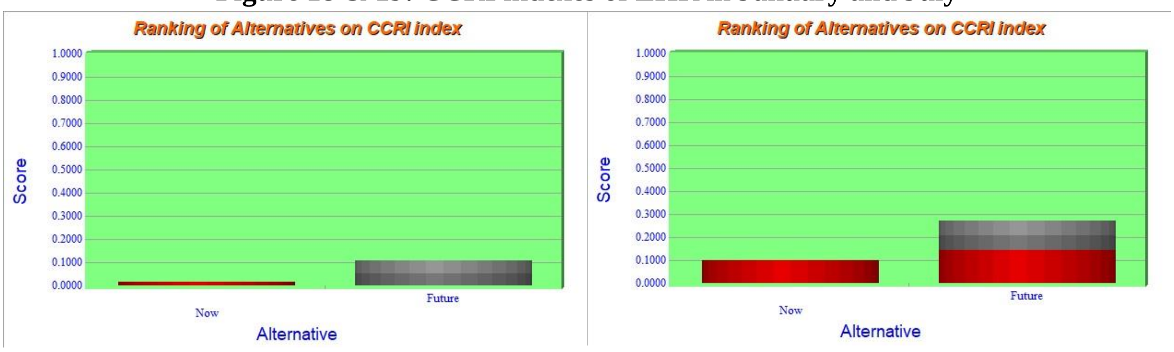


Table 7: CCRI indexes of two UK airports in January and July with forecasting

Location		ABZ		LHR	
Month		January	July	January	July
Now	Best Possible	0.1297	0.0677	0.0184	0.1009
	Average	0.1664	0.1015	0.0184	0.1009
	Worst Possible	0.2031	0.1353	0.0184	0.1009
	Deviation	0.0734	0.0676	0	0
Future (2050)	Best Possible	0.0791	0.0936	0	0.1439
	Average	0.1958	0.2085	0.0554	0.2083
	Worst Possible	0.3125	0.3234	0.1108	0.2727
	Deviation	0.2334	0.2298	0.1108	0.1288

6. Conclusion

Current CCRI framework has been implemented to airports and seaports, and CCRI indexes of two airports are successful visualized. The success of the CCRI framework has been proved by tracking the climate risks changed monthly in different timeframes. The study is ongoing, and the next stage of the study is to gather more information from different airport stakeholders about climate vulnerabilities assessment and climate change adaptation. Also, six airports and six seaports have been assessed by the CCRI framework and the scale of assessment will be expanded possibly. Besides, more climate information for analysing high wind, lightning, and fog are needed for assessing the undefined climate risks. Therefore, a further qualitative survey from airport stakeholders and experts, which has been mentioned in Section 3, are required to be done to for validate and enhance the practicability of the CCRI framework (Kerstein and Wang, 2018). Also, socioeconomic and sensitive factors in a regional and national scale can be collected to utilise the framework. This kind of regional climate vulnerability assessment has been successfully established for seaports (Duncan McIntosh and Becker, 2017). Lastly, the CCRI framework can be applied to other kinds of transportation modes, such as roads and railways. And then, the CCRI framework can be used to develop a decision-making model for deciding suitable adaptive measures for a dedicate region with different transportation modes.

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Impacts of Different Low-carbon Policies on Route Decisions in Intermodal Freight Transportation: The Case of the West River Region in China

Xing-Qun Cheng[1], *Chun Jin*[1,*], *Cong Wang*[2], *and Yuliya Mamatok*[3]

[1] Institute of Systems Engineering, Dalian University of Technology, Dalian 116024, PR China
[2] School of Maritime Economics and Management, Dalian Maritime University, Dalian 116026, PR China
[3] Business School, Quanzhou Normal University, Quanzhou 362000, PR China

[*]Corresponding Author

Abstract

Different low-carbon policies usually result in the variety of decisions on an exact amount of carbon emission, especially in the industry with more environmental concerns. To analyze the impacts of low-carbon policies on route decisions during the process of intermodal freight transportation (IFT), this paper investigates how an IFT enterprise chooses the optimal route under three kinds of low-carbon policies (the carbon cap policy, the carbon tax and the cap-and-trade policy).

Firstly, we confirm the direct costs, time and carbon emissions (CO_2) during transportation (on arcs) and transfer (in nodes). And then, a basic model for route decisions in IFT is proposed, which is a bi-objective optimization model minimizing total direct cost and total emissions. Finally, we extend the basic model into three integer programming models under corresponding policies after a brief introduction of them.

The IFT system of the West River region in southern China is investigated to illustrate decision-making characteristics under three low-carbon policies mentioned above. The network of this transportation system consists of 10 nodes and three kinds of transportation modes (roadway, railway and inland waterway), which represents a typical medium-sized ITF system. Numerical experiments show that low-carbon policies impact IFT route decisions in different ways, (1) the cap policy can always reduce IFT emissions effectively if we set a proper emission limit. Under a loose or strict lead time, the minimum carbon emissions and transportation cost can be achieved simultaneously, while under a moderate lead time, the most environmentally-friendly route sacrifices the monetary benefit .(2) Carbon tax can sometimes reduce emission, but the corresponding tax rate may be much higher than a reasonable one. The reason why carbon tax cannot always reduce IFT emissions effectively is that the cost of carbon emissions under carbon tax policy accounts for a relatively low proportion of the total cost. (3) The emission reduction of the cap-and-trade policy is less than that of carbon tax policy. Because carbon tax policy covers all carbon emissions, while the cost of emissions generated under the cap-and-trade policy is only the portion that exceeds the emission limit.

The paper provides guidelines for emission reduction in IFT. It’s suggested that a combined emission regulation based on the cap policy is preferred currently to achieve emission reduction in IFT. Transportation sectors with lower emissions intensity like waterway and railway could take advantage of those policies to promote their own proportion.

Keywords: Route Decisions, Intermodal Freight Transportation, Carbon Emissions, Low-carbon Policies

[*]Corresponding author. Email: jinchun@dlut.edu.cn

1. Introduction

Intermodal freight transportation (IFT) has an increasing importance on account of the surge in international trade and logistics. Meanwhile, resource shortage, global warming, and public awareness about environmental issues are driving countries and firms to reduce greenhouse gas (GHG) emissions (Bouchery and Fransoo, 2015; Geske, Berghout, and Machteld, 2015). Government programs (e.g. the European Union Greenhouse Gas Emission Trading Scheme, the Carbon Emission Trading Market Construction Plan of China) and voluntary-membership organisations (e.g. the Intergovernmental Panel on Climate Change) have been carried out to control GHG emissions released by human activities, primarily carbon emissions (Peter et al, 2018). Since it is recognized that transportation is one of the main contributions of carbon emissions (IPCC, 2017), IFT enterprises should take the existing or forthcoming low-carbon policies into consideration during the process of decision-making.

Route decision is one of the common decisions in FIT (Steadieseifi et al, 2014; Agamez and José, 2017), which tries to find out the shortest path from the origin to the destination of the transportation task (Lozano and Storchi, 2001). A route information in IFT contains the sequence of nodes that cargo will travel through, and the modes chosen among the nodes (Chang and Tsung, 2008). The majority of related researches about route decisions were carried out from the perspectives of minimum of transportation cost or transportation risk, meeting the transportation time window et al. In the context of low-carbon transportation, route decisions in IFT with carbon emission considering were investigated, which put the quantity/cost of carbon emission into the objectives or constraints of the optimization models (Kim et al, 2009; Demir et al, 2015; Jasmine and Gu, 2016). Low-carbon policies (such as carbon cap, tax and cap-and-trade policy) control carbon emission or emission cost to achieve the purpose of emission reduction and affect economic decisions (Hoen et al, 2014). Different carbon emission control policies will leads different transportation route choices. Therefore, based on the analysis of carbon emissions from different transportation modes, it is necessary to further study the optimal route decision problem in IFT under different policies.

Until now, little attention has been paid to route decision problem in IFT under different policies. But other decision problems under low-carbon policies have been studied recently. Hua et al (2011) investigated how firms manage carbon footprints in inventory management under the carbon emission trading mechanism. They found that the cap-and-trade mechanism induces the retailer to reduce carbon emissions, which may result in an increase in the total cost. Rosič and Jammernegg (2013) extended the dual sourcing model based on the newsvendor framework by considering emission tax and emission trading. They thought if emission trading is used instead of an emission tax, the offshore order quantity and the related transport emissions can be reduced while the economic performance measures are nearly not harmed. Toptal et al (2014) also extended the economic order quantity model to consider carbon emissions reduction investment availability under carbon cap, tax and cap-and-trade policies. Their founding implied that all three regulation policies are effective in reducing carbon emissions when carefully designed. The cap and tax policies always lead to higher annual costs for the retailer compared to when no regulation policy is in place, while the retailer may reduce his/her costs by selling permits equivalent to his/her excess carbon capacity under a cap-and-trade policy. Those studies introduced low-carbon policies into the classical decision problems, and they found how the policies impact decision results differently.

Since green operation and lean management are required for the whole society, it is crucial and necessary to look into route decision problem in IFT under different policies. Carbon emissions of transportation (on arcs) and transfer (in nodes) are calculated according to 2006 IPCC Guidelines for National Greenhouse Gas Inventories and related articles to estimate carbon emissions of potential routes. Modelling is conducted by two steps: firstly we give a basic model of route decisions in IFT, and then we extend the basic model into models under different low-carbon policies. The case of the West River region in China is given and solved by CPLEX. Our study aims to find the impacts of low-carbon policies on route decisions, and to identify what kind of policy is currently better for emissions reduction and promotion of IFT. This study may provide guidelines for IFT enterprises to choose a satisfactory route decision under low-carbon policies, and insights for government departments to propose effective carbon emission regulations.

The rest of the paper is organised as follows: In Section 2, we describe the problem and settings more detailed. In section 3, we firstly introduce how to calculate direct costs time and carbon emissions in IFT, and then propose models under three kinds of low-carbon policy after a brief introduction of them. A case study of the West River region in southern China is given in Section 4, and we conclude the paper with some final remarks in Section 5.

2. Problem Definition

We consider a directed graph *G* (*N*, *A*, *M*), in which *N* is the set of nodes, *A* is the set of arcs, and *M* is the set of transportation modes. Optimal decision in IFT can defined as a route selection problem : there is batch of goods to be transported from node *O* to node *D* ($O, D \in N$), and the transportation is under regulation of three kinds of low-carbon policies (the cap policy, the carbon tax policy, and cap-and-trade policy). Try to find the most economical route meeting requirements of lead time and carbon emission. The following modeling assumptions are made: (1) Transport task is indivisible, that is, only one mode of transport can be selected between two nodes. (2) Transfer of transportation modes can only take place in nodes, and it could happen up to once in a single node. Related notations are listed as follows.

C, *C*1: Total cost, direct cost of transportation (Yuan RMB).

E: Total emissions (kg).

q: Quantity of cargos (ton).

d_{ij}^{k} : Transportation distance of mode *k* from node *i* to node *j* (Yuan RMB).

F^k: Fixed transportation cost of mode *k* (Yuan RMB).

F^{kl}: Fixed transfer cost from mode *k* to mode *l* (Yuan RMB).

v^k: Travel speed of mode *k* (km/h).

P_t: Rate of carbon tax.

P_s: Carbon price under the cap-and-trade policy.

U_c: Emission limit under the cap policy (kg).

U_s: Emission quota under the cap-and-trade policy (kg).

T: Total time of transportation (hour).

T^u: Lead time of transportation task (hour).

x_{ij}^{k} : Binary decision variables. 1 if mode *k* is selected on arc(*i, j*) and 0 otherwise.

y_{i}^{kl} : Binary decision variables. 1 if a transfer from mode *k* to mode *l* happens in node *i* and 0 otherwise.

3. Model Formulations

The optimal route decisions under different carbon emission policies need to consider carbon emissions within a specific low-carbon policy framework based on the classical problem, and then put the carbon emissions into classical model's constraints or convert them into carbon emissions costs in model's objective function. Thus, basic model minimizing carbon emissions as well as total cost is proposed firstly, and then expand the basic model into the optimal path decision model of multimodal transport path under low carbon policies.

3.1 Calculation of Cost, Time and Emissions in IFT

(1) Direct transportation costs

The direct transportation costs consist of transportation costs on arcs and transfer costs in nodes. Transportation costs include variable costs (associated with transportation mode, volume of goods and distance of transportation) and fixed costs (associated with the type of transfer). Therefore, the direct costs of mode k on arc (i, j) is shown as Eq. 1.

$$C_{ij}^{k} = \begin{cases} \alpha_k \cdot q^{\beta_k} \cdot d_{ij}^{k}, (i \neq O) \cap (\sum_{l \in M} \sum_{k \in M} y_i^{kl} = 0) \\ \alpha_k \cdot q^{\beta_k} \cdot d_{ij}^{k} + F^k, otherwise \end{cases} \tag{1}$$

In Eq. 1, α_k is the variable cost of mode k, and its unit is Yuan/ (km*ton). $\beta_k \in (0,1)$ is the scale discount coefficient of mode k in transportation.

Transfer costs include fixed costs (associated with workers and equipment), and variable costs (associated with the type of transfer and quantity of cargos). Transfer from mode k to l occurs at node i is shown as Eq. 2.

$$C_i^{kl} = F^{kl} + \alpha_{kl} \cdot q^{\beta_{kl}} \tag{2}$$

In Eq. 2, α_{kl} is the variable cost coefficient of the transfer from mode k to l. β_{kl} is the variable cost discount coefficient the transfer from mode k to l.

Thus, total direct transportation costs can be obtained as shown in Eq. 3.

$$C_1 = \sum_{i \in N} \sum_{j \in N} \sum_{k \in M} C_{ij}^{k} \cdot x_{ij}^{k} + \sum_{i \in N} \sum_{k \in M} \sum_{l \in M} C_i^{kl} \cdot y_i^{kl} \tag{3}$$

(2) Transportation time

Transportation time includes transportation time on arcs and transfer time in nodes. It is obvious that Transportation time of mode k on arc (i, j) can be obtained by corresponding speed since we know the length of the arc, where $T_{ij}^{k} = d_{ij}^{k} / v^k$ .Transfer time includes the transfer operation time associated with cargo volume and the waiting time associated with the mode of transportation phase, hence the transfer time from mode k to mode l in node i is shown as Eq. 4.

$$T_i^{kl} = (T_w^l + \gamma \cdot q) \cdot y_i^{kl} \tag{4}$$

In the Eq. 4, γ is the carrying time per unit cargo, and the unit is hour/ton. The sum transportation on arcs and transfer time in nodes is the total transportation time of the task, as shown in Eq. 5.

$$T = \sum_{k} \sum_{i} \sum_{j} T_{ij}^{k} \cdot x_{ij}^{k} + \sum_{k} \sum_{l} \sum_{i} T_i^{kl} \cdot y_i^{kl} \tag{5}$$

(3) Carbon emissions (CO_2)

Carbon emissions are also released during the process of transportation and transfer. According to the recommendations of the 2006 IPCC Guidelines for National Greenhouse Gas Emissions (2019 Refinement), CO_2 emissions from transportation vehicles are generally based on two calculation methods based on distance travelled and fuel consumption (IPCC, 2019). When the vehicle/train/ship can travel normally at the design speed, distance-based method is recommended, as shown in Eq. 6.

$$E_{ij}^{k} = O^{k} \cdot f^{k} \cdot d_{ij}^{k} \cdot q \tag{6}$$

In Eq. 6, E_{ij}^{k} is the transportation emissions of mode *k* on arc (*i*, *j*); O^k is the fuel consumption coefficient of mode k, and its unit is kg/ (t*km). When the value of this parameter is obtained from statistical data, vehicle depreciation is considered. f^k is the emission coefficient of the fuel used for transportation mode *k*, and its unit is $kgCO_2$/kg.

Transfer emissions are associated with the type of transfer and cargo volume (Hanssen et al, 2012). Calculation of transfer emissions from mode *k* to *l* in *i* is shown in Eq. 7.

$$E_{i}^{kl} = q \cdot e^{kl} \tag{7}$$

In Eq. 7, e^{kl} is the emissions per unit of the transfer from mode *k* to *l*. Hence, the total amount of system carbon emissions can be obtained as shown in Eq. 8:

$$E = \sum_{i \in N} \sum_{j \in N} \sum_{k \in M} E_{ij}^{k} \cdot x_{ij}^{k} + \sum_{i \in N} \sum_{l \in M} \sum_{k \in M} E_{i}^{kl} \cdot y_{i}^{kl} \tag{8}$$

3.2 Basic Model for Route Decisions in IFT

Here we firstly propose a multi-objective route selection model (denoted as Model I) without any low-carbon policy considering, which minimize the total direct transportation costs and carbon emissions.

$$\min z_1 = C_1 \tag{9}$$

$$\min z_2 = E \tag{10}$$

s.t.

$$\sum_{k \in M} x_{ij}^{k} = 1, \forall i \neq j, i, j \in N \tag{11}$$

$$\sum_{l \in M} \sum_{k \in M} y_{i}^{kl} \leq 1, \forall i \in N \tag{12}$$

$$\sum_{j \in N} \sum_{k \in M} x_{ij}^{k} - \sum_{j \in N} \sum_{k \in M} x_{ji}^{k} = \begin{cases} 1, \ i = O \\ -1, \ i = D \\ 0, \ i \neq O, D \end{cases} \tag{13}$$

$$x_{ij}^{k} \leq W / d_{ij}^{k}, \ \forall i, j \in N, k \in M \tag{14}$$

$$\sum_{h \in N} x_{hi}^{k} + \sum_{j \in N} x_{ij}^{l} \geq 2 y_{i}^{kl} \ , \ \forall i, j, h \in N, k, l \in M \tag{15}$$

$$T \leq T^{u} \tag{16}$$

$$x_{ij}^k, y_i^{kl} \in \{0,1\}, \forall i, j \in N, k, l \in M \tag{17}$$

The objective function (Eq. 9, 10) minimizes the total direct costs and CO_2 emissions respectively, and the corresponding calculation process is given by Eq. 3, 8. In the constraints, Eq. 11 means that only one mode of transportation can be selected between any two points. Eq. 12 means that transfer occurs up to once in any node. Eq. 13 is the node flow conservation constraint. Eq. 14 indicates that if mode k does not exist on an arc, it cannot be selected for transportation, W is a sufficiently large positive number. Eq. 15 indicates the continuity of the transportation mode. Eq. 16 is the time limit of the transport task. Eq. 17 indicates that the decision variables are 0-1 variables.

3.3 Route Decision Models in IFT under Low-carbon Policies

According to the carbon policies currently studied, we choose the carbon cap policy, carbon tax and the cap-and-trade policy to introduce briefly, and then construct corresponding expanded models based on Model I.

(1) Model II: Optimal route decision model under the carbon cap policy

Under the carbon cap policy, enterprises must organize their operation activities strictly under the regulation of carbon emission limit set by government. So the optimal route decision problem can only select the optimal route under the constraint of the carbon emission limit. Model II contains the constraint of carbon emission limit U_c is constructed as follows.

$$\min C = C_1 \tag{18}$$

s.t.
Eqs. 11-17

$$E \le U_c \tag{19}$$

The objective function (Eq. 18) minimizes direct transportation costs. Eq. 19 indicates that the total carbon emissions must be less than the limit.

(2) Model III: Optimal route decision model under the carbon tax policy

Under the carbon tax policy, government levies the emission tax with a fixed tax rate P_t. Emission tax and the direct transportation costs are included in the total cost of the system. Thus, Model III is constructed as follows.

$$\min C = C_1 + P_t \cdot E \tag{20}$$

s.t.
Eqs. 11-17

The objective function (Eq. 20) minimizes total cost consisting of the carbon emission cost under the carbon tax policy, and the total direct transportation costs.

(3) Model IV: Optimal route decision model under the cap-and-trade policy

There is a certain amount of emission quota under the cap-and-trade policy. Enterprise need to purchase extra quota from outside when total emissions is over the emission quota, or sell excess quota when total emissions is less than the quota. The cap-and-trade cost or profit is included in the total cost. Thus, Model IV is constructed as follows.

$$\min C = C_1 + P_s \cdot Q_s \tag{21}$$

s.t.

Eqs. 11-17

$$E + Q_s = U_s \tag{22}$$

$$Q_s \in R \tag{23}$$

The objective (Eq. 21) minimizes total costs including direct transportation costs and emission costs due to the cap-and-trade policy. Eq. 22 indicates that the actual emission amount is equal to the emission quota after trade. Eq. 23 indicates that the actual purchased emission amount is a real number.

Models II-IV are traditional integer programming models. Generally, such kind of decision problems in IFT can be solved in two different ways: (1) design heuristic algorithms or exact algorithms according to specific characteristics of the given problem (Kun and Hong). (2) Use existing mathematical programming software, such as CPLEX, GUROBI, and MOSEK (Meraklı and Yaman). Since the network of the case in this paper is a middle-sized one, CPLEX is efficient and effective to solve those models.

4. Case Study

To verify the validity of the models in this paper, and to explore the impacts of different low-carbon policies on the optimal route decisions in IFT, the IFT system in the West River region is investigated to conduct numerical experiments.

4.1 Basic Information of the Case

The West River is the longest river in South China, the third largest river in China, and the longest river in the Pearl River system. Its length is second only to the Yangtze River and the Yellow River. Shipping volume ranks second in China, second only to the Yangtze River. As shown in Figure 1, roadways, railways and inland waterways for freight are developed in this region.

Figure 1: Cities, Ports and Channels in the West River Region

The structure of the roadway-railway-inland waterway intermodal freight transportation system in the West Rives region (Liuzhou-Nansha) is shown in Figure 2. The nodes in this intermodal network are numbered from 0 to 9. The distance adjacency matrix corresponding to the roadway-railway-waterway intermodal network is obtained by the Ministry of Transport, the Railway Transportation Corporation and the websites of local expressway companies. Other related data are derived from field research (ports, logistics companies and so on), Yearbook of China (2016-2018), Yearbook of Chinese Logistics (2016-2018), Statistical Bulletin on the Development of Transportation Industry (2016-2018). The version of the mathematic programming solver is

CPLEX Optimization Studio V12.7.0, and all experiments of the case are solved in seconds under the environment of Intel-i7, 3.40 GHz, 8G RAM.

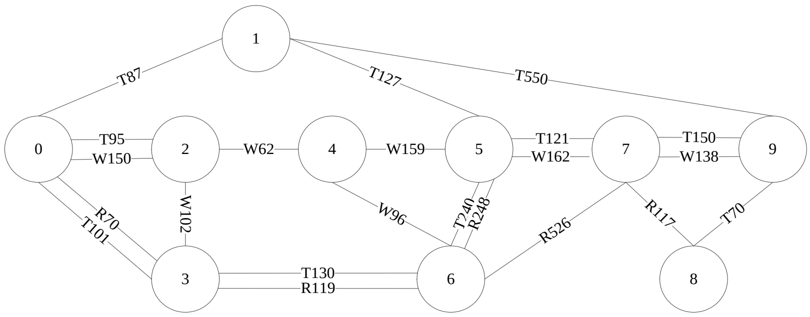

Figure 2: Network of IFT System in the West Rivers Region

(T/R/W: roadway/ railway/ inland waterway ； T87: The distance of roadway transportation is 87 km.)

A Serious of contrast experiments are designed to analyze the impacts of different low-carbon policies on the optimal route decisions in the case respectively. The results are shown in Table 1 and Table 2 and the analyses about results are as follows.

4.2 Impacts of the Cap Policy on Route Decisions in IFT

In this part, experimental results based on model II are analyzed. Because time and carbon emissions are compulsory constraints, six time constraints are divided (T^u = 48, 44, 40, 32, 28, 24, unit: hour). Contrast experiments with different caps are further analyzed under each time constraint. As shown in Table 3, the unsolvable experimental group indicated there is no feasible solution satisfying both time and carbon emissions constraints. In the table, "-" is used to represent the relevant information when there is no solution.A comparative experiment of three groups of scenarios is set up, including loose lead time, strict lead time and moderate lead time.

(1) Loose lead time. Result of Exp. 1 and 2 shows that the change of carbon cap will change the optimal route under a loose leading time. That's because the total cost of the route with waterway only is the lowest , which could satisfy the time constraints under a sufficiently loose lead time, and the carbon emissions of this route is the lowest (usually the carbon emissions of a single railway transport is lower, but there is no feasible route of a single railway transport in this transportation network), so the optimal solutions under different carbon cap are the routes with the lowest cost and carbon emissions, until there is no feasible solution to the low carbon cap. Therefore, for transport tasks with loose lead time, the lowest cost and the lowest carbon emissions can be achieved simultaneously, which is applicable for those freight with low value and loose transportation time requirement. In another word, direct transportation cost is the most important factor that determines the optimal route under a loose lead time. An IFT network with more developed waterway transportation could provide the IFT operators with more economical and low-carbon routes simultaneously, due to the low cost and carbon of waterway.

Table 1: Optimal Routes under the Cap Policy

ID	T^u(h)	U_c(kg)	optimal route	total cost (Yuan)	Emissions(kg)	time(h)
Exp. 1	48	[1161,+∞)	$0_W2_W4_W5_W7_W9$	4137.04	1160.12	44.73
Exp. 2	48	[0,1160]	-	-	-	-
Exp. 3	44	[5417,+∞)	$0_T2_W4_W5_W7_W9$	9619.31	5416.82	41.09

(Continued) Table 1: Optimal Routes under the Cap Policy

ID	T^u(h)	U_c(kg)	optimal route	total cost (Yuan)	Emissions(kg)	time(h)
Exp. 4	44	[5119,5416]	$0_R3_R6_R7_W9$	18183.55	5118.49	36.12
Exp. 5	44	[4149,5118]	$0_R3_R6_R7_R8_T9$	22508.70	4148.80	24.87
Exp. 6	44	[1461,4148]	$0_T1_T5_T7_T9$	25250	1460.18	6.92
Exp. 7	44	[0,1460]	-	-	-	-
Exp. 8	40	[5119,+∞)	$0_R3_R6_R7_W9$	18183.55	5118.49	36.12
Exp. 9	32	[5478, +∞)	$0_T1_T5_T7_W9$	20399.51	5477.18	28.98
Exp. 10	32	[4149,5477]	$0_R3_R6_R7_R8_T9$	22508.70	4148.80	24.87
Exp. 11	32	[1461,4148)	$0_T1_T5_T7_T9$	25250	1460.18	6.92
Exp. 12	28	[4149, +∞)	$0_R3_R6_R7_R8_T9$	22508.70	4148.80	24.87
Exp. 13	28	1461,4148	$0_T1_T5_T7_T9$	25250	1460.18	6.92
Exp. 14	28	[0,1460]	-	-	-	-
Exp. 15	24	[1461,+∞)	$0_T1_T5_T7_T9$	25250	1460.18	6.92
Exp. 16	24	[0,1460]	-	-	-	-

(2) Strict leading time. Result of experiment 15, 16 shows that the unique feasible solution is the optimal solution under the strict leading time. There are two scenarios under a certain carbon cap under this situation: when the carbon cap is higher than a specific value, value changes of the cap won't affect the route decision (Exp. 15); when it is lower than a specific value, the problem has no feasible solution (Exp. 16), and strict lead time makes high-cost, high-carbon route decision irreplaceable. That's because leading time is the most important factor impacting the route decisions under a strict lead time. A short leading time forces the IFT operators to choose a route with more roadway transportation, which increases the carbon emissions finally.

(3) Moderate leading time. Comparing Exp. 3-7, 9-11 and 12-14, the change of carbon cap will change the transportation decision-making. In an appropriate range, a lower carbon cap can effectively reduce the carbon emissions in the optimal transportation decision. Taking Exp. 3-7 as an example, in Exp. 3, the carbon cap is higher, and the optimal solution meeting the lead time is the combination of roadway and waterway. From Exp. 3 to Exp. 6, the carbon cap decreases gradually, and the change of route decision has the following characteristics: ①The cost is increasing while the carbon emission is decreasing, as shown in Figure 3. ② Transportation mode is changing from an economical transportation (waterway) to more environmentally friendly transportation (railway). And it is converted from IFT to a single mode of transportation (roadway only), as shown in Figure 4. Because the single mode transportation avoids the carbon emissions caused by the transformation of transportation modes. The reason why the cap policy could achieve reduction (even though leads to a higher cost) of carbon emission is that, carbon emission and the cap are the most import factors impacting route decisions under a moderate leading time. And also, leading time and cost could affect route decisions as well. A compromise route combining different transportation modes will be chosen to satisfy the target of emission, time and cost.

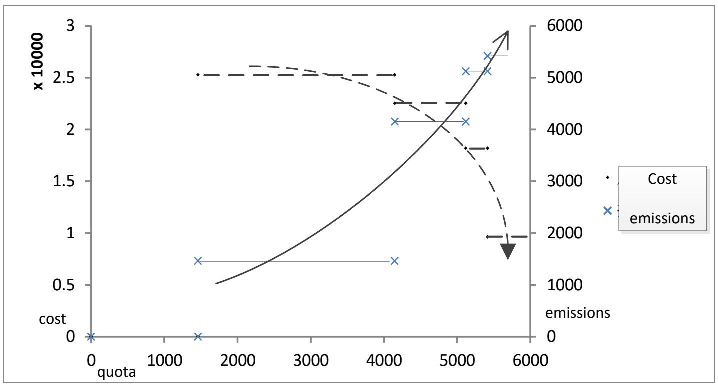

Figure 3: Costs and Emissions of Optimal Routes under Different Caps (Loose Lead Time)

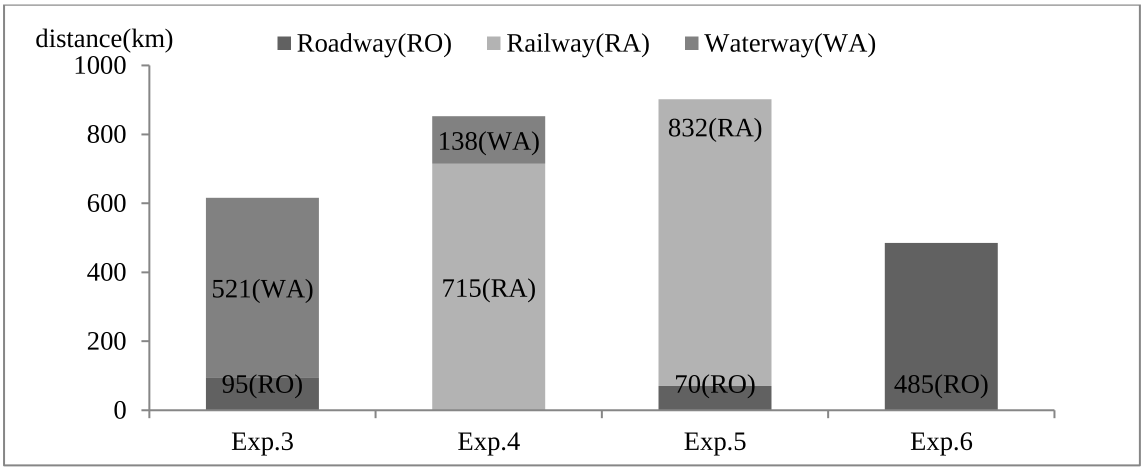

Figure 4: Proportion of Three kinds of Modes (Optimal Routes of Experiments 3-6)

It can be found that under the loose or strict lead time, the minimum carbon emissions and transportation costs can be achieved simultaneously, and the effect of carbon cap policy is not significant at this time. While under the moderate lead time, the most economical transportation solution sacrifices the environmental benefits, at this time, by properly adjusting the carbon cap can effectively affect transportation decision-making and achieve low-carbon transportation. And also, the government and transportation sectors should pay more efforts on promoting waterway, railway, and high-speed railway transportation. Higher proportion and service quality of waterway and railway will leads to lower carbon emissions under different kinds of leading time.

4.3 Impacts of carbon tax and the cap-and-trade policy on route decisions in IFT

The impacts of carbon tax and cap-and-trade policies on path decision-making are shown in Table 2.

(1) The effects of different carbon tax rates on route decision. Exp. 21, 25 solved the optimal route when the carbon tax rate is 0, 50, 100 Yuan/kg under different transportation time. Route decisions under three kinds of carbon taxes are identical, because the cost of carbon emissions from carbon tax accounts for a relatively low proportion of the total cost (in Exp. 21, the cost of carbon emissions from 100 Yuan/kg carbon tax is only 3.44% of the total cost). At this time, the carbon tax policy cannot effectively affect the route decision in intermodal freight transportation. In Exp. 22, 23, taking T^u=44 hours, the unit carbon emission tax rate has an impact on the transport decision when it is increased to 4 Yuan. The corresponding carbon emissions of the taxed path are greatly reduced, but the carbon tax rate at this time is significantly higher than the recommended tax rate (e.g., the carbon tariff recommended in the US Clean Energy Security Act passed in 2009 is only $10-70 per ton). Therefore, it can be concluded that under a reasonable carbon tax level, a simple carbon tax policy can sometimes effectively affect the route decision of intermodal freight transportation

(2) The effect of cap-and-trade policy on route decision. Unlike the carbon tax policy, which covers all carbon emissions, the cost of emissions generated under a cap-and-trade policy is only the portion that exceeds the emission limit. The emission reduction of this policy within reasonable carbon emission price is less than that of carbon tax policy, that is, the impact on the route decision of intermodal freight transportation is weaker, as evidenced by the data in Exp.27.

In summary, under the carbon tax and cap-and-trade policy, the proportion of emission cost in total cost is relatively small, so purely pursuing emission reduction will not reduce too much emission cost, but may lead to a significant increase in direct transport costs. Therefore, the impact of these two policies on the route decision of intermodal freight transportation is not significant. Cost and leading time are much more important than policy's parameters under these two policies, thus they should proposed with the carbon cap policy together to achieve emission reduction.

Table 2: Optimal Routes under Carbon Tax and the Cap-and-trade Policy

	T^u	U	P(Yuan/kg)	Optimal route	Total cost(Yuan)	Emissions	time
Exp. 21	48	0	0/10/100	$0_W2_W4_W5_W7_W9$	4137.04/1573863/120152.94	1160.16	44.73
Exp. 22	44	0	0/2	$0_T2_W4_W5_W7_W9$	9619.31/20452.96	5416.82	41.09
Exp. 23	44	0	4/8/…/100	$0_T1_T5_T7_W9$	3109072/3411.09/171268.1	1460.18	6.92
Exp. 24	40	0	0/1	$0_R3_R6_R7_W9$	18183.55/50643.56/530032	5118.49	36.17
Exp. 25	40	0	2/4	$0_T1_T5_T7_W9$	28170.36/31090.72	1460.18	6.92
Exp. 26	24	0	0/10/100	$0_T1_T5_T7_T9$	25250/39851.80/171268.1	1460.18	6.92
Exp. 27	24	1000	0/10/100	$0_T1_T5_T7_T9$	25250/29851.8/71268.1	1460.18	6.92

5. Conclusions

This paper looks into route decision problem in intermodal freight transportation under low-carbon policies. We find some interesting information about as follows.

I. Low-carbon policies impact IFT route decisions in different ways, comparison of effectiveness and strength among the policies on emission reduction is summarized in Table 3. The cap could always achieve emission reduction effectively and efficiently under a proper gap, while the other two policies usually could not achieve that under a reasonable tax rate or trade price.

Table 3: comparison of effectiveness and strength among 3 policies

	The cap policy	The carbon tax policy	The cap-and-trade policy
Weather could reduce carbon emission	always	sometimes	sometime
Strength to reduce carbon emission	rather strong	limited	limited

II. For the government, a combinational policy based on the cap policy is preferred currently to reduce emission and promote IFT. Meanwhile, the promotion of IFT could facilitate emission reduction, especially the promotion of waterway and high speed railway.

III. For the firms of IFT industry, even though roadway transportation holds the largest percentage among all the transportation modes currently, the firms should no longer focus on the traditional roadway transportation only. When an IFT enterprise has tasks under different leading times, lack of any transportation mode will bring higher cost or higher carbon emission.

We study route decisions in IFT under three low-policies rather than a single one, and compare impacts of those policies on route decisions. The proposed models can help IFT enterprises find the optimal route under different policies, meanwhile, the case study of the West River Region provides with references for government and transportation sectors about how to promote IFT and emission reduction. It should be noted that some important issues in intermodal freight transportation are not included in this study, such as road congestion and disruption of the system. Further work in this area could concern the robust optimization under uncertainty caused by congestion or system disruption.

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Environmental Efficiency of China's Transportation Sectors

Young-Tae Chang[1], *Donggyu Jeon*[2], *and Seong-Hyun Cho*[1]

[1] Graduate School of Logistics, Inha University, Inha Ro 100, Nam-gu, Incheon, 22212, South Korea
[2] Department of Business administration, Seoul National University, Gwanak Ro 1, Gwanak-gu, Seoul, 08826, South Korea

Abstract

Climate change and global warming have become increasingly important globally. China is the world's largest energy-consuming and CO_2-emitting country, and is expected to play an important role in sustainable development. This study develops a new slacks-based measure (SBM) data envelopment analysis (DEA) model under variable returns to scale and weak disposability, to examine the energy and environmental efficiency of China's transportation sector by province. It further provides optimal reduction targets for energy consumption and CO_2 emission for the provinces. The changes in the environmental efficiency of each province is also analyzed with the technological change and pure efficiency change by applying the Malmquist productivity index combined with super efficiency concept. It is shown that the average efficiency values of eastern region increased significantly during 2009-2016, but the western region had a slight increase and the central region suffered diminishing change. The new model's results are proven to be more valid than those of existing models, as the transportation industries of most provinces in China operate at increasing returns to scale or decreasing returns to scale rather than constant returns to scale. Even though most of China's provinces performed better by the new model than the results by previous models, it is suggested that the Chinese government focus on reducing input wastes and CO_2 emissions, rather than increasing the value addition of the transportation sector. To improve China's environmental efficiencies, different approaches and measures should be devised by province, as each province is confronted by different circumstances.

Keywords: Environmental efficiency; China's transportation; SBM-DEA models; Strong and weak disposability; Returns-to-Scale; Malmquist index; Super efficiency

1. Introduction

Climate change and global warming (henceforth, CCG) are increasingly important, globally. To respond to the challenge of improving CCG, major countries have attempted to reduce CCG's principal cause-greenhouse gases (GHG), in particular, carbon dioxide (CO_2) emissions. China, the world's largest energy-consuming and CO_2-emitting country, is expected to play an important role in this movement. In response to the expectation, China committed to implement sustainable development policies in phases through its 11th, 12th, and 13th five-year plans. China's dedication to reducing energy consumptions and CO_2 emissions was confirmed by President Xi Jinping at the 2015 Paris Climate Change Conference. China set binding targets to reduce CO_2 emissions per unit of gross domestic product (GDP) by 18% and energy consumption per unit of GDP by 15% during 2016-2020 in the 13th five-year plan (State Council of the People's Republic of China, 2016).

Improving energy consumption and environmental efficiency in China's transportation sector by province is important to address this issue, at least for two reasons. First, the CO_2 emissions from the transportation sector accounted for 8.1%-8.6% of the national total during 2012-2014, following "electricity and heat production" (52-53%) and "manufacturing and construction" (31-33%) (World Bank, 2014). Therefore, improving the efficiency of the transportation sector could contribute to considerable reduction of CO_2 emissions. Second, future economic growth in China, and the corresponding increasing demand for transportation, will bring more cargo and passenger flows into the transportation sector. Therefore, better energy use and improved environmental performance of the transportation system is crucial for China's continued economic development.

The 13th five-year plan defines various measures, including replacing worn-out vehicles or facilities with new ones, introducing new technologies such as electric vehicles and hydrogen powered cars, and enormous investment in transportation. Against this background, examining the environmental efficiency by province and finding out the rational reduction targets of CO_2 emissions and energy consumption is important for academia and industry, and for government policy formulations.

Several studies measured the environmental efficiency of China's provinces, so as to examine the effectiveness of environmental policies (Watanabe and Tanaka, 2007; Shi et al., 2010; Chang et al., 2013; Wang et al., 2013; Zhang and Choi, 2013; Wang et al., 2014). These researchers mostly proposed models based on data envelopment analysis (DEA), which can provide both the environmental efficiency scores and the improvement targets of decision-making units (DMUs) by incorporating undesirable outputs into their framework. However, their models have some limitations. First, Shi et al. (2010) and Wang et al. (2014) assumed that all inputs should be reduced by the same proportion (radial), which is not realistic, as some input factors are more difficult to reduce than others—for example, capital compared to labor. Next, (Watanabe and Tanaka, 2007; Wang et al., 2013) utilized directional distance function DEA, assuming a non-radial property; however, the manner in which it sets the directional vector depends on researchers. On the other hand, Chang et al. (2013) and Zhang and Choi (2013) developed a slacks-based measure (SBM) DEA, which determines the efficiency scores by maximizing slacks, that is, the amount of input or output that can be improved. It satisfies the non-radial assumption because the direction of improvement is derived from the size of the slacks. However, these models presumed that undesirable and desirable outputs are independent of each other (strong disposability (SD)), whereas undesirable outputs such as CO_2 emissions are usually produced in proportion to the amount of desirable output produced in the real world (weak disposability). Furthermore, Chang et al. (2013) assumed constant returns to scale (CRS), which means that every DMU is producing at the optimal scale; this may not be true in China, as the transportation industries of most Chinese provinces are deemed to operate at increasing returns to scale (IRS). In addition, Shi et al. (2010), Watanabe and Tanaka (2007), and Zhang and Choi (2013) are lack of dynamic approach in DEA to find out efficiency changes and technological changes between each two consecutive years even though they use the multiple year data. Moreover, the main results of efficiency scores in some papers (Shi et al. (2010); Chang et al. (2013); Zhang et al. (2013)) show that there are several efficient DMUs and their models cannot further rank them. For these reasons, this study contributes to the literature by developing a more robust model, which can solve the limitations of the existing models.

The objective of this study is to examine the energy and environmental efficiency of China's transportation sector by province, and to provide optimal reduction targets for provincial energy consumption and CO_2 emission. In addition, this study extends Chang et al. (2013) by improving the methodology to address the biased results. Specifically, a new SBM-DEA model under variable returns to scale (VRS) and weak disposability is developed. Furthermore, Malmquist productivity index is applied in the model to accurately measure productivity change, pure efficiency change, and technological change between two consecutive years from 2009 to 2016. This paper also resolves an infeasibility problem that occurs when the slacks-based measure DEA is attempted to be combined into the Malmquist productivity index. The super-efficiency concept is applied to manage the problem. The details of this model and the problem-solving process are explained in methodology section. The data sampled contain three inputs (labor, capital, energy), one desirable output (value added) and one undesirable output (CO_2) related to China's transportation industry of thirty provinces in 2009-2016.

The rest of the paper is organized as follows. Section 2 presents a literature review of the environmental efficiency of transportation. Section 3 describes the methodology, and Section 4 outlines the results and discussions. Finally, the paper concludes and suggests future study directions.

2. Literature Review in Environmental Efficiency of Transportation

Various approaches have been adopted to measure environmental efficiency. An initial approach for measuring environmental performance was developed by Pittman (1983), who extended the "multilateral superlative indexes" defined in Caves et al. (1982), using the undesirable output concept. However, one problem of

Pittman's work was that the prices of pollutants were difficult to measure (Zhou et al., 2007). Another line of research is using Data Envelopment Analysis (DEA), a dominant approach in recent years.
DEA, proposed by Charnes et al. (1978), is a nonparametric framework to identify the relative efficiency of DMUs by comparing output-to-input proportions. Its strength is based on its simplicity, since it only requires the observed data of multiple inputs and outputs without considering the underlying functional relationships between them (Seiford and Thrall, 1990). In terms of the returns to scale (RTS) property, the original DEA proposed in Charnes et al. (1978) assumed CRS, which was extended to the VRS DEA by Banker et al. (1984). Although Ramanathan (2003) suggested that VRS might be a more appropriate assumption than CRS, both VRS and CRS were used frequently in the literature (Zhou et al., 2008).

While the traditional DEA models assume that all the outputs should be maximized, this assumption is not suitable when measuring environmental efficiency, as undesirable outputs are generated as a by-product of desirable outputs. Therefore, numerous methods have been proposed to incorporate undesirable outputs in DEA models, which can be classified into two main approaches. One of them utilizes the traditional DEA models, based on the translated version of original data (Knox Lovell et al., 1995; Seiford and Zhu, 2002). The other approach is to utilize the concept of weak disposability without changing the data (Fare et al., 1989; Zhou et al., 2007). Under the weak disposable reference technology, undesirable outputs can only be reduced when the desirable outputs are reduced, holding the inputs constant (Fare and Grosskopf, 2004). On the other hand, the reduction of undesirable outputs and the increase of desirable outputs are independent under the strong disposability assumption (Watanabe and Tanaka, 2007).

Some researches focus on the dynamic change of efficiency during multiple years rather than just one year. There are two representative methods to measure efficiency growth, which are the Malmquist productivity index and the Luenberger productivity index. The main difference between them is that while the Malmquist index is defined in a ratio approach, the Luenberger index is based on a difference approach. While some contemporary researchers recommend using the Luenberger index instead of the Malmquist index because of the robustness issue that the Malmquist index tends to overestimate the productivity growth, both methods are still widely used (Boussemart et al., 2003; Zhang and Wei, 2015).

Among more recent approaches of DEA, the SBM-DEA proposed by Tone (2001) is noteworthy. Though most DEA models follow radial efficiency measures, SBM follows non-radial efficiency measures, meaning that their inputs and outputs can be non-proportionally adjusted. In SBM, the shortfall of outputs and excess of inputs, also known as slacks, of an inefficient DMU are compared to the reference set, that is, the set of benchmarks. SBM-DEA measures efficiency by finding the maximum slacks. In other words, an inefficient DMU is projected to the furthest point in the reference set, allowing it to improve as much as possible. An SBM model has several strong points. First, it is unit-invariant since the slacks divided by the observed data are used in its objective function. Second, it is monotone because input excesses or output shortfalls consistently decrease the efficiency score. Finally, as mentioned above, it is non-radial (Tone, 2001).

However, the obtained efficiency scores from SBM model are ranged from 0 to 1, thus if there are multiple efficient DMUs with no input and output slacks, the model cannot further rank them. In this respect, the "super-efficiency" issue is addressed by Tone (2002) and the previous model in Tone (2001) is extended to super-efficiency SBM (Super-SBM) model. Later, Fang et al. (2013) proposed an alternative super-efficiency SBM model indicating that the projection identified by Super-SBM model may not be strongly Pareto efficient.

Several studies measured the transport sector's environmental efficiency. Chin and Low (2010) measured the environmental efficiency of 156 Origin-Destination pairs between 13 major East Asian ports using 5 DEA models, including SBM-DEA models adjusted by the loading/utilization of a vessel. Cui and Li (2017) investigated the energy efficiency and the carbon abatement efficiency of 22 international airlines from 2008 to 2012 using a two-stage network SBM-DEA model under weak disposability property. Chang et al. (2014) examined the environmental efficiency of 27 global airlines using SBM-DEA under VRS and the weak disposability assumption. Their models were different from other studies, such as Cui and Li (2017), in that the undesirable outputs were explicitly considered in both the objective function and the constraints. By doing so, the undesirable output slacks could be maximized together with input and desirable output slacks, while the weak disposability assumption was maintained.

As for China's transport sector, several studies examined environmental efficiency using various DEA models. Zhou et al. (2013) investigated the environmental efficiency of 30 provinces during 2003-2009 using the radial DEA model. The model was extended to the Russell Measure Model (RMM) by Zhou et al. (2014). However, the discriminatory powers of both the radial model and the RMM were much weaker than the SBM and the Directional Distance Function (DDF), which made their results less practical (Meng et al., 2016). DDF-DEA was adopted by Zhang and Wei (2015), Li et al. (2017), and Wang and He (2017). Zhang and Wei (2015) developed the meta-frontier non-radial Luenberger carbon emission performance index (MNLCPI) to measure dynamic changes in total factor carbon emissions performance within China's transportation sector from 2000 to 2012 focusing on the heterogeneity of three regions in China. Li et al. (2017) used the Malmquist-Luenberger (ML) index to measure the sustainability performance of China's transportation industry from 2000 to 2010 under the general and strict levels of environmental regulation. Wang and He (2017) measured CO2 emission efficiency and marginal abatement costs of 30 regions from 2007 to 2012. One main limitation of DDF is that the direction vector of each variable should be decided by researchers; it is therefore subjective, and the results can be sensitive. Chang et al. (2013), Song et al. (2015), and Liu et al. (2017) chose the SBM-DEA model. Chang et al. (2013) examined the environmental efficiency in transportation sector of China's 30 provinces in 2009 and Song et al. (2015) evaluated the environmental efficiency values with SBM-DEA model with China's regional transportation sector data from 2003 to 2012 to discuss changes in efficiency. Liu et al. (2017) measured the environmental efficiency and the resource utilization of land transportation sectors in 30 provinces in China. They used a parallel SBM-DEA model to evaluate the overall land transportation efficiency and individual highway and railway efficiency at the same time. However, all of them measured environmental efficiency under the strong disposability and CRS assumption, which makes the studies less realistic.

The literature review reveals that a few studies on China's transportation sector may have involved potential biases due to unrealistic assumptions of strong disposability and CRS. This paper contributes to the literature by proposing an improved SBM-DEA methodology, considering both the weak disposability and VRS assumptions, and by solving the bias problems of former studies. Furthermore, we adopted Malmquist productivity index to measure the dynamic change between two consecutive years and to decompose the total productivity change into efficiency change and technological change for an in-depth analysis. Super-SBM concept was additionally utilized to tackle the infeasibility problem that emerges when SBM-DEA is combined with Malmquist index. The model we adopt is an extended version of Chang et al. (2014) and the dataset contains three inputs (labor, capital, and energy), one desirable output (value added), and one undesirable output (CO_2 emissions) of thirty Chinese provinces from 2009 to 2016. It is up-to-date data since the newest version of China Energy Statistical Yearbook contains the relevant China energy data of 2016.

3. Methodology

Chang et al. (2013) developed a measurement framework for analysis of the environmental efficiency of China's transportation system based on CO_2 emissions (undesirable outputs). Their approach is problematic due to assumptions and properties imposed on the efficiency estimation models, such as CRS and SD. They estimated the total factor Green Performance Index (GPI), which is assigned values between 0 and 1. This GPI value represents the eco-efficiency figure for each province in China, considering both environmental and economic factors. Next, potential carbon reductions (PCR) were measured by the slack of undesirable output (s_j^-), indicating the amount of carbon emissions that each province can reduce without sacrificing their GDP or adding more inputs. Additionally, the Carbon Efficiency (CE) of the transportation sector in China's 30 provinces was calculated by the following formula: Target carbon emissions/Actual carbon emissions. The model represents an extended version of the SBM-DEA framework by Tone (2001), by adding the undesirable output into both the objective function and a separate constraint function (Chang et al., 2013; Chang and Zhang, 2017).

The first CRS assumption is suitable only when the operations or productions are at an optimal scale. However, DMUs, in reality, operate on VRS production technology, experiencing IRS and/or decreasing returns to scale (DRS). In other words, DMUs are not operating optimally in their scale operation (Coelli et al., 2005). Moreover, the SD assumption imposed in Chang et al. (2013) implies that an increase in the desirable outputs to the benchmarking points, and holding the inputs and undesirable outputs constant, is always feasible. Under contemporary technology, undesirable outputs can be reduced only if the desirable outputs are simultaneously reduced (Färe and Grosskopf, 2004); therefore, the SD in Chang et al. (2013) is unrealistic. A more realistic approach is to impose the weak disposability (WD) assumption on the undesirable output and by-product of the usual production process, as such, the CO_2 level is not reducible without sacrificing some of the desirable outputs.

To overcome the two problems of the CRS and SD assumptions in (Chang et al., 2013; Chang and Zhang, 2017), this study transformed the strong disposability-based DEA model into a weak disposability-based DEA model with the VRS assumption. The results of the "CRS + strong disposability" DEA model and the "VRS + weak disposability" DEA will be compared.

3.1. The Environmental Efficiency SBM-DEA Model with CRS and SD Assumptions

Chang et al. (2013) and Chang and Zhang (2017) proposed the following SBM-DEA model under the CRS an d SD assumptions. Suppose that there are *n* DMUs to be considered, and each DMU *k* has three variables in th e production possibility set—inputs, desirable (good) outputs, and undesirable (bad) outputs. Each DMU *k* use s *M* input factors to generate *N* desirable outputs and *Q* undesirable outputs. If inputs, good outputs, and bad o utputs are denoted as three matrices *X*, *Y*, and *C*, respectively, we can define the three vectors $\boldsymbol{x}$, $\boldsymbol{y}$, and $\boldsymbol{c}$, as $\boldsymbol{x}$=$[x_{ik}]$=$[x_1, \dots, x_n]$∈ $\boldsymbol{R}^{M\times n}$, $\boldsymbol{y}$=$[y_{rk}]$=$[y_1, \dots, y_n]$∈ $\boldsymbol{R}^{N\times n}$, $\boldsymbol{c}$=$[c_{jk}]$=$[c_1, \dots, c_n]$∈ $\boldsymbol{R}^{Q\times n}$. Then, the production possi bility set (PPS) can be defined as follows:

$$P(x) = \left\{ (y,c) \middle| \begin{array}{c} x \text{ produce } (y,c), \sum_{k=1}^{n} \lambda_k x_{ik} \le x_i, \sum_{k=1}^{n} \lambda_k y_{rk} \ge y_r, \sum_{k=1}^{n} \lambda_k c_{jk} \le c_j, \\ \lambda_k \ge 0 \text{ for } i = 1, \dots, M, r = 1, \dots, N, j = 1, \dots, Q, k = 1, \dots, n \end{array} \right\} \tag{1}$$

where λ is the non-negative intensity vector, implying that the above definition corresponds to the CRS assum ption.

The undesirable outputs SBM-DEA model in Chang et al. (2013) and Chang and Zhang (2017) have the follo wing objective function and constraints:

$$p_0^* = \text{Minimize } p = \frac{1 - \frac{1}{M}\sum_{i=1}^{M} \frac{s_i^-}{x_{io}}}{1 + \frac{1}{N+Q}\left(\sum_{r=1}^{N} \frac{s_r^+}{y_{r0}} + \sum_{j=1}^{Q} \frac{s_j^-}{c_{j0}}\right)}$$

S.T.

$$\sum_{k=1}^{n} \lambda_k x_{ik} + s_i^- = x_{i0}, \qquad i = 1, \dots, M$$

$$\sum_{k=1}^{n} \lambda_k y_{rk} - s_r^+ = y_{r0}, \qquad r = 1, \dots, N$$

$$\sum_{k=1}^{n} \lambda_k c_{jk} + s_j^- = c_{j0}, \qquad j = 1, \dots, Q$$

$$\lambda_k, s_i^-, s_r^+, s_j^- \ge 0, \qquad \forall k, i, r, j \tag{2}$$

The subscript 0 refers to a DMU for which the efficiency is being estimated. The vector s_r^+ represents the shortfall of desirable outputs, and the vectors s_i^- and s_j^- denote the excesses of inputs and undesirable outputs, respectively. The DMU is considered as efficient if p^*=1, indicating that all the slacks variables (s_i^-, s_r^+, s_j^-) are 0 (Chang et al., 2013).

3.2. Environmental Efficiency SBM-DEA Model with VRS and WD Assumptions

To transform CRS DEA into VRS DEA, a new convexity constraint ($\sum_{k=1}^{n}\lambda_k = 1$) has to be added to both the production possibility set (PPS) definition (1) and the constraint part of Model (2). In addition, a transformation of the third constraint $\left(\sum_{k=1}^{n}\lambda_k c_{jk} + s_j^- = c_{j0}\right)$ in Model (2) into $\sum_{k=1}^{n}\lambda_k c_{jk} + s_j^- = (1 + \frac{1}{N}\sum_{r=1}^{N}\frac{s_r^+}{y_{r0}})\, c_{j0}$ results in a SBM-DEA model under the weak disposability property. This transformation was first introduced in Chang et al. (2014) to incorporate weak disposability by demonstrating that an increase of desirable outputs to the reference point leads to an increase of undesirable outputs. Thus, the efficiency score (GPI) under weak disposability tends to become lower than GPI under strong disposability.

Furthermore, a new constraint ($c_{j0} - s_j^- \geq 0$) should be added along with the weak disposability constraint ($\sum_{k=1}^{n}\lambda_k c_{jk} + s_j^- = (1 + \frac{1}{N}\sum_{r=1}^{N}\frac{s_r^+}{y_{r0}})\, c_{j0}$) in Model (2) to avoid a certain circumstance ($s_j^- > c_{j0}$) that allows the CE figure to obtain a negative number. In Model (2), although it is not written, s_j^- is less than or equal to c_{j0} due to $s_j^- = c_{j0} - \sum_{k=1}^{n}\lambda_k c_{jk}$, and $s_j^-,\ c_{j0},\ \sum_{k=1}^{n}\lambda_k c_{jk} \geq 0$. This implicit inequality ($c_{j0} - s_j^- \geq 0$) is quite logical and clear, since no DMU can reduce its CO_2 emissions by more than what they are currently emitting. However, after the weak disposability constraint transformation, the implicit inequality can be violated, which means s_j^- can exceed c_{j0} in some circumstances. This unrealistic situation can occur when y_{r0} is much smaller than $\sum_{k=1}^{n}\lambda_k y_{rk}$, because the gap between y_{r0} and $\sum_{k=1}^{n}\lambda_k y_{rk}$ represents the good output slack (s_r^+). Therefore, we included $c_{j0} - s_j^- \geq 0$ as a new constraint in Model (2); this represents a new extension to the SBM-DEA model with WD in Chang et al. (2014).

Hence, so as to transform Model (2), which is based on the CRS assumption under strong disposability, into the VRS-based model under weak disposability, the production possibility set (PPS) should be redefined as follows:

$$P(x) = \left\{ (y,c) \middle| \begin{array}{c} x \text{ produce } (y,c), \sum_{k=1}^{n}\lambda_k x_{ik} \leq x_i, \sum_{k=1}^{n}\lambda_k y_{rk} \geq y_r, \sum_{k=1}^{n}\lambda_k c_{jk} \leq c_j, \\ \sum_{k=1}^{n}\lambda_k = 1, \\ \lambda_k \geq 0 \text{ for } i = 1,\dots,M, r = 1,\dots,N, j = 1,\dots,Q, k = 1,\dots,n \end{array} \right\} \tag{3}$$

Then, the environmental efficiency SBM-DEA model, based on the VRS assumption under the weak disposability property, plus our new constraint ($c_{j0} - s_j^- \geq 0$), can be expressed as follows:

$$p_0^* = \text{Minimize } p = \frac{1 - \frac{1}{M}\sum_{i=1}^{M}\frac{s_i^-}{x_{io}}}{1 + \frac{1}{N+Q}\left(\sum_{r=1}^{N}\frac{s_r^+}{y_{r0}} + \sum_{j=1}^{Q}\frac{s_j^-}{c_{j0}}\right)}$$

S.T.

$$\sum_{k=1}^{n}\lambda_k x_{ik} + s_i^- = x_{i0}, \qquad i = 1,\dots,M$$

$$\sum_{k=1}^{n}\lambda_k y_{rk} - s_r^+ = y_{r0}, \qquad r = 1,\dots,N$$

$$\sum_{k=1}^{n}\lambda_k c_{jk} + s_j^- = (1 + \frac{1}{N}\sum_{r=1}^{N}\frac{s_r^+}{y_{r0}})c_{j0}, \qquad j = 1,\dots,Q$$

$$\sum_{k=1}^{n}\lambda_k = 1,$$

$$c_{j0} - s_j^- \geq 0, \quad j = 1,\dots,Q$$

$$\lambda_k, s_i^-, s_r^+, s_j^- \geq 0, \qquad \forall k,i,r,j \tag{4}$$

Following Chang et al. (2013), the GPI and PCR in the transportation system are measured by p^*, and slack variable s_j^-, respectively. The same CE formula is used, as follows:

CE = (Target carbon emission / Actual carbon emission) = $\frac{c_{j0}-s_j^-}{c_{j0}}$ (5)

3.3. Dynamic Productivity Growth Analysis: Malmquist Productivity Index

Malmquist productivity index (MPI), first introduced by Malmquist (1953), represents the productivity change over two consecutive years. In order to evaluate MPI of each DMU, four distance functions (two within-period distance functions and two cross-period distance functions) should be defined and calculated. In general, $D^t(x^t, y^t)$ and $D^{t+1}(x^{t+1}, y^{t+1})$ are defined as within-period distance functions, which produce the efficiency values of DMUs at period t and t+1, compared with the production frontier of period t and t+1, respectively. On the other hand, $D^{t+1}(x^t, y^t)$ and $D^t(x^{t+1}, y^{t+1})$ are cross-period distance functions, and they are used to measure the efficiency scores of DMUs at period t and t+1 under the production frontier of period t+1 and t. The range of the function values of $D^t(x^t, y^t)$ and $D^{t+1}(x^{t+1}, y^{t+1})$ is between 0 and 1 as every DMU is enveloped within the same-period production possibility set. However, this boundary can be intruded in the case of cross-period. Since $D^{t+1}(x^t, y^t)$ and $D^t(x^{t+1}, y^{t+1})$ do not necessarily require DMUs under analysis to be inside of the production possibility set of the other period, they can have efficiency scores over 1.

Productivity change between two years can be measured by $MPI^t = M^t(x^t, y^t, x^{t+1}, y^{t+1})$=[$\frac{D^t(x^{t+1},y^{t+1})}{D^t(x^t,y^t)}$] or MPI^{t+1}=$M^{t+1}(x^t, y^t, x^{t+1}, y^{t+1})$=[$\frac{D^{t+1}(x^{t+1},y^{t+1})}{D^{t+1}(x^t,y^t)}$] (Caves et al., 1982). In a simple case of one input and one output situation, both MPI^t and MPI^{t+1} can be used for productivity change between two periods since they have the same value. However, in case of multiple input and output variables, Fare et al. (1994) suggested to use a geometric mean of MPI^t and MPI^{t+1} (MPI$^{t,t+1}$) as a newly-defined MPI, which is represented as follows:

$$\text{MPI} = M^{t,t+1}(x^t, y^t, x^{t+1}, y^{t+1}) = \sqrt{\frac{D^t(x^{t+1},y^{t+1})}{D^t(x^t,y^t)} * \frac{D^{t+1}(x^{t+1},y^{t+1})}{D^{t+1}(x^t,y^t)}} \quad (6)$$

Following Fare et al. (1994), MPI can be divided into two parts as follows:

$$\text{MPI} = \sqrt{\frac{D^t(x^{t+1},y^{t+1})}{D^t(x^t,y^t)} * \frac{D^{t+1}(x^{t+1},y^{t+1})}{D^{t+1}(x^t,y^t)}} = \frac{D^{t+1}(x^{t+1},y^{t+1})}{D^t(x^t,y^t)} * \sqrt{\frac{D^t(x^t,y^t)}{D^{t+1}(x^t,y^t)} * \frac{D^t(x^{t+1},y^{t+1})}{D^{t+1}(x^{t+1},y^{t+1})}} \quad (7)$$

The first term $\frac{D^{t+1}(x^{t+1},y^{t+1})}{D^t(x^t,y^t)}$ evaluates a rate of efficiency change (EC), which illustrates the concept of catching-up effect. EC relatively compares how far the *k*th DMU is from the production frontier at each period. In other words, it indicates whether the kth observation in the arbitrary point of time between period t and t + 1 is closer to or farther away from the production frontier than at the previous point in time. For example, EC > 1 means the distance between the DMU and the production frontier of period t+1 is shorter than the distance between the DMU and the production frontier of period t. EC < 1 is vice versa and EC = 1 implies no change in efficiency.

The second term $\sqrt{\frac{D^t(x^t,y^t)}{D^{t+1}(x^t,y^t)} * \frac{D^t(x^{t+1},y^{t+1})}{D^{t+1}(x^{t+1},y^{t+1})}}$ measures a rate of technological change (TC), which represents a technological advancement or a technological setback. $TC^t = \frac{D^t(x^t,y^t)}{D^{t+1}(x^t,y^t)}$ denotes the expansion rate of the production frontier measured in period t, while $TC^{t+1} = \frac{D^t(x^{t+1},y^{t+1})}{D^{t+1}(x^{t+1},y^{t+1})}$ is an extent of expansion in period t+1. Similar to MPI^t and MPI^{t+1}, both TC^t and TC^{t+1} can be used for explaining TC in a simple situation of one input and one output. However, in a more complex situation where multiple variables are considered, they may not be equal to each other. Therefore, geometric mean is applied to describe TC = $\sqrt{TC^t * TC^{t+1}}$. If TC > 1, production possibility set is expanded, so we interpret as technological advancement has occurred. If TC < 1, since PPS is contracted, we thus detect technological setback in terms of the movement of the production frontier. TC = 1 implies no change in technological standard.

Since this paper employed undesirable output variable, undesirable output index should be contained in MPI. Thus, MPI is redefined as follows (Chang and Zhang, 2017):

$$\text{MPI} = \sqrt{\frac{D^t(x^{t+1},y^{t+1},c^{t+1})}{D^t(x^t,y^t,c^t)} * \frac{D^{t+1}(x^{t+1},y^{t+1},c^{t+1})}{D^{t+1}(x^t,y^t,c^t)}} \tag{8}$$

In order to measure MPI between two consecutive years (period t and t+1) using SBM-DEA approach, four distance functions should be calculated, and they are the optimal solutions obtained by solving the following SBM-DEA model (case of $D^{t+1}(x^t, y^t, c^t)$ is presented):

$$D^{t+1}(x^t, y^t, c^t) = \text{Minimize } \frac{1 - \frac{1}{M}\sum_{i=1}^{M}\frac{s_i^-}{x_{io}^t}}{1 + \frac{1}{N+Q}\left(\sum_{r=1}^{N}\frac{s_r^+}{y_{ro}^t} + \sum_{j=1}^{Q}\frac{s_j^-}{c_{jo}^t}\right)}$$

$$\begin{aligned}
&\text{S.T.}\\
&\sum_{k=1}^{n}\lambda_k x_{ik}^{t+1} + s_i^- = x_{io}^t, \qquad i = 1, \dots, M\\
&\sum_{k=1}^{n}\lambda_k y_{rk}^{t+1} - s_r^+ = y_{ro}^t, \qquad r = 1, \dots, N\\
&\sum_{k=1}^{n}\lambda_k c_{jk}^{t+1} + s_j^- = \left(1 + \frac{1}{N}\sum_{r=1}^{N}\frac{s_r^+}{y_{ro}^t}\right)c_{jo}^t, \qquad j = 1, \dots, Q\\
&\sum_{k=1}^{n}\lambda_k = 1,\\
&c_{jo}^t - s_j^- \geq 0, \qquad j = 1, \dots, Q\\
&\lambda_k, s_i^-, s_r^+, s_j^- \geq 0, \qquad \forall k, i, r, j
\end{aligned} \tag{9}$$

It is worth noting that $D^{t+1}(x^t, y^t, c^t)$ and $D^t(x^{t+1}, y^{t+1}, c^{t+1})$ can theoretically have greater than 1 value when a DMU falls beyond the production frontier. Unfortunately, model (9) does not allow DMUs to be located beyond the frontier and restricts optimal objective function solutions to be between 0 and 1. At this point, the infeasibility problem, which is also addressed in Arabi et al. (2015), may occur. Arabi et al. (2015) proposed a new method to resolve the infeasibility problem embedded in DDF models when measuring cross-period distance functions. This paper differs from Arabi et al. (2015) in that we discuss the infeasibility problem that can occur when SBM model is implemented to measure mixed period distance functions to calculate MPI. We effectively handled infeasibility problem of SBM by employing super-efficiency concept, suggested by Tone (2002), and incorporated input savings and desirable output surplus, and undesirable output savings index in the model.

3.4. Slacks-based Measure of Super-efficiency for Application of Malmquist Index

SBM-based super-efficiency concept was proposed by Tone (2002), following some previous researches focusing on the methods for discrimination between efficient DMUs and ranking among the efficient performers. Main theoretical background of super-efficiency is that when there are more than two efficient DMUs within the data set, a problem of discrimination ability may occur, and this can be pointed out as a critical limitation of the conventional slacks-based model. In addition, in some cases like our study, when one or more DMUs are located beyond the frontier of PPS, infeasibility problem may arise, thus super-efficiency SBM model should be employed to precisely measure each DMU's current status by comparing it with the frontier spanned by DMUs excluding itself. In line with this thought, this paper applied Weak-VRS SBM-DEA model to all DMUs first, and then applied Super-efficiency SBM model not only to make discriminations between efficient DMUs first, and then applied Super-efficiency SBM model not only to make discriminations between efficient DMUs but cope with infeasibility problem embedded in SBM model for measuring cross-period distance functions as model (9). Although there is no possibility of infeasibility situation in SBM model when measuring within-period distance functions, this paper applied Super-SBM to measuring all four distance functions to secure discrimination power among efficient DMUs. This process enables a consistent measure of distance functions to obtain Malmquist productivity index.

It is also quite noteworthy that there is a slight difference between Super-SBM models for measuring within-period distance functions and cross-period distance functions. Super-SBM for within-period distance functions are represented as follows (case of $D^{t}_{super}(x^{t}, y^{t}, c^{t})$ is presented):

$$D^{t}_{super}(x^{t}, y^{t}, c^{t}) = \text{Minimize } \frac{1 + \frac{1}{M}\sum_{i=1}^{M} \frac{w_i^-}{x_{io}^t}}{1 - \frac{1}{N+Q}\left(\sum_{r=1}^{N} \frac{w_r^+}{y_{ro}^t} + \sum_{j=1}^{Q} \frac{w_j^-}{c_{jo}^t}\right)}$$

S.T.

$$\sum_{k=1,k\neq 0}^{n} \lambda_k x_{ik}^t - w_i^- \leq x_{io}^t, \qquad i = 1, \dots, M$$

$$\sum_{k=1,k\neq 0}^{n} \lambda_k y_{rk}^t + w_r^+ \geq y_{ro}^t, \qquad r = 1, \dots, N$$

$$\sum_{k=1,k\neq 0}^{n} \lambda_k c_{jk}^t - w_j^- \leq \left(1 - \frac{1}{N}\sum_{r=1}^{N} \frac{w_r^+}{y_{r0}^t}\right) c_{jo}^t, \qquad j = 1, \dots, Q$$

$$\sum_{k=1,k\neq 0}^{n} \lambda_k = 1,$$

$$w_r^+ \leq y_{ro}^t, \qquad r = 1, \dots, N$$

$$w_j^- \leq c_{jo}^t, \qquad j = 1, \dots, Q$$

$$\lambda_k \geq 0, \qquad k = 1, \dots, n, k \neq 0$$

$$w_i^-, w_r^+, w_j^- \geq 0, \qquad \forall i, r, j \tag{10}$$

On the other hand, Super-SBM model for measuring cross-period distance functions are defined as follows (case of $D^{t+1}_{super}(x^{t}, y^{t}, c^{t})$ is presented):

$$D^{t+1}_{super}(x^{t}, y^{t}, c^{t}) = \text{Minimize } \frac{1 + \frac{1}{M}\sum_{i=1}^{M} \frac{w_i^-}{x_{io}^t}}{1 - \frac{1}{N+Q}\left(\sum_{r=1}^{N} \frac{w_r^+}{y_{ro}^t} + \sum_{j=1}^{Q} \frac{w_j^-}{c_{jo}^t}\right)}$$

S.T.

$$\sum_{k=1}^{n} \lambda_k x_{ik}^{t+1} - w_i^- \leq x_{io}^t, \qquad i = 1, \dots, M$$

$$\sum_{k=1}^{n} \lambda_k y_{rk}^{t+1} + w_r^+ \geq y_{ro}^t, \qquad r = 1, \dots, N$$

$$\sum_{k=1}^{n} \lambda_k c_{jk}^{t+1} - w_j^- \leq \left(1 - \frac{1}{N}\sum_{r=1}^{N} \frac{w_r^+}{y_{r0}^t}\right) c_{jo}^t, \qquad j = 1, \dots, Q$$

$$\sum_{k=1}^{n} \lambda_k = 1,$$

$$w_r^+ \leq y_{ro}^t, \qquad r = 1, \dots, N$$

$$w_j^- \leq c_{jo}^t, \qquad j = 1, \dots, Q$$

$$\lambda_k \geq 0, \qquad k = 1, \dots, n$$

$$w_i^-, w_r^+, w_i^- \geq 0, \qquad \forall i, r, j \tag{11}$$

Model (10) and (11) are quite similar to each other in that when they are applied to DMUs, the optimal distance function values are always greater than or equal to 1 due to the structure of an objective function. Thus, DMUs located within the frontier, considered as inefficient, have distance function score of 1 as w_i^-, w_r^+, w_j^- are all zero, whereas general slacks-based model produces distance function score of between 0 and 1. However, the difference between model (10) and (11) is whether $k \neq 0$ is included in the model. Model (10) measures $D_{super}^t(x^t, y^t, c^t)$ which is the super-efficiency based within-period distance function at period *t*. In this case, since each DMU is compared with the production frontier formed by DMUs excluding oneself of the same period *t*, $k \neq 0$ must be included in the model as an indispensable condition to conduct super-efficiency calculations. On the other hand, model (11) measures $D_{super}^{t+1}(x^t, y^t, c^t)$ which is super-efficiency based cross-period distance function of DMUs at period *t* compared with the frontier at period *t*+1. In this case, since PPS is spanned by DMUs of period *t*+1, not period *t*, it is reasonable to conclude that $k \neq 0$ condition need not be considered in the model for super-efficiency calculations.

To measure productivity change of n DMUs between two consecutive periods for t years, n * (3t – 2) number of optimal distance function values are required. For instance, since this paper analyzes 30 DMUs each year from 2009 to 2016 (8 years), 30 * (3 * 8 – 2) = 660 number of optimal (distance function) solutions should be calculated to obtain MPI values. We define each distance function value($\emptyset^*$) as follows:

$$\emptyset_{t,t}^* = \begin{cases} \dfrac{1-\frac{1}{M}\sum_{i=1}^{M}\frac{s_i^-}{x_{io}^t}}{1+\frac{1}{N+Q}\left(\sum_{r=1}^{N}\frac{s_r^+}{y_{ro}^t}+\sum_{j=1}^{Q}\frac{s_j^-}{c_{jo}^t}\right)}, & if \quad \dfrac{1-\frac{1}{M}\sum_{i=1}^{M}\frac{s_i^-}{x_{io}^t}}{1+\frac{1}{N+Q}\left(\sum_{r=1}^{N}\frac{s_r^+}{y_{ro}^t}+\sum_{j=1}^{Q}\frac{s_j^-}{c_{jo}^t}\right)} < 1 \\[2ex] \dfrac{1+\frac{1}{M}\sum_{i=1}^{M}\frac{w_i^-}{x_{io}^t}}{1-\frac{1}{N+Q}\left(\sum_{r=1}^{N}\frac{w_r^+}{y_{ro}^t}+\sum_{j=1}^{Q}\frac{w_j^-}{c_{jo}^t}\right)}, & Otherwise \end{cases} \tag{12}$$

$$\emptyset_{t,t+1}^* = \begin{cases} \dfrac{1-\frac{1}{M}\sum_{i=1}^{M}\frac{s_i^-}{x_{io}^t}}{1+\frac{1}{N+Q}\left(\sum_{r=1}^{N}\frac{s_r^+}{y_{ro}^t}+\sum_{j=1}^{Q}\frac{s_j^-}{c_{jo}^t}\right)}, & if \quad \dfrac{1-\frac{1}{M}\sum_{i=1}^{M}\frac{s_i^-}{x_{io}^t}}{1+\frac{1}{N+Q}\left(\sum_{r=1}^{N}\frac{s_r^+}{y_{ro}^t}+\sum_{j=1}^{Q}\frac{s_j^-}{c_{jo}^t}\right)} < 1 \\[2ex] \dfrac{1+\frac{1}{M}\sum_{i=1}^{M}\frac{w_i^-}{x_{io}^t}}{1-\frac{1}{N+Q}\left(\sum_{r=1}^{N}\frac{w_r^+}{y_{ro}^t}+\sum_{j=1}^{Q}\frac{w_j^-}{c_{jo}^t}\right)}, & Otherwise \end{cases} \tag{13}$$

$$\emptyset_{t+1,t}^* = \begin{cases} \dfrac{1-\frac{1}{M}\sum_{i=1}^{M}\frac{s_i^-}{x_{io}^{t+1}}}{1+\frac{1}{N+Q}\left(\sum_{r=1}^{N}\frac{s_r^+}{y_{ro}^{t+1}}+\sum_{j=1}^{Q}\frac{s_j^-}{c_{jo}^{t+1}}\right)}, & if \quad \dfrac{1-\frac{1}{M}\sum_{i=1}^{M}\frac{s_i^-}{x_{io}^{t+1}}}{1+\frac{1}{N+Q}\left(\sum_{r=1}^{N}\frac{s_r^+}{y_{ro}^{t+1}}+\sum_{j=1}^{Q}\frac{s_j^-}{c_{jo}^{t+1}}\right)} < 1 \\[2ex] \dfrac{1+\frac{1}{M}\sum_{i=1}^{M}\frac{w_i^-}{x_{io}^{t+1}}}{1-\frac{1}{N+Q}\left(\sum_{r=1}^{N}\frac{w_r^+}{y_{ro}^{t+1}}+\sum_{j=1}^{Q}\frac{w_j^-}{c_{jo}^{t+1}}\right)}, & Otherwise \end{cases} \tag{14}$$

$$\emptyset^*_{t+1,t+1} = \begin{cases} \dfrac{1-\frac{1}{M}\sum_{i=1}^{M}\frac{s_i^-}{x_{io}^{t+1}}}{1+\frac{1}{N+Q}\left(\sum_{r=1}^{N}\frac{s_r^+}{y_{ro}^{t+1}}+\sum_{j=1}^{Q}\frac{s_j^-}{c_{jo}^{t+1}}\right)}, & if \quad \dfrac{1-\frac{1}{M}\sum_{i=1}^{M}\frac{s_i^-}{x_{io}^{t+1}}}{1+\frac{1}{N+Q}\left(\sum_{r=1}^{N}\frac{s_r^+}{y_{ro}^{t+1}}+\sum_{j=1}^{Q}\frac{s_j^-}{c_{jo}^{t+1}}\right)} < 1 \\ \dfrac{1+\frac{1}{M}\sum_{i=1}^{M}\frac{w_i^-}{x_{io}^{t+1}}}{1-\frac{1}{N+Q}\left(\sum_{r=1}^{N}\frac{w_r^+}{y_{ro}^{t+1}}+\sum_{j=1}^{Q}\frac{w_j^-}{c_{jo}^{t+1}}\right)}, & Otherwise \end{cases} \tag{15}$$

Then, MPI of each DMU is measured by calculating $\sqrt{\frac{\emptyset^*_{t+1,t}}{\emptyset^*_{t,t}} * \frac{\emptyset^*_{t+1,t+1}}{\emptyset^*_{t,t+1}}}$, EC by $\frac{\emptyset^*_{t+1,t+1}}{\emptyset^*_{t,t}}$, and TC by $\sqrt{\frac{\emptyset^*_{t,t}}{\emptyset^*_{t,t+1}} * \frac{\emptyset^*_{t+1,t}}{\emptyset^*_{t+1,t+1}}}$.

4. Results and Discussion

4.1. Input and Output Data

This paper examined the total factor environmental efficiency in the transportation sector of 30 provinces in China, excluding Tibet since the relevant energy data is not available. For the definition of transportation sector, we followed China Statistical Yearbooks which defined transportation sector in China to consist of transport, storage and post. To examine the total factor efficiency of each province, three input, one desirable output and one undesirable output factors were selected. For input variables, labor and capital were selected based on the principles of economics. We also consider energy as an input variable because how much value is added using the same amount of energy is an indispensable component to measure efficiency in transportation sector. Therefore, the employed population (thousand persons), the amount of fixed capital investment (billion yuan), and the volume of energy consumed (thousand tons) in the transportation industry were used as input values. As a proxy of capital input, we used the amount of fixed capital investment instead of capital stock, since capital stock data are not available and changes in capital investment can approximately convey changes in capital stock assuming a constant depreciation rate (Shi et al., 2010). For output variables, the amount of added value in the transportation sector, which is the same concept as the Gross Domestic Product (GDP) in the sector, was used as the desirable output and the volume of CO2 emission in the sector was selected as the undesirable output to consider environmental aspect. The similar configuration of these five variables has been also frequently used in existing papers to measure the efficiency of China's transportation industry (Chang et al., 2013; Song et al., 2015; Zhang and Wei, 2015), so we follow this approach.

The input and output data for China's transportation sector in the 30 provinces from 2009 to 2016 were collected. The data related to labor, capital, and added value were collected from the China Statistical Yearbook 2010 to 2017. The energy volume data were obtained from the China Energy Statistical Yearbook 2010 to 2017 and converted to million tonnes of coal equivalent (Mtce) using the relevant conversion factors. Since there is no official data for CO2 emissions from the transportation industry by province, we applied a fuel-based carbon footprint model suggested by the Intergovernmental Panel on Climate Change guidelines (IPCC, 2006). The descriptive statistics for the aggregated data sampled from 2009 to 2016 are shown in Table 1. A correlation matrix among the variables is presented in Table 2 to verify whether isotonicity between the input and output variables is preserved. It is shown that there exists a high correlation between the input and output with significance level of 0.01 for all years, and the presented values in Table 2 are the average correlation coefficients from 2009 to 2016. Therefore, the correlation matrix proves that the input and output variables were well-selected for the analysis of this study.

Table 1: Data descriptive statistics table.

Variable	Unit	Mean	Max	Min	Std. dev.
Labor	10^9 Yuan	250.038	854.000	29.000	156.385
Capital	10^3 persons	108.623	373.800	9.000	68.756
Energy	10^3 Mtce	9386.369	31852.251	920.400	5929.217
Added Value	10^9 Yuan	92.488	320.972	4.900	67.768
CO2 emissions	10^3 tons	20378.876	66752.372	2069.400	12519.544

Table 2: Correlation matrix of input and output variables.

	Labor	Capital	Energy	Value-added	CO2
Labor	1				
Capital	0.784	1			
Energy	0.723	0.828	1		
Value-added	0.765	0.655	0.596	1	
CO2	0.781	0.997	0.831	0.66	1

4.2. Analytical Result

Table 3 shows the total factor green performance index (GPI), the potential carbon reductions (PCR) and the carbon efficiency (CE) of provincial transportation sector in China measured by using super SBM models under two assumptions, which are strong disposability under CRS assumption (SD CRS model) and weak disposability under VRS assumption (WD VRS model). GPI, PCR and CE in this table are the average values in China's transportation sector from 2009 to 2016. In SD CRS result, Hebei turns out to be the best practice in terms of both GPI and CE. While the average GPI score is 0.443, 17 of 30 provinces have their GPI scores below it and the scores of 23 provinces are below 0.5. The suggested amount of carbon reduction is 11371.271 million tons on average and the average carbon efficiency score is 0.415 which is also below than 0.5. For most of provinces, GPI and CE values in the WD VRS result are higher than those in the SD CRS result. Similarly, most of the amount of PCR in the WD VRS result are smaller than in the SD CRS result. The only exception is Hainan, which has lower PCR and CE value in WD VRS. In WD VRS result, Hebei, Ningxia and Qinghai are the most efficient provinces while their GPI ranks are 1, 2 and 3 respectively. The average GPI and CE are improved to 0.597 and 0.544 and the average PCR is decreased to 8892.066.

Table 3: GPI, PCR, and CE of 30 provinces in China by two SBM-DEA models, 2009-2016.

Province	**Strong disposability under CRS**			**Weak disposability under VRS**			**GPI Rank Change[a]**
	GPI	**PCR**	**CE**	**GPI**	**PCR**	**CE**	
Hebei	1.254	0	1	1.718	0	1	0
Ningxia	0.617	1487.447	0.557	1.575	0	1	3↑
Qinghai	0.173	2102.530	0.222	1.231	0	1	26↑
Jiangsu	0.826	8412.214	0.751	0.989	1404.289	0.958	2↓
Shandong	0.672	18564.332	0.597	0.903	4644.553	0.899	1↓
Shanghai	0.738	14806.401	0.639	0.751	14012.405	0.658	3↓
Tianjin	0.589	3328.635	0.623	0.724	1832.870	0.793	1↓
Guangdong	0.411	37009.964	0.346	0.699	15434.106	0.727	8↑
Guizhou	0.499	7036.640	0.447	0.684	3920.459	0.692	1↓
Liaoning	0.554	17502.279	0.487	0.567	16873.572	0.506	3↓

(Continued) Table 3: GPI, PCR, and CE of 30 provinces in China by two SBM-DEA models, 2009-2016.

Province	Strong disposability under CRS			Weak disposability under VRS			GPI Rank Change[a]
	GPI	PCR	CE	GPI	PCR	CE	
Beijing	0.498	9358.010	0.550	0.540	7864.094	0.622	2↓
Jiangxi	0.463	6017.059	0.470	0.538	4607.809	0.594	1↑
Fujian	0.492	8397.623	0.530	0.524	7477.862	0.582	3↓
Inner Mongolia	0.469	16725.146	0.346	0.498	15711.924	0.386	2↓
Henan	0.475	11341.807	0.483	0.498	10437.579	0.524	4↓
Hainan	0.246	4944.698	0.190	0.479	5149.775	0.157	12↑
Zhejiang	0.433	15530.020	0.411	0.450	14767.655	0.440	3↓
Anhui	0.387	10486.570	0.340	0.440	9066.971	0.430	1↓
Hunan	0.412	13000.684	0.402	0.439	11982.838	0.449	4↓
Shanxi	0.386	10876.539	0.370	0.438	9357.709	0.458	2↓
Gansu	0.300	6166.191	0.268	0.412	5878.846	0.302	1↑
Jilin	0.305	9729.142	0.278	0.371	8106.746	0.398	3↓
Heilongjiang	0.304	13872.324	0.261	0.345	12405.368	0.339	3↓
Guangxi	0.297	11364.091	0.313	0.341	9917.494	0.401	1↓
Chongqing	0.285	10052.084	0.315	0.338	8542.703	0.418	0
Shaanxi	0.289	11190.876	0.307	0.335	9713.532	0.398	2↓
Xinjiang	0.258	11037.981	0.216	0.324	9337.635	0.337	1↓
Hubei	0.301	20592.992	0.282	0.320	19498.146	0.320	7↓
Sichuan	0.247	12911.070	0.351	0.275	11693.760	0.412	2↓
Yunnan	0.112	17292.772	0.106	0.155	17121.268	0.115	0
Average	0.443	11371.271	0.415	0.597	8892.066	0.544	

[a]Up-arrow means that the rank of DMU improved in the weak VRS model. For example, Qinghai is "26↑," which means that Qinghai increased in weak VRS rankings by 26 positions from the strong CRS model. A down-arrow indicates the opposite. Zero donates no change.

It is interesting to compare SD CRS model with WD VRS model across three performance indicators: GPI, PCR, and CE. Intuitively, converting CRS assumption models into VRS assumption models would increase the efficiency scores of DMUs due to the frontier line that is closer to each DMU in the latter models. On the other hand, changing strong disposability into weak disposability would decrease the GPI scores. In other words, there is a trade-off relationship between changes of disposability and the scale assumption. Therefore, in Table 3, the overall increase of average GPI values from SD CRS model to WD VRS model indicates the higher influence of the transition of "CRS into VRS" than from "SD into WD" in the change of efficiency scores. According to Table 4 below, most of the DMUs, except for a few DMUs which have constant returns to scale, are operating under an IRS or a DRS situation. Moreover, many of them under IRS are in a state of producing output that is more than double the amount invested in input resources. This corroborates the higher significance of transition of "CRS into VRS." On the contrary, the WD transition had weaker impact on the GPI scores and this can be explained with Table 5. Table 5 shows the slacks in the transportation sector value-added of Hainan, Yunnan and Gansu in each year from 2009 to 2016. The value-added slack values of the other provinces are not presented since they are all zeros, meaning that most of provinces in China performed well in terms of transportation sector's GDP. As illustrated in chapter 3.2., the third constraint of model (5) is used to adopt weak disposability assumption by making the value-added slacks lead increase of the CO2 slacks. However, since only small number of DMUs demonstrated in Table 5 are affected by this assumption, the transition of "SD into WD" is dominated by "CRS into VRS".

Table 4: Degree of output increase for one unit of input increase.

Provinces	Degree of Returns to Scale							
	rts2009	**rts2010**	**rts2011**	**rts2012**	**rts2013**	**rts2014**	**rts2015**	**rts2016**
Beijing	2.679	2.452	2.589	2.711	2.802	2.222	1.000	1.567
Tianjin	3.168	2.983	3.237	3.237	3.334	3.325	3.236	3.267
Hebei	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Shanxi	2.853	2.669	2.706	2.611	2.666	3.006	2.642	2.546
Inner Mongolia	1.930	1.994	1.967	1.867	1.824	1.824	2.170	2.075
Liaoning	1.886	1.884	1.790	1.706	1.718	1.609	1.000	1.000
Jilin	4.363	4.669	4.861	4.789	4.890	4.626	4.453	4.243
Heilongjiang	3.438	3.720	3.763	3.696	3.869	3.508	3.337	3.126
Shanghai	2.350	2.103	2.433	1.000	1.000	1.000	1.000	1.464
Jiangsu	1.048	1.000	1.000	1.000	1.000	0.879	0.872	0.835
Zhejiang	1.680	1.622	1.695	1.730	1.793	1.570	1.446	1.335
Anhui	3.188	3.313	3.469	3.403	3.362	3.055	2.980	2.865
Fujian	1.987	2.004	2.123	2.030	2.021	1.815	1.525	1.402
Jiangxi	3.777	3.913	4.032	3.509	3.672	3.375	3.205	2.975
Shandong	1.000	0.895	0.900	0.899	0.900	1.030	0.942	0.869
Henan	1.811	1.999	2.128	1.921	1.816	1.418	1.304	1.222
Hubei	2.320	2.317	2.353	2.367	2.205	2.028	1.899	1.826
Hunan	2.116	2.098	2.157	2.053	2.025	1.905	1.827	1.747
Guangdong	0.935	0.957	0.979	0.935	0.913	0.874	0.805	0.738
Guangxi	3.937	3.636	3.479	3.537	3.508	3.266	2.937	2.769
Hainan	16.764	17.134	17.089	16.589	16.867	12.943	12.562	11.853
Chongqing	4.287	4.482	4.485	4.296	4.093	3.395	3.099	2.793
Sichuan	2.864	3.043	3.203	3.129	3.164	2.244	1.934	1.609
Guizhou	3.730	3.635	3.463	3.219	3.068	2.892	2.563	2.399
Yunnan	8.335	9.034	9.420	8.940	8.693	8.307	7.748	7.214
Shaanxi	3.527	3.679	3.703	3.584	3.617	3.547	3.309	3.070
Gansu	6.972	7.685	7.299	6.923	6.848	8.536	8.589	8.735
Qinghai	30.449	28.500	30.301	30.791	32.030	29.332	26.053	24.942
Ningxia	12.974	12.054	12.106	1.000	12.204	12.047	11.757	11.515
Xinjiang	7.139	7.848	7.971	6.183	5.629	4.988	4.401	4.175
Average	4.817	4.811	4.923	4.355	4.751	4.386	4.053	3.906

Table 5: Value-added slacks of Hainan, Yunnan, and Gansu, 2009-2016.

Province	Value-added slack							
	2009	2010	2011	2012	2013	2014	2015	2016
Hainan	4.497	5.067	0	6.309	8.305	14.147	14.162	13.034
Yunnan	0	0	0	0	0	6.031	6.961	7.835
Gansu	0	0	0	0	0	13.139	13.998	14.933

In addition to general improvements of efficiency performances by the change of the model, more provinces became efficient. As shown in Table 3, Qinghai and Ningxia also joined the efficient frontier, totaling three efficient provinces out of thirty provinces in China by the WD VRS model. The most noteworthy change is that Qinghai had ranked 29th in the previous model, but improved its GPI by 105.8%, resulting in a new efficient province. Qinghai used a small amount of inputs and produced a small amount of good outputs, therefore facing the IRS situation instead of the optimal scale CRS operation. Thus, allowing DMUs to operate on various scales by our new models, rather than under the strict assumption of optimal scale, made Qinghai efficient. For a similar reason, the GPI and CE of Ningxia changed from 0.617 to 1.575 and 0.557 to 1, respectively.

Another interesting point is the trend of returns to scale in transportation sector in China. Since returns to scale can be defined as the degree of output increase for one unit of input increase, a highly developed region is likely located under decreasing returns to scale situation. In Table 4, even though the average returns to scale shows decreasing tendency, the direction of change varies by province. While many provinces show decreasing pattern of returns to scale (Beijing, Liaoning, Jiangsu, Fujian, Jiangxi, Henan, Hubei, Hunan, Guangdong, Guangxi, Hainan, Chongqing, Sichuan, Guizhou, Yunnan, Qinghai, Xinjiang, etc.), some provinces have little change in pattern (Tianjin, Hebei, Shanxi, Inner Mongolia, Jilin, Heilongjiang, etc.). Some even have an increasing pattern (Gansu, etc.) and the others have more than two patterns or fluctuations. It implies that the status of economic development in each region is very different and diverse, although majority of provinces are still facing increasing returns to scale and have high potential of economic growth. Such implication can also help to establish a policy. For example, Jiangsu, Shandong and Guangdong are not only the provinces under decreasing returns to scale, but they are also the provinces which PCR is reduced the most from the transition of "SD CRS" into "WD VRS". That is, the Chinese government can understand which provinces will return more outputs with the same amount of input or how much carbon reductions are required to make a DMU efficient. This understanding can provide the Chinese government with a more accurate PCR to mitigate the target carbon emission levels of provinces, than the overregulated targets under the SD CRS models.

Table 6-9 presents efficiency change (EC), technical change (TC), and Malmquist productivity index (MPI) between two consecutive years from 2009 to 2016. Table 6 shows that China's average productivity increased between 2009 and 2010 as well as 2010 and 2011, scoring 1.052 and 1.252, respectively. It is noteworthy that productivity of all provinces in China increased between 2010 and 2011. Beijing improved both with regard to EC and TC, implying that there have been efficiency improvements and technological advancement between 2010 and 2011. Shanghai, Shandong, and Guangdong improved in terms of productivity mainly due to technological progress between 2010 and 2011. Meanwhile, Hainan is the most improved province among 30 provinces between 2010 and 2011, scoring 2.859 for MPI and 2.736 for efficiency improvements.

China's average productivity increased between 2011 and 2012 but decreased between 2012 and 2013. Specifically, productivity of Beijing decreased between 2011 and 2012 due to a low score of EC, while there was an increase in productivity between 2012 and 2013 because of efficiency improvements. From 2011 to 2012, Shanghai was the most improved province, scoring 2.646 for MPI and 2.638 for EC. In addition, Guangdong showed productivity improvement derived from improvement in both EC and TC. Shandong also improved its productivity mainly based on technological advancement. From 2012 to 2013, Tianjin showed improvement in productivity due to efficiency improvements, while Guangdong increased its productivity based on technological progress.

China's average productivity decreased slightly between 2013 and 2014 but increased between 2014 and 2015. From 2013 to 2014, Beijing, Jiangxi, Shandong, and Gansu showed meaningful decrease in productivity, while

Shanghai and Guangdong showed improvement in productivity. From 2014 to 2015, Beijing, Liaoning, and Guizhou showed noticeable productivity improvement, scoring 1.407, 2.689, and 1.703, respectively. In contrast, Shanghai and Henan decreased their productivity both due to efficiency downgrade and technological setbacks.

Lastly, from 2015 to 2016, China's average productivity increased while Shandong being the most improved province during this period. Shandong showed remarkable increase in productivity, scoring 1.435 for MPI. This resulted from improvement in both EC and TC. In the meantime, Shanghai and Qinghai showed noticeable decrease in productivity; due to EC downsize for Shanghai, and both EC and TC downgrade for Qinghai.

Overall, China's average productivity increased between 2009 and 2012, and slightly decreased between 2012 and 2014. After 2014, China again showed productivity improvement until 2016. Interestingly, Guangdong is the only province that showed productivity improvement every year. Also, it is noteworthy that every province in China showed improvement in productivity between 2010 and 2011.

It is quite interesting that the more developed and economically flourishing provinces, which are mostly located in the eastern areas of China, have higher cumulative MPI values than those of central and western areas of China. From 2009 to 2016, cumulative MPI (CMPI), cumulative EC (CEC), and cumulative TC (CTC) of eastern provinces (Beijing, Shanghai, Shandong, Liaoning, Tianjin, Hebei, Jiangsu, Zhejiang, Fujian, Guangdong, Guangxi, Hainan) are 1.687, 1.276, and 1.307, respectively, which implies eastern provinces have shown productivity improvement each year on average. Western provinces (Xinjiang, Qinghai, Sichuan, Yunnan, Gansu, Ningxia, Shaanxi, Chongqing, Guizhou) have 1.036 CMPI, 1.164 CEC, and 0.888 CTC indicating that productivity of western provinces have slightly increased on average despite of technological setback. Meanwhile, Central provinces (Jiangxi, Anhui, Inner Mongolia, Shanxi, Hubei, Hunan, Henan, Heilongjiang, Jilin) have CMPI of 0.934, CEC of 0.961, and CTC of 0.978. This insinuates that central provinces in China have shown overall declines of productivity indices on average.

Table 6: EC, TC, and MPI of 30 provinces in China, 2009-2016.

Provinces	2009-2010			2010-2011		
	EC	TC	MPI	EC	TC	MPI
Beijing	1.328	0.907	1.204	1.183	1.63	1.928
Tianjin	1.166	0.973	1.135	0.956	1.244	1.188
Hebei	0.932	1.039	0.968	0.956	1.183	1.13
Shanxi	1.248	0.967	1.207	0.927	1.178	1.092
Inner Mongolia	1.001	0.987	0.988	1.002	1.19	1.192
Liaoning	1.054	0.938	0.988	1.087	1.225	1.331
Jilin	1.014	0.969	0.982	0.983	1.177	1.158
Heilongjiang	1.071	0.954	1.021	0.892	1.185	1.057
Shanghai	1.692	0.914	1.546	0.999	1.789	1.787
Jiangsu	1.721	0.88	1.514	0.986	1.274	1.256
Zhejiang	1.178	0.964	1.136	0.88	1.19	1.047
Anhui	1.091	0.957	1.044	0.869	1.24	1.078
Fujian	1.004	0.994	0.998	0.888	1.176	1.044
Jiangxi	0.955	0.955	0.912	0.971	1.186	1.151
Shandong	0.977	1.029	1.005	0.993	1.455	1.445
Henan	0.915	0.856	0.783	0.842	1.209	1.018
Hubei	1.211	0.944	1.143	0.87	1.193	1.038
Hunan	1.085	0.981	1.065	0.909	1.178	1.071
Guangdong	1.017	1.589	1.617	0.886	1.844	1.633
Guangxi	1.074	0.976	1.048	1.055	1.178	1.243
Hainan	1.082	0.994	1.075	2.736	1.045	2.859
Chongqing	1.001	0.987	0.988	0.91	1.172	1.066
Sichuan	1.087	0.995	1.082	0.993	1.161	1.153
Guizhou	0.973	0.989	0.962	0.981	1.178	1.155
Yunnan	0.834	1.022	0.853	0.95	1.143	1.086
Shaanxi	1.033	0.965	0.997	0.903	1.183	1.068
Gansu	0.846	0.758	0.641	0.917	1.2	1.1
Qinghai	0.953	0.779	0.742	1.006	0.999	1.006
Ningxia	1.025	0.94	0.964	1.039	1.05	1.091
Xinjiang	0.97	0.99	0.96	0.914	1.18	1.079
Average	1.085	0.973	1.052	1.016	1.241	1.252

Table 7: EC, TC, and MPI of 30 provinces in China, 2009-2016. (continued)

Provinces	2011-2012			2012-2013		
	EC	TC	MPI	EC	TC	MPI
Beijing	0.744	1.03	0.766	1.392	0.818	1.138
Tianjin	0.835	1.049	0.876	1.567	0.874	1.37
Hebei	1.039	1.056	1.097	0.95	1.012	0.961
Shanxi	1.014	1.048	1.062	1.165	0.897	1.045
Inner Mongolia	0.974	1.049	1.021	1.193	0.894	1.067
Liaoning	0.99	1.042	1.032	0.984	0.854	0.84
Jilin	0.97	1.037	1.006	0.967	0.88	0.851
Heilongjiang	1.1	1.036	1.139	1.12	0.854	0.957
Shanghai	2.638	1.003	2.646	1.04	0.856	0.89
Jiangsu	0.997	1.021	1.018	0.986	0.97	0.957
Zhejiang	0.897	1.05	0.942	1.084	0.894	0.969
Anhui	0.822	1.041	0.855	0.928	0.879	0.816
Fujian	0.993	1.057	1.049	1.026	0.92	0.943
Jiangxi	1.195	1.042	1.246	1.134	0.744	0.844
Shandong	0.988	1.286	1.271	1.011	1.005	1.016
Henan	1.043	1.045	1.09	1.044	0.84	0.877
Hubei	0.968	1.043	1.01	1.072	0.891	0.955
Hunan	1.115	1.052	1.173	1.054	0.895	0.943
Guangdong	1.231	1.465	1.803	0.941	1.386	1.304
Guangxi	0.907	1.041	0.944	1.2	0.899	1.078
Hainan	0.386	0.995	0.384	0.919	0.58	0.533
Chongqing	0.95	1.038	0.986	0.95	0.896	0.851
Sichuan	0.868	1.047	0.909	1.284	0.927	1.19
Guizhou	0.969	1.046	1.013	1.059	0.707	0.749
Yunnan	1.115	1.014	1.131	1.016	0.882	0.896
Shaanxi	1.092	1.039	1.134	1.158	0.888	1.028
Gansu	0.953	1.031	0.982	0.863	0.874	0.754
Qinghai	1.061	0.787	0.835	0.977	0.786	0.768
Ningxia	1.132	0.906	1.025	0.993	0.857	0.851
Xinjiang	1.183	1.029	1.217	1.025	0.871	0.893
Average	1.039	1.048	1.089	1.070	0.884	0.944

Table 8: EC, TC, and MPI of 30 provinces in China, 2009-2016. (continued)

Provinces	2013-2014			2014-2015		
	EC	TC	MPI	EC	TC	MPI
Beijing	1.081	0.793	0.857	1.983	0.709	1.407
Tianjin	0.801	0.927	0.743	1.031	0.967	0.997
Hebei	1.135	0.982	1.115	0.988	0.999	0.988
Shanxi	0.935	1.005	0.939	1.095	0.965	1.057
Inner Mongolia	0.971	1.024	0.995	0.883	0.974	0.86
Liaoning	0.96	1.028	0.986	2.772	0.97	2.689
Jilin	0.973	0.96	0.934	0.961	0.96	0.923
Heilongjiang	0.933	0.936	0.874	0.904	0.958	0.866
Shanghai	1.184	1.099	1.301	0.787	0.781	0.615
Jiangsu	0.985	0.837	0.824	1.003	1	1.002
Zhejiang	1.017	1.03	1.048	0.96	0.978	0.939
Anhui	0.934	0.993	0.928	0.955	0.969	0.925
Fujian	1.01	1.032	1.043	1.084	0.98	1.061
Jiangxi	0.737	0.808	0.595	0.954	0.962	0.918
Shandong	0.473	1.023	0.484	1.313	1.024	1.344
Henan	1.207	1.043	1.259	0.866	0.878	0.76
Hubei	0.992	1.018	1.01	0.988	0.976	0.965
Hunan	0.948	1.021	0.969	0.964	0.975	0.94
Guangdong	2.032	0.645	1.311	1.011	1.215	1.228
Guangxi	0.925	0.996	0.922	1.058	0.971	1.028
Hainan	1.273	0.911	1.16	0.912	0.949	0.865
Chongqing	1.153	0.989	1.14	0.947	0.969	0.918
Sichuan	0.983	1.024	1.006	1.174	0.981	1.152
Guizhou	0.969	1.006	0.974	1.809	0.941	1.703
Yunnan	0.968	0.935	0.905	1.035	0.967	1.001
Shaanxi	0.94	0.99	0.931	0.941	0.966	0.909
Gansu	0.713	0.931	0.664	1.038	0.962	0.998
Qinghai	0.968	0.923	0.893	0.958	0.912	0.874
Ningxia	0.943	0.947	0.893	0.908	1.009	0.916
Xinjiang	1.01	0.948	0.958	0.958	0.959	0.918
Average	1.005	0.960	0.955	1.108	0.961	1.059

Table 9: EC, TC, and MPI of 30 provinces in China, 2009-2016. (continued)

Provinces	**2015-2016**		
	EC	**TC**	**MPI**
Beijing	0.78	1.284	1.001
Tianjin	1.413	0.745	1.053
Hebei	0.859	1	0.859
Shanxi	1.239	0.879	1.089
Inner Mongolia	1.218	0.927	1.128
Liaoning	1.151	1.105	1.271
Jilin	1.058	0.919	0.972
Heilongjiang	1.082	0.919	0.994
Shanghai	0.517	1.397	0.723
Jiangsu	0.998	1.09	1.087
Zhejiang	1.129	0.934	1.054
Anhui	1.028	0.927	0.953
Fujian	1.14	0.919	1.048
Jiangxi	1.103	0.911	1.005
Shandong	1.279	1.122	1.435
Henan	1.175	0.918	1.079
Hubei	0.942	0.939	0.884
Hunan	1.046	0.941	0.985
Guangdong	1.021	1.204	1.229
Guangxi	1.068	0.93	0.993
Hainan	1.121	0.877	0.983
Chongqing	1.112	0.919	1.023
Sichuan	1.018	0.916	0.932
Guizhou	1.001	1.115	1.116
Yunnan	1	0.937	0.938
Shaanxi	1.24	0.908	1.126
Gansu	0.983	0.918	0.902
Qinghai	0.879	0.61	0.537
Ningxia	1.095	0.901	0.987
Xinjiang	1.23	0.917	1.128
Average	1.064	0.968	1.017

4.3. Discussion

“Sustainability” or the “Sustainable development” concept has been widely purported as a core value for retaining the prosperity of both current and future generations. Accurately measuring environmental efficiency on a regional level, and seeking measures to ameliorate eco-efficiency figures, is a key environmental issue for many countries. Suggesting a more realistic and robust eco-efficiency measurement model, this study provides the Chinese government with more precise information on the environmental status by province in China.

To improve China’s environmental efficiencies, different approaches and measures should be devised by province, as each province faces different circumstances. To assess the priority of environmental policies in each province, we examined the slack ratios of each variable. Slack ratios were calculated by (Slack / Real value) using 2016 data and are listed in Table 10. A high slack ratio indicates that there is an urgent need to improve its eco-efficiency. Using the slack ratios of each province, the Chinese government can implement environmental transportation policies in the right direction.

Beijing, for instance, should place more emphasis on reducing its labor force, as it had the higher labor slack ratio (0.561) among 30 provinces and the highest among the 5 input and output variables. On the other hand, Yunnan should concentrate on reducing its investment on fixed assets and energy consumption, as Yunnan had the highest capital and energy slack ratios (0.795 for the capital variable and 0.786 for the energy variable) among the 30 provinces in China. Meanwhile, for Yunnan, 4 out of 5 slack ratio figures except value-added were the highest, with its value-added slack being the third among 30 provinces. This led Yunnan to obtain a score of 0.112 and 0.155 in SD CRS and WD VRS, respectively, and to be the most environmentally inefficient province, indicating that strong measures are required in terms of all its inputs and outputs to improve its eco-efficiency.

Table 10: Slack Ratio of input and output variables, 2016.

Provinces	Slack Ratio (Slack / Real value)				
	Labor	Capital	Energy	Value-added	CO2 emissions
Beijing	0.561	0	0.013	0	0.017
Tianjin	0	0	0	0	0
Hebei	0	0	0	0	0
Shanxi	0.431	0	0.422	0	0.442
Inner Mongolia	0.363	0.219	0.371	0	0.39
Liaoning	0	0	0	0	0
Jilin	0.517	0.445	0.628	0	0.612
Heilongjiang	0.628	0.287	0.678	0	0.669
Shanghai	0.519	0	0.51	0	0.498
Jiangsu	0	0	0	0	0
Zhejiang	0.307	0.372	0.519	0	0.486
Anhui	0.525	0.47	0.612	0	0.597
Fujian	0.109	0.38	0.366	0	0.329
Jiangxi	0.481	0.131	0.481	0	0.436
Shandong	0.097	0.181	0.11	0	0.1
Henan	0.482	0.104	0.399	0	0.375
Hubei	0.534	0.562	0.69	0	0.674
Hunan	0.292	0.338	0.621	0	0.575
Guangdong	0	0	0	0	0
Guangxi	0.422	0.521	0.581	0	0.547

(Continued) **Table 10: Slack Ratio of input and output variables, 2016.**

Provinces	Slack Ratio (Slack / Real value)				
	Labor	**Capital**	**Energy**	**Value-added**	**CO2 emissions**
Hainan	0.266	0	0.267	0.652	0.848
Chongqing	0.58	0.46	0.566	0	0.563
Sichuan	0.546	0.631	0.553	0	0.534
Guizhou	0	0	0	0	0
Yunnan	0.652	0.795	0.786	0.239	1
Shaanxi	0.638	0.483	0.429	0	0.4
Gansu	0.517	0.51	0.464	0.551	1
Qinghai	0	0	0	0	0
Ningxia	0	0	0	0	0
Xinjiang	0.525	0.215	0.673	0	0.68
Average	0.333	0.237	0.358	0.048	0.392

Fig. 1 presents several groups of province clusters, each with problems of a differing extent. The yellow regions such as Beijing, Shaanxi, Henan, Chongqing, Jiangxi, and Shanghai represent one homogeneous cluster, where the labor slack ratio is the highest among five variables; they are thus required to mainly focus on reducing labor excesses in order to improve GPI values. The orange cluster provinces such as Heilongjiang, Jilin, Anhui, Hubei, Zhejiang, Hunan, Fujian, and Guangxi represent another homogeneous cluster, with a priority to reduce energy consumptions. Shandong and Sichuan are the provinces in the green cluster which are required to reduce fixed capital investment, since this variable had the highest slack ratio among the five variables. The red regions such as Xinjiang, Gansu, Inner Mongolia, Shanxi, Yunnan, and Hainan symbolize a group where the CO_2 emissions should be managed to improve their Carbon Efficiency. It is also noted that the energy and CO_2 emissions slack ratios are highly correlated in all provinces, implying that it is necessary to reduce energy consumption for provinces to improve their CO_2 emissions. Yunnan and Gansu need to reduce the carbon emissions to the maximum extent, and also added value in the transportation sector to reduce the shortfall of desirable output (s_r^+), as they were one of the few among 30 provinces without a zero slack ratio in value-added, but with the highest slack ratio in CO_2 emissions.

Fig. 1. Several groups of Chinese province clusters with problems of differing extent

5. Conclusion

China is the world's largest energy-consuming and CO_2-emitting country, and is as such expected to play an important role in implementing sustainable development. This study developed a new SBM-DEA model under VRS and weak disposability to examine the energy and environmental efficiency of China's transportation sector by province, and to provide optimal provincial reduction targets for energy consumption and CO_2 emissions. Also, this paper compared the results obtained from SD CRS and WD VRS model, and addressed the features and properties of assumptions embedded in each SBM model. The results of the new model are more valid than those of the existing models (Chang et al., 2013), as most Chinese provinces operate their transportation industries at IRS or DRS rather than CRS. According to the results, it is recommended that the Chinese government should focus on reducing input wastes and CO_2 emissions, rather than on increasing the transportation sector's value added. To improve China's environmental efficiencies, different approaches and measures should be devised by province, as each province faces different circumstances.

In addition, this paper employed super-efficiency concept in SBM to make discriminations between efficient DMUs and effectively cope with the infeasibility problem, which can occur when SBM-DEA is implemented to measure MPI. By calculating MPI of each DMU in every year, this paper conducted dynamic productivity growth analysis between DMUs from different periods. The major finding is that China showed productivity improvement between 2009 and 2012 on average, while there was a slight productivity decline between 2012 and 2014. From 2014 to 2016, China restored their productivity improvement status.

This study has following limitations. First, this paper regarded transportation sector as an entity, without considering the difference between passenger transportation and freight transportation, which are the two main subsystems within transport industries. Since their structural properties and characteristics are quite different from each other, it is necessary to distinguish between those two to accurately analyze the environmental efficiency and productivity change of transportation sectors. Next, this study presented slack ratios of each variable to evaluate the severity of problems and assess the priority of environmental policies. When considering priority of environmental policies, however, we must reflect the cost and time required to implement those policies, which this paper neglected, to accurately assign priorities to environmental policies. Lastly, since DEA provides relative efficiency among DMUs under analysis, it is suggested that data from other developed countries be included and compared with that of the Chinese provinces to obtain more reliable results. These remain potential areas for future extension of the research.

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When is a Good Time? Market Entry Timing from Competitive Dynamics Perspective: Case of Asia-Pacific Low Cost Airlines

Don Jyh-Fu Jeng[1], *Le Truong Bao Tran*[2]

[1] Graduate Institute of Technology, Innovation and Intellectual Property Management, National Chengchi University, Taipei 11605, Taiwan

[2] Institute of International Management, National Cheng Kung University, Tainan 70101, Taiwan

Abstract

Market entry timing has been previously studied in conjunction with firm's internal resources as well as market and industry general landscape. In this study, we focus on dyadic relationship between new comer and existing incumbent in low cost airline industry, expressing through elements of Market commonality and Resource similarity, instead of evaluating competition by general industry measures and standards as previous studies did. We also set out to detect if market growth potential influences these relationships. In addition, our study re-examines whether market entry timing results in a substantial difference in post-entrance performance. Using a sample of 38 low cost airlines in East Asia, Australia and New Zealand, we studied market entry speed of early follower in 155 new markets (airline route) by analyzing their Market commonality and Resource similarity with existing incumbent in each market in relation to Awareness- Motivation-Capability perspective. Besides, the growth potential of each market, measured by market size, is applied as a moderator for the relationship between dyadic competition elements and entry speed. The difference in performance between early follower and the pioneer is then evaluated against the entry timing of the second mover. The result of our study suggests that dyadic competition between the pioneer and the early follower indeed has an impact on early follower's entry timing, with little regards to market growth potential. Market commonality is a stronger predictor of entry speed compared to Resource similarity, and the interaction between them leads to balancing effect against the individual factors. Earlier entrance has also been confirmed to have a positive effect on the early follower's performance. Theoretically, our study contributed to market entry research a new perspective of analyzing competition, bridging the gap between competitor analysis and prediction of inter-firm rivalry (entrance timing). In practice, our result suggests that early follower is wary of multi-market retaliation and possibly delay such confrontation with a big, direct competitor. On the other hand, pioneering firms can consider possible early aggressive expansion strategy to fence off potential followers.

Keywords: Market entry timing, Competitive dynamics, Market commonality, Resource similarity, Low cost airline industry.

1. Introduction

Previous researches have proven that the sooner a company established its foothold in a new market, the better their performance in that market would be (Gómez & Maícas, 2011; Hawk et al., 2013; Lilien & Yoon, 1990). A growing number of evidences suggest that ultimate leaders in global industries are often first movers (Lambkin, 1988; Robinson, 1988; Urban, Carter, Gaskin, & Mucha, 1986) and the majority of market shares are in the hand of early movers rather than late entrants (Lilien & Yoon, 1990; Mascarenhas, 1992). This proves the significance of entry timing decision towards the survival and growth of global businesses. The exact timing decision, however, have to be a balanced act between various factors such as the firm's internal capability, as well as external influencing factors (Mascarenhas, 1992; Schoenecker & Cooper, 1998), especially the degree of competition existing in the objective market (Baum & Korn, 1996; Porter, 1980).

When a new comer decides to join a market with existing incumbent, it's more likely that the intensity of competition is felt not simply in the objective market, but also across the market that the new comer share with the incumbents (Baum & Korn, 1996; Haveman & Nonnemaker, 2000). Subsequent studies did manage to differentiate between the timing decision of pioneers and followers (Lilien & Yoon, 1990), and they tend to be very much focused either on the *internal factors* such as capabilities of the firm (Hawk et al., 2013) and its commitment to core markets (Schoenecker & Cooper, 1998) or the *general market conditions* such as market growth or proximity of the objective market compared with their core markets and the degree of competition exist in the objective market (Baum & Korn, 1996; Fuentelsaz, Gomez, & Polo, 2002; Haveman & Nonnemaker, 2000).

Even though the current researches provide us with useful information about market entry decision, there is room for researchers to analyze market entry decision as a form of competitive action which requires careful competitor analysis as part of the decision making process. Baum and Korn (1996) put forth the argument that market entry (and exit) provides useful theoretical proxy for the intensity of rivalry between firms. Previous studies about market entry did concern about competition; however, it is viewed from a very macro perspectives, in which competition is simply measured by market concentration or number of competitors (Fuentelsaz et al., 2002; Mitchell, 1989). It is important to realize, though, that competition is not only characterized by industry environment, but also the dynamic interaction between firms. In this sense, even though the industry players are all influenced by the same market conditions, each firms have different interpretation of the competitive atmosphere depending on its interaction with a specific competitor, or more specifically the degree of inter-firm rivalry (Chen, 1996). The decision to enter a market with an existing incumbent can be viewed as an important form of competitive action (Chen & Miller, 1994). Market entry and exit is one of the most influencing actions that can profoundly alter the interaction between firms (Gielens, Van de Gucht, Steenkamp, & Dekimpe, 2008).

In relation to market entry decision making process, a few studies attempted to factor in this interaction between firms by applying the theory of multimarket (or multipoint) competition (Baum & Korn, 1999; Gimeno & Woo, 1996; Haveman & Nonnemaker, 2000; Yu, Subramaniam, & Cannella, 2009). Although multimarket contact lays a good foundation to analyze the intensity of competition between firms operating across multiple markets, it does not fully reflect the multiple aspects of competition itself (Chen, 1996).
Instead of a simple measure such as number of markets shared by two firms, the analysis should go deeper into considering the degree of importance of the shared market felt by each firms as well as the similarity in resource endowment between them.

Given the gaps in current literature regarding market entry timing decision as previously discussed, we have two main objectives to fulfill. Firstly, looking at the market entry as a proxy of competitive action, we would investigate the possible relationships between market entry timing decision and the elements of dyadic competitive dynamics. This paper will specifically look at the situation from an early followers' perspective, which will be referred to as the focal firm. Their market entry timing have to be a balance act so as not to miss out a potential early-in advantage but at the same time be wary of the competition posed by the first mover. In this study, we aim to fill in the gaps of previous study which did not attempt to address the entry timing decision by analyzing the exact interaction between the early follower and the incumbent. Secondly, we will also attempt to study the influence of market potential (market growth) as a moderator of the relationships between entry timing and other competition related factors.

Current researches on market entry have gathered data from developed and matured market, such as consumer products (Urban et al., 1986), oil and gas industry (Hawk et al., 2013; Mascarenhas, 1992), telecommunication in Europe (Gómez & Maícas, 2011), and US airlines industry (Baum & Korn, 1996). In this work, we incorporate the young and developing low cost airlines market in Asia alongside with the US low cost airlines market for potential comparison. The Asian low cost airlines industry has experienced amazing growth in past decade after deregulation, and we hope to draw additional insight to timing decisions of those low cost airlines while venturing into new geographic market under such highly competitive yet uncertain environments.

2. Literature Review

2.1. Competitive Dynamics

Competitive dynamics studies inter-firm rivalry that is based on specific competitive actions and reactions, their strategic and organizational contexts as well as their drivers and consequences (Baum & Korn, 1996; Smith, Grimm, & Gannon, 1992). Competitive dynamics attempts to characterize and predict competitive attacks: the likelihood, number and speed of the attacks as well as the probability of getting a response (Chen & Miller, 2012). In this paper, we regard market entry decision as a form of competitive action. The decision of an early follower entering a market with existing incumbent can be seen as a competitive attack against the incumbent/pioneer. Competitive dynamics give us a vehicle to understand the "pressure" that the early followers have to face when deciding to enter a market, in particular against the pioneer, at a more "fine grained", behavior based level (Chen & Miller) rather than a pure static characterization like that of industry- structure analysis (Porter, 1980). Scholars in competitive dynamics research field has incorporated frameworks that offer us guidelines in examining the competitive behavior of firms, among which is the expectancy valance theory (Chen & Miller, 1994) and subsequently the awareness-motivation-capability (AMC) perspective (Chen, Su & Tsai, 2007; Smith, Ferrier, & Ndofor, 2001).

2.2. Expectancy Valence Framework and AMC Perspective

The expectancy-valance motivational framework (Atkinson, 1964; Vroom, 1964) has been applied in strategic researches to analyze the exchange in actions between firms. Several studies have shown the three building blocks that helps to explain organization's behavioral actions composed of the *awareness* of competitor's action and its implications, *motivation* to counteract (which comes from the "valence", or rewards, of launching an corresponding action) and the *capability* to proceed with such actions (Chen & Miller, 1994; Dutton & Jackson, 1987; Kiesler & Sproull, 1982; Lant, Milliken, & Batra, 1992). Chen and Miller (1994) utilize this framework to build a model to predict characteristics of competitive attack that would minimize retaliation. They put forth linkage between a firm's tendency to respond to competitive attacks with the visibility of the attack (the A in AMC), the "valence", or rewards, for promoting a successful attack (the M in AMC) together with the respondent's confidence in their ability to launch a successful retaliation (the C in AMC).

From the viewpoint that market entry is a proxy of competitive attack to the first mover, AMC model can be seen as a guideline to analyze the determinant which influences an early follower firm's speed in approaching a market. The more attractive a new market appears to be in terms of overall size and growth rate, the more motivation firms have to finalize investment decisions to participate in the market (Fuentelsaz et al., 2002; Mascarenhas, 1992). The degree of similarity between new entrant and existing incumbents in their market domain or sphere of influence is also one factor that can either motivates or discourage entrants to take on the challenge of entering the market (Baum & Korn, 1996). Resource similarity (Gimeno, 1999) affects the capability of firms to respond to new strategic windows opening. Market attractiveness, market commonality and resource similarity are often associated with awareness of the competitive interactions between firms as well (Chen, 1996).

2.3. Multipoint Contact Competition and Market Commonality-Resource Similarity Framework

The degree to which both firms have their spheres of influence overlapped is one indications of their competitive tension (Chen & Miller, 2012). Since we are focusing on firms who are active in multiple geographic markets, the concept of realized multimarket contact (Gimeno, 2002) would be relevant to this issue. Yu and Cannella (2007) suggest that higher level of multimarket contact does influence enterprises' speed in responding to each other's competitive moves across various geographic markets. However, those studies only highlight the importance of market domain overlap in competition. They lack the consideration of how differently each firm may views certain market, the importance and magnitude of each market to individual firms (Chen, 1996). One of the reasons why firms choose to venture into new market is because an important market has been threatened with severe competition and they are losing their foothold (Mitchell, 1989). Drawing from this aspect, the timing of entry may be influenced by how committed each firm is towards their core markets (Schoenecker & Cooper, 1998). Overall, we can see that to measure to the effect of competition on entry timing more effectively, we need a more comprehensive measure to describe the intensity of competition between the pioneer and the follower resulting from their overlapped sphere of influence. This is the reason why we choose "*market commonality"* to analyze this aspect ofcompetition.

Market commonality is one of the component in the "market commonality- resource similarity" framework (Chen). Upson, Ketchen, Connelly, and Ranft (2012) find that these two constructs can be used to predict the likelihood of interactions between rivals with "foothold" positions in multimarket context.

2.4. Relationship between Research Constructs

2.4.1. Market Potential and Entry Speed of Early Follower

Market potential may imply two simultaneous effects on entry behavior: on one hand, a higher market potential can lead to higher expected profits and faster entry; on the other hand, it also implies a long queue of other potential entrants and hence reduce the overall attractiveness of the opportunity (Cotterill & Haller, 1992). In this study the effect of other potential entrants would be accounted for through the use of control variable. With the effect of potential competition taken care of, we argue that a market with high potential, measured in market size, would motivate the potential entrants to shorten their waiting time to enter the objective market. Previous works on market entry decision have mentioned the effect of market potential in the form of "demand potential". Lilien and Yoon (1990) suggest that potential entrants should hasten their market entry when the demand growth rate is still high (indicating product still in introduction/growth stage) since further delay would negatively impact the post entry performance. Subsequent study by Fuentelsaz et al. (2002) similarly put forth the argument that high demand potential is expected to have a positive effect on the speed of entry. In line with these arguments and applying the concept of AMC perspective, we argue that high market growth potential would raise the awareness about the potential of the objective market as well as attract and provide motivation for the early follower to introduce their product/services more quickly into the objective market.

Hypothesis 1: The bigger the size of the objective market, the faster the entry speed of an early follower would be.

2.4.2. Market Commonality and Entry Time of Early Follower

Even though multimarket contact/domain overlap is a forerunner of the market commonality construct, we expect the latter to be a more comprehensive measure for the degree that the pioneer manifests its presence in the follower's market. By applying this construct, we hope to observe how much "pressure" the early follower undergoes while making the decision to go head to head with the pioneer in a new market. Chen (1996) suggests that firms are prone to respond quickly to actions of competitors with whom they possess high degree of market commonality. This finding is once again supported in a study on the speed of multinational enterprise (MNE) response to competitive actions by Yu and Cannella (2007). These researchers found a significant positive relationship between the MNE's speed of response to a specific competitor's action and the degree of multi-market competition between the two firms. Therefore, we can argue that if we view the follower's entry decision as an attack to the pioneering competitor's territory, pioneering firms should not do this too early to avoid multi-market retaliation. Drawing from AMC aspect, we argue that a higher degree of market commonality indicates that the pioneer pays more attention to the actions of the follower (keep them "in check"). Entry into an incumbent established market is a strategic move and hence would definitely raise the awareness about the attack and subsequently can lead to more tension. Besides, high market commonality partially reflects that important markets to the follower are being shared with the pioneer. Other researcher also found that firms are prone to quickly grab new opportunities of growth once the market under their influences is threatened (Fuentelsaz et al., 2002). Therefore, high market commonality brings about motivation for incumbent firm to react quickly to the follower's entry decision, either direct retaliation or a race to grab new market opportunity so as not to "loose out" to each other and reduce the impact of the follower's arrival. This will be a vicious circle and if the follower tries to provoke the incumbent too early, it might bring more harm than good. In this sense, we hypothesize that early follower would try to delay touching the pioneer's "turf" and wait till they achieve a comparable position with the pioneer before launching such attack.

Hypothesis 2: The higher level of market commonality between the following firm and the pioneer in the objective market at the point of market opening, the more time the following firm waits to enter in the objective market.

2.4.3. Resource Similarity and Entry Time of Early Follower

If the incumbent is aware of the follower's market entrants and motivated to react, what constitute their capability to react quickly to such opportunity/threat? In many literatures, firm's slack resources have been commonly mentioned as one of the indicators of such capability. An organization's slack is defined as a buffer of actual or potential resources that the company can use to counter threat or exploit opportunities (Bourgeois, 1981). A larger pool of slack resource enables the firm to execute more competitive moves over a longer period of time (Ferrier, 2001). Slack may act as a cushion for firms to experiment with their surrounding environments. However, in order to enter in a new market quickly, firms would need even more specialized assets. Firms who already possess specialized assets that can help to ease their process of venturing into new market may enter the market earlier (Mitchell, 1989). For example, R&D strength, presence of a direct sales force in the new market, and financial resources (Schoenecker & Cooper, 1998). Drawing on the relationship between competitor analysis and inter-firm interaction, Chen (1996) finds that the firms whose have similar strategic endowments tend to react quickly to each other's competitive action. In line with this stream of arguments, we propose that following firm is less motivated to quickly enter territories of an incumbent that share strong resemblance with them in term of strategic resources because that means they are more capable of retaliating.

Hypothesis 3: The more the resource endowment of the following firm is similar to that of the pioneer, the faster the following firm would enter the market.

2.4.4. The Moderating Effect of Market Growth

Market commonality entails both rivalry and mutual forbearance effect (Chen, 1996). The mutual forbearance element between firms interaction comes about when firms are weary of multi-market retaliation (Karnani & Wernerfelt, 1985). Following firms who choose to enter a pioneer's market risk posing themselves as a threat to the pioneer. However, with the presence of a high market growth rate, we argue that the benefit of entering the market may outweigh the danger of enlarging their overlapping market domain. A bigger market with high potential demand allows both firms to grow concurrently to satisfy customer unmet demand. Even in fear of multi-market retaliation, following firms cannot afford to wait for too long under such circumstances since the higher the market potential, the more ambitious the pioneer may feel to establish their foothold position. Allowing the pioneer more time to operate as the sole provider of the product/service in such lucrative environment will easily let it becomes their "turf" (Haveman & Nonnemaker, 2000), and then they would be even more protective of such market and feel more threatened once the follower announce their entry decision.

Hypothesis 4: Market potential weakens the positive relationship between degree of market commonality of pioneer and following firm and the market entry time of the following firm.

Lilien and Yoon (1990) proof that pioneering firms performs much better in market with high potential.

Given that pioneer performs better in such environment, it may also indicate that the pioneer enjoy more advantages in accumulating resources to grow bigger in a shorter time, given no other raise up to rival them. Therefore, if a follower want to challenge the pioneer in a new, highly potential market, they have to react more quickly when their resource endowment have not differ too much from the pioneer.

Hypothesis 5: Market potential weakens the positive relationship between degree of resource similarity of pioneer and following firm and the market entry time of the following firm.

2.4.5. Entry Time of Early Follower and Performance Gap

A number of studies have been dedicated to predict performance of firms based on the order of their entry and the time between entries, among other parameters (Gómez & Maícas, 2011; Lilien & Yoon, 1990; Urban et al., 1986). Growing evidences show that surviving pioneers enjoy a substantial larger market share, followed by the “fast second” or early followers (Lilien & Yoon, 1990; Mascarenhas, 1992; Urban et al., 1986). In the case of innovative products, the pioneer may be rewarded with the advantage brought about by patent protection or tacit knowledge unrivaled by competitors. If we are talking about a known product being introduced to a new geographic market, for example, pioneers can still enjoy a considerable and lasting sales advantage (Bond & Lean, 1977) that comes from building first mover word of mouth, seizing scarce resources and creating buyer’s switching cost (Lieberman & Montgomery, 1988; Schmalensee, 1982). However, their first mover advantage can be fathomed by following entrants who learn from their mistakes and offer products or service with good differentiation strategies and backed by heavy promotional expenditure (Whitten, 1979). Lilien and Yoon (1990) suggest that early followers who enter the market in introduction of growth stage should not delay its product entry for long because in many situation they can enjoy the benefit of market development by pioneers and further delay to introduce a “completely new” product may not produce satisfactory returns. The question here is, the benefit of fast tracking the introduction of a new product has to be balanced with risks that the actual market might still be filled with uncertainties and more information need to be collected. Hawk et al. (2013) point out that early followers are usually large, international firms who have the capability to wait and collect data about the market before going for a full blown attack with the pioneer in new markets. In this paper, we investigate how the amount of time fast followers delay before entering a new market affects the performance gap between them and the pioneer.

Hypothesis 6: The shorter time an early following firm waits to enter in new market, the smaller the performance gap between them and the pioneering firm.

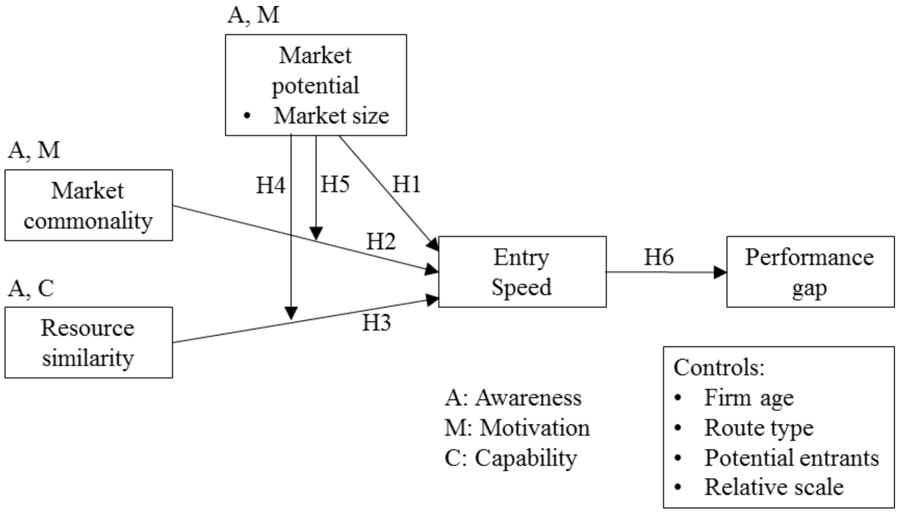

Figure 1: Conceptual Framework

3. Research Method

This empirical investigation adapts the data from the low cost airlines industry in East Asia, New Zealand and Australia, dating from January 1995 to December 2013. This sample currently includes a total of 38 airlines operating across North East Asia, South East Asia, Australia and New Zealand. Those airlines are selected based on their market domain (Asia and Australia, New Zealand) and business model (low cost), all of which is verified through the Center for Asia Pacific Aviation (CAPA) database (CAPA, 2014). The market, in this industry, is defined as a route (Chen, 1996; Gimeno & Woo, 1999). In this study, we only account for direct route and omit any route that requires transit for the simplicity of collecting data. Any route shared by at least two low cost airlines in the sample pool will be considered an objective market for analysis. We manually compared the route maps of 38 airlines to identify potential market for analysis. All information on those route maps are provided by the company's booking website and are updated as of 24th March, 2014.

After identifying all potential markets for analysis, we proceed to analyze the speed to market of the early follower, whose decision have to be balanced between calculating risk of competing against pioneer and leveraging opportunity of market growth. A pioneer is defined as the first mover who provides the low cost service on a specific route. The early follower is then identified as the second mover who enters the route after the pioneer and remains in operation to date (December 2013).

Entry timing is determined as the amount of time elapsed, decoded in years, since the pioneer commences their operation in the route until the identified second mover officially joined the route (Fuentelsaz et al., 2002; Lilien & Yoon, 1990). The information on entry timing of both the pioneer and follower can be collected from the corresponding airline's news portal, media releases or specialized industry news portal such as CAPA news (CAPA, 2014).

Market potential is operationalized into measures of market size, which is measured by the total annual passenger volumes at the respective airports of both destinations of the route. This measure of movement reflects the popularity of the city to air passengers (not only as a destination but might also be as a transit hub).

Therefore, the combined volumes of two destinations would reflect the "potential" for the market/route growth in the future. If a destination has two large airport (which is common for hub cities such as Melbourne, Bangkok, Taipei, Shanghai, etc.) then both airport would be included in the calculation. Although market growth rate would be a good measure to be included, we opt out to simply using market size based on two assumptions. Firstly, since we are only studying the market at the point of time when the second follower joined in, we can assume that the market is still enjoying the growth phase. Secondly, market size measured in annual air passenger volumes reflects not only the potential of the selection as a destination, but also as a potential transit hub for the airline.

Market commonality between the follower and the pioneer in each route is calculated based on the index measurement proposed by (Chen, 1996). More specifically, the construct would be measured via the following expression:

$$M_{ab} = \sum_{i=1}^{m} [(P_{ai}/P_a) \times (P_{bi}/P_i)] \qquad (1)$$

Where
M_{ab} = Market commonality that airline *b* (the pioneer) has with the focal airline *a* (the follower);
P_{ai} = Seat capacity provided by *a* in route *i*;
P_a = Seat capacity provided by *a* across *a*'s network;
P_{bi} = Seat capacity provided by *b* in route *i*;
P_i = Seat capacity provided by both airlines in route *i*;
i = A route served by both *a* and *b*

The result is expected to lie between 0 and 1, with 1 meaning the follower's market completely lies within the first mover's sphere of influence, and 0 means there has been no overlapping in domain between two firms till date (Chen & Hambrick, 1995).

Resource similarity concerns about firm's own strategic endowment, and in this airlines industry, fleet structure is a reliable proxy for such strategic assets (Chen et al., 2007; Taneja, 1987). In order to carry out our analysis, resource similarity between the following firm and corresponding pioneer in each route is conducted from a detailed type-by-type analysis across all type of aircraft they had in common.

$$C_{ab} = \sum_{i=1}^{n} [(F_{ai}/F_a) \times (F_{bi}/F_i)] \quad (2)$$

Where

C_{ab} = Resource commonality that airline *b* (the pioneer) has with the focal airline *a* (the follower);
F_{ai} = Number of aircraft *i* that *a* have;
F_a = Total number of aircraft that *a* have;
F_{bi} = Number of aircraft *i* that *b* have;
F_i = Total number of aircraft *i* that both *a* and *b* have;
i = A common aircraft type that both *a* and *b* have.

The result is expected to lie between 0 and 1, with 1 meaning the follower's fleet structure is 100% similar to that of the pioneer, and 0 means there has been no similarity in fleet type between two firms till date (Chen & Hambrick, 1995).

Performance gap is measured by the difference in load factor by the early follower and the pioneer per route at the end of the subsequent year after the follower's entry. Although market share has been widely used in researches for first mover advantages and entrants performance (Hawk et al., 2013; Kerin et al., 1992; Porter, 1985), it is difficult for us to obtain such data for the whole sample. On the other hand, load factor has also been a common measure of performance in aviation industry. Load factor might be affected by seasonality, but since we are measuring the 'gap' between load factors of followers and pioneer, the difference should be accounted for itself.

This study has also include the following control variables. *Firm age* is measured as the number of years the airlines have been in operation up to the point of comparison. *Relative scale* is a measure that we included in order to compare the relative size of the second mover compared to the first mover. The size of the airline is measured in terms of available-seat kilometers. This term is widely used in aviation industry to measure the annual production volume of an airline, which is specifically calculated as (annual seat capacity x kilometers flown). Relative scale is then calculated by dividing the size of the second mover by the size of the first mover.

This gives us a value larger than 1 if the second mover is bigger, and a value less than one of the second mover is smaller in size. *Route type* is included to account for the difference setting of domestic versus international route. *Number of potential entrants* is the potential competitive pressure in the market in the long run that a firm might have to consider. This measure include the number of other low cost airlines currently existing domestically (for domestic route) or in both countries of destinations (for international route).

In this study, multiple regression analysis is applied to test the relationship among construct, and hierarchical regression analysis is used to analyze the moderating effects.

4. Analysis

The final dataset includes 155 observations, which are airlines routes served by two or more low cost airlines. The original sample includes 633 airlines routes served by low cost airlines within Asia Pacific and Oceania region. Due to lack of data available for the performance and entrance history, only about 25% of these routes remain in the final set, although it gives us an idea of the intensity of competition between low cost airlines in Asia Pacific and Oceania region. Each observation entails a pairwise comparison between the incumbent (first mover) in the respective route and the second entrant (early follower). With 155 observations, we are able to make 41 pairwise comparisons among 30 companies.

Table 1 shows the descriptive statistics and Pearson's correlation for the model constructs. Table 2 presents the results of multiple and hierarchical regression analysis.

Table 1: Correlation Matrix

Pearson's correlation coefficients			Means	S.D.	1	2	3	4	5	6	7	8	9
Constructs	1	Entry speed	2.09	2.36	1								
	2	Market commonality	0.34	0.29	-0.129	1							
	3	Resource similarity	0.37	0.23	0.11	-.470**	1						
	4	Market size	39,633, 744	25,778, 199	.204*	-.215**	0.088	1					
	5	Performance gap	0.04	0.03	.321**	-0.131	.202*	-0.096	1				
Controls	6	Firm age	3.77	2.36	.596**	-.431**	0.054	.294**	0.042	1			
	7	Route type	N.A	N.A	-.201*	.430**	-.168*	-.332**	-0.096	-.301**	1		
	8	Potential entrants	3.9	2.4	-.034	-.316**	.220**	.330**	-.023	.058	-.606**	1	
	9	Relative scale	12.7	21.4	-.350**	.624**	-.449**	-.225**	-.242**	-.463**	.273**	-.287**	1

Correlations were two-tailed.
* p < .05 ; ** p < .01.

Table 2: Regression Analysis Result

Hypothesis tested		H1,2,3		H6	H4		H5	
Variables	Predictors	**Model 1**	**Model 2**	**Model 3**	**Model 4**	**Model 5**	**Model 6**	**Model 7**
Controls	Firm age	.581***	.518***	-.270***	.543***	.536***	.512***	.495***
	Route type	-.193*	-.144+	-.140	-.188*	-.195*	-.105	-.116
	Potential entrants	-.178*	-.205*	-.151	-.172*	-.175*	-.182+	-.170+
	Relative scale	-.283**	-.353***	-.270*	-.288**	-.303***	-.103	-.128
Independent	Market commonality	.375***	.222*		.319***	.324***		
	Resource similarity	.151*	.019				.054	.037
	Market potential	.036	.062		.037	.027	.045	.032
	Entry speed		.408***					
Interaction	Market commonality x Resource similarity	-.267***						
	Market commonality x Market potential				-.037			
	Resource similarity x Market potential						.072	

(Continued) Table 2: Regression Analysis Result

Hypothesis tested		H1,2,3		H6	H4		H5	
Variables	Predictors	**Model 1**	**Model 2**	**Model 3**	**Model 4**	**Model 5**	**Model 6**	**Model 7**
R^2	.451	.491	.198	.435	.436	.384	.388	
Adjusted R^2	.424	.463	.171	.412	.409	.359	.359	
F-value	17.217	17.590	7.366	18.973	16.228	15.351	13.307	
P-value	.000	.000	.000	.000	.000	.000	.000	
D-W	1.896	1.888	2.139	1.925	1.933	2.003	2.019	

Note: ***p<.001; **p<.01; *p<.05; +p<.1.

5. Discussion

5.1. Conclusion

The decision of market entry speed was not significantly influence by WHAT market it is (market potential), but more about WHO is sharing that market with them. Although market size does not reflect the overall attractiveness of a market, the difference does highlight how important competition is in the context of market entry. The fact that the market is big or small could not downplay the importance of competition in the decision making process. Among the two elements of dyadic competition, market commonality proves to be a dominant factor influencing market entry speed of a follower while resource similarity reflects a notable yet not as strong effect on market entry speed. This is in line with previous findings about how market commonality is a stronger predictor of competitive attack and response than is resource similarity (Chen, 1996). This can be explained by the fact that market commonality is much more visible to players on the market while resource endowment of each firms can differ drastically in nature and requires more extensive analysis. However, the interaction effect of market commonality and resource similarity can produce interesting directions when analyzing/predicting interfirm rivalry. While individually, both construct would have delaying effect on Entry speed (the higher the value of market commonality or resource similarity, the longer it takes for the firm to make a competitive move), their interaction provides a balancing act towards competition. Our result (e.g. Model 2) can be interpreted in a way that the presence of high market commonality, if the second mover shares similar endowment with the first mover, there are still chance that they choose to move fast. In other words, resource similarity can be viewed as a moderator that weakens the relationship between market commonality and entry speed.

5.2. Academic Implications

A market entry timing decision, among other important strategic decisions, was proven to have direct impact on firm’s performance. The ability to move fast into a market therefore can be translated into a form of competitive advantage (Hawk et al., 2013). In the past, the classic definition of competitive advantage came from Resource Based View (Barney, 1991). However the theory itself was developed based on the assumption of a static (equilibrium) environment (Barney, 2001) and hence is hard to apply to the dynamic and ever changing market place that currently is. This shows that taking the step to draw a bridge between strategic decisions (market entry timing) and insights from dynamic relationships between firms can help us develop more applicable theories to decode future business strategies.

Competitive dynamics and the market commonality-resource similarity framework has gathered much interest from its inauguration in 1990s (Chen, 1996). By analyzing market entry as a proxy of competitive attack, our study contributed to the path of bridging competitor analysis and prediction on inter-firm rivalry. Going beyond predicting the probability of attack and response, we attempted to translate the indicators of competitive tension between two firms into predictors of actual timing an attack may happen. The Awareness- Motivation-Capability
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5.3. Managerial Implications

In fast-paced and competitive market place, firms have evolved to adapt clever strategies to grow their market. Our study interestingly show that competition plays even a big part in the entry timing decision made by firms than the market potential itself. It reflects in the pattern that no matter what market, companies choose to delay going head to head with an entrenched incumbent whose sphere of influence or resource endowment greatly resembles their own. The idea is not to raise too much attention from a strong competitor in the early stage in fear of retaliation, or a “mutual forbearance” in effect. For example, Walmart managed to survive in the early stages by focusing on serving rural, less populated area and then attack the metropolitan cities once it gathered enough strength and resources. The low cost airlines, in its early day, also focus on serving smaller market to get a foothold and avoid being attacked by national carriers. The low cost airline industry in Asia, however, evolved in rather unique ways compared with their counterparts in the US or Europe. Population in Asia is highly concentrated in metropolitan areas and hence when it comes to the choice of destination/airport airliners would have significantly less freedom over whether or not to choose a market over the other. So it all comes down to the matter of timing, when to enter a market. From the result of our research, we can deduce that firms that are early follower seem to follow a pattern to expansion: gradually build up their network by evenly spread out competition with other competitors, avoid making continuous advances into a competitor’s territories in short period. This strategy serves to avoid raising the awareness of competitors and also minimize the possibility of damage from retaliation.

In this scenario, what is the implication for the first mover? If it’s already proven that market commonality seems to be a hindrance in the process for following firm to keep up, would it be worthy to try an aggressive network expansion strategy at the start just to get the foothold in important markets? This decision of course had to be balanced with firm’s internal resources, yet it might worth considering over the option of staying focused in one single market, especially if the company is offering a generic product/service. Take the competitive landscape of low cost airlines in Asia for example, with an intense focus in offering the lowest pricing, airlines’ opportunity to differentiate themselves from the crowd in term of product is significantly reduced since cost cutting is priority rather than developing other unique competitive advantage. In this case, a first mover advantage would be significant in helping the airline to gain brand awareness as well as fencing off potential competitors.

5.4. Limitations and Suggestions

This research obtains data solely from low cost airline industry in Asia, Australia and New Zealand. In order to validate the applicability of our model in general, a more comprehensive database across different industry would help to significantly improve the value of our current study.

Due to the limitation of data availability, market size is selected as a proxy of market potential. Besides, since we are only surveying the first and second entrants, we made the assumption that all the market are still in growth phase at the point in time where the second player enter the market, which is also the time when the observation is recorded. However, in future study, it would be beneficial to incorporate more complicated measure of market attractiveness such as growth rate, cultural distance, or regulatory environment. Market attractiveness can then reflect a more complete picture about the climate of an objective market and then comparison about the effects of market attractiveness versus competitive interactions on decision making process can be done more objectively.

Our study focused only on individual airlines established in each country as a separate entity. In fact, the interaction between these entities and their network expansion might have been further influenced by their parent companies/group's interaction with other groups that operates in similar regions. This complicated, high level strategic competition is hard to capture yet would be an interesting direction to take on in the future.

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Evolution and Emerging Trends in Cruise Research

Grace Wang[*,1] *, and Peyton Heinze*[1]

[1]Texas A&M University at Galveston
Email: wangw@tamug.edu

*Corresponding Author

Abstract

The cruise industry has exhibited significant growth over the past 10 years. The purpose of this study was to identify research trends and where the industry is headed. Evaluation of research trends can lead the way to future research in targeted fields of need. The primary objective is not only to show discrepancies between research and industry trends within the cruise industry, but also to predict the emergent areas of importance. We surveyed 86 papers from 16 transportation journals, obtained by searching for "cruise" within the journal titles and keywords. Out of our sample, 18.6% of the papers focused on environmental issues, followed by port studies (15.1%), regional studies (10.5%), economic studies and shipping business (9.3%), and cruise supply chain (8.1%). Of that, 56.3% of the papers were published between 2014 and 2018, followed by 21.2% in between 2009-2013. A network analysis of the co-occurrence of authorships and the concentration of study areas was used to show regional clusters on an international scale. This paper will benefit the industry by identifying the shortcomings of cruise research within the scope of transportation journals and showing the path to rectify this. We are seeking to bridge the gap between theory and practice addressing the concerns to the policy makers. The emerging trends demonstrate fundamental shifts in the cruise studies.

Keywords: Cruise, Environmental, Emerging trends in cruise, Literature review

1. Introduction

The cruise industry has exhibited significant growth in the previous 10 years. The total passengers in 2008 was 15.8 million, which grew to 26.7 million in 2017. This is a 69.0% increase in the number of passengers over the past 10 years. This fast growth is expected to continue. Between 2016 and 2017, the cruise industry grew from 25.2 to 26.7 million passengers, representing 6.3% growth from 2016 (Kennedy, 2018). The growth of the cruise industry has been reflected in the increasing publications of cruise related topics in transportation journals. The increase in publications in transportation journals reflects the increasing trend in the overall market. The last 10 years have tripled the number of papers published between 1980 and 2008, 19 papers to 67 papers between 2009 and 2018. The increase in studies in the cruise sector correlates with the increasing demand as shown by the rise of the importance of the industry and the growing concerns associated with cruise development between 2008 and 2017.

In this study, we pay detail look into methodology used, scope of the study, impact areas, and international collaboration of researchers to identify growing emerging trends in cruise research. This increase of publications in transportation related journals show an increasing trend of recognition of cruise as a subsection of the transportation industry. Themes changed significantly over time as the focus shifted from regional itineraries and port studies to larger scale issues such as economic impacts and environmental problems. With some other emerging areas such as shipping routes and logistics, marmite finance, shipping business, and maritime security, we foresee two major areas that attract more international and interdisciplinary collaboration.

First, the cruise industry is developing towards a more environmentally conscientious and locally responsive industry climate. The industry growth and high visibility of the cruise sector leads to an increasingly reliable, elastic and aware industry. This visibility is what pushes the cruise sector towards a more sustainable and efficient business standard than the rest of the maritime industry. Cruise shipping's greater visibility and reliance on the environment can lead the industry to have increased environmental awareness. The cruise sector must embrace sustainable practices or the regions and environments that cruises rely upon will be destroyed by it. Johnson (2002) calls attention to this through a life cycle analysis of cruise shipping and its impact on the environment. The duel nature of cruise tourism makes environmental sustainability a key area of concern. The emissions caused by cruise ships impact the hinterlands of the ships ports of call. The issue of ship emissions is key to the progress of the cruise industry. The effects of climate change also provide unique opportunities for arctic cruises. Arctic cruises present a new market which can has room for additional demand and market expansion. This expansion is held back due to a complex regulatory especially in arctic Canada, this can discourage expansion into arctic regions. For instance, Dawson et al. (2016) used interviews to identify the examine effectiveness of the Canadian arctic regulatory system.

Second, efficient cruise routing, repositioning, and rescheduling is essential to produce reliable cruise services. Reliability is key to maintaining passenger satisfaction. Itinerary design is important for establishing effective and satisfactory cruise experiences. The optimization of arrival and departure times can help to decrease idle time and increase port of call duration. Wang et al. (2016), identify issues in cruise operation planning and itineraries in order to optimize utility. Cruise shipping lines must maintain reliable and flexible services for passengers. The cruise itinerary and port of call design is important for successful cruise networks.

This paper will benefit the industry by identifying the shortcomings of cruise research within the scope of transportation journals and showing the path to rectify this. We have observed that the emerging trends demonstrate fundamental shifts in the cruise studies. Through this exercise, we aim to bridge the gap between theory and practice addressing the concerns to the policy makers.

2. Method, Data, and Scope of the Study

2.1. Journals of Focus

Transportation and hospitality represent the dual nature of the cruise industry; they are two sides of the same coin. Even with transportation and tourism journals appearing parallel with similar scopes in overlapping sectors, the transportation journals are known for the focus on practical solutions in port or cruise development while tourism journals focus on consumer applications. The journals that we sampled were 16 transportation journals including Asian Journal of Shipping and Logistics (ASL), Accident Analysis Prevention (AAP), Geoforum (GEF), International Journal of Shipping and Logistics (ISL), Journal of Transportation Geography (JTG), Marine Policy (MAP), Maritime Economics and Logistics (MEL), Maritime Policy and Management (MPM), Transportation Reviews (TRS), Transportation Research A (TRA), Transportation Research B (TRB), Transportation Research C (TRC), Transportation Research D (TRD), Transportation Research E (TRE), World Maritime University Journal of Maritime Affairs (WMU), Research in Transportation Business and Management (TBM), and Maritime Business Review (MBR).

Table 1: Sample Journal List

	Time period							Total
Journal	before 1989	1989-1993	1994-1998	1999-2003	2004-2008	2009-2013	2014-2018	
AAP						1	2	3
ASL						1	2	3
GEF						1		1
ISL						3		3
JTG						1	2	3
MAP		1	0	2	2	1	4	10
MPM	2	2	3	2	1	5	8	23
MEL					2	3	2	7
MBR							5	5
TRS	1							1
TRA							1	1
TRB							2	2
TRD					1	1	6	8
TRE							4	4
TBM							10	10
WMU						1	1	2
Total	3	3	3	4	6	18	49	86

Source: Conduced by authors. Journals were counted in a 5-year interval.

A comprehensive search of "cruise" articles was been conducted to show the growth of the cruise industry as a focus in transportation journals. The sample was cross referenced through science direct and journal searches. The sample consists of 86 papers across 16 journals between 1980 and 2018. These papers all contain a focus on cruise and are within transportation journals. The number of cruise papers published in transportation journals dramatically increased over the past 5 years. This increase of publications in transportation related journals show an increasing trend of recognition of cruise as a subsection of the transportation industry. 77.9% of our sample fell within the last 10 years; this shows dramatic growth in interest in the cruise industry in the past 30 years.

2.2. Evolution of Research Themes

To understand the big picture of the cruise emerging trends, we need to establish top concerns or major interests through literature and industry. To bridge industry and academic perspectives, 14 maritime conferences were selected from the shipping industry. The major maritime conferences were selected based on the diverse perspectives on the maritime and shipping industry, displaying different aspects and focuses. These conferences call for papers topics were used to define "Research Themes" in this study. Themes were retrieved from the last three years of the conferences.

Conferences selected:

- International Associate Maritime Economists (IAME) conferences
    - Focus on maritime economics. The theme varies from year to year

- World Conference on Transportation Research (WCTR)
    - Research in all areas of transportation research.

- Centre for Maritime Research (MARE)
    - Maritime activities such as cruise tourism that deal with maritime mobilities

- International Conference on Maritime Transport (ICMT)
    - Interdisciplinary approaches to maritime issues

- International Conference on Maritime Transport and Climate Policy (ICMTCP)

- International Conference on Maritime Management and Logistics (ICMML)

- International Conference on Logistics and Maritime Systems (ICLMS)
    - Maritime systems and clusters from a logistics perspective

- International Conference on Maritime Safety and Security Law (ICMSSL)
    - Maritime safety and security

- International Conference on Maritime Energy Management (MARENER)
    - Energy efficiency within maritime transportation

2.2.1 Mapping of Theme to Literature

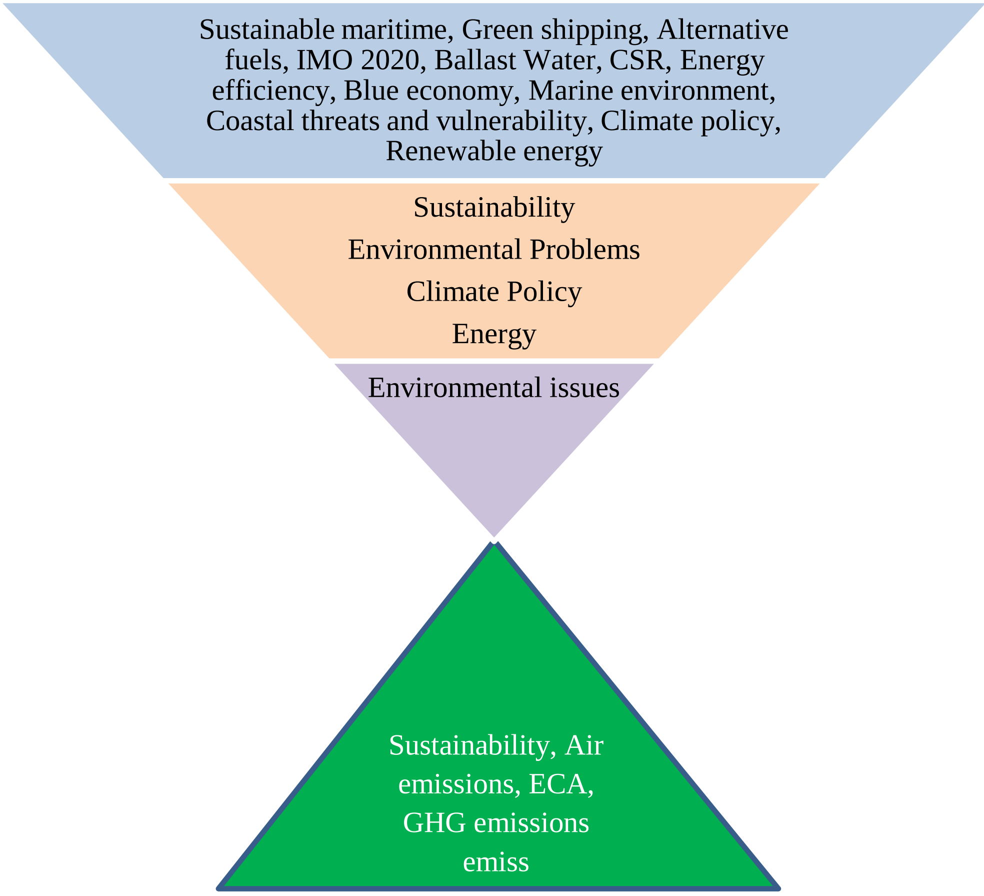

Figure 1: Merger of Research Theme and Mapping to the Literature

Source: Conducted by authors.By mapped the literature into each subcategory, major themes were defined by taking topics from maritime conferences and identifying the emerging trends.

For example, the IAME 2018 focuses on “Sustainable maritime, port and logistics industries” giving an environmental economic perspective to our themes. IAME 2017 focuses on “Maritime transport quality in the evolving world trade” giving a global transportation perspective. Table 2 displays the themes in an interval of 5 years. This showed an increased focus on environmental problems after 2008. The change of focuses between 1980 and 2018 is portrayed in the theme. The increase of research in cruise can also be attributed to the industry growth over the past 30 years. The increase in the cruise fleet capacity and the growth in the industry research are likely a part of a larger cruise trend. The themes transitioned from regulatory, competition and logistics to environmental issues and sustainable themes. The thematic changes represent the changing attention away from ship design, and regional studies toward a larger worldwide cruise perspective. The cruise themes appear to be leading towards studies in cruise rescheduling and emergency supply chain. The emerging growth of the arctic cruise sector presents new opportunities for research and development within the industry.

Table 2: Major Theme of Cruise Research

	before 1989	1989-1993	1994-1998	1999-2003	2004-2008	2009-2013	2014-2018	Total
Environmental issues				1	1	3	11	16
Regional study				1	2	2	4	9
Maritime education								0
Port studies			1			3	9	13
Shipping routes and logistics		1				1	4	6
Security and risk				1	1	1	4	7
Shipping business						3	5	8
Competition		1	1				2	4
Economic impact	1					2	5	8
Maritime regulation	1					2	1	4
Engeneering and Technology	1		1					2
Intermodel transportation		1		1		1		3
Maritime finance					2		4	6
Total	3	3	3	4	6	18	49	86

Source: Conduced by authors. Journals were counted in a 5-year interval.

Themes changed significantly over time as the focus shifted from regional itineraries and port studies to larger scale issues such as economic impacts and environmental problems. To take a deeper look, the environmental theme includes papers focusing on energy efficiency, energy management, alternative fuels, greenhouse gas emissions, climate change, pollution, ballast water treatment, green shipping, and IMO 2020 sulfur regulations. Most discussion were towards environmental problems to address the important, challenges, and solutions to the maritime and cruise industries. The economic impact theme includes papers focusing on the impact on ports on economies, economic impact of shipping, the social role of ports in the economy, the role of shipping as an economic engine. The regional studies theme includes papers focusing on regional analysis, development, regional clusters and trend research.

Other than that, some emerging areas are 1) shipping routes and logistics; 2) marmite finance; 3) shipping business; 4) maritime security. The shipping routes and logistics theme includes papers focusing on maritime logistics, optimization, efficiency, cruise resupply, cargo handling, cruise itineraries, berth scheduling, fleet management, transportation network design, shipping route exploration, and ship rescheduling. This theme is aimed at optimization and reliability of logistical and itineraries within the maritime sector. It is essential for reliability in the supply chain and cruise satisfaction. The maritime finance theme as includes papers about maritime insurance, shipbuilding funding and cost analyses. It focuses on revenue management and improvement of the financial status of shipping and cruise players. The security and risk theme include maritime and cruise issues such as port security, threats, cybersecurity, shipping accidents, piracy, and risk management. This includes papers that focus on maritime security threats, how their handled and the management or risk. The shipping business theme focuses on the management of business operations within the maritime space. It includes papers that focus on maritime management challenges, strategic issues, quality control, reliability, and other business solutions.

3. Status of cruise emerging trends

3.1. Research Approach and Methodologies Used

Table 3: Major Research Approaches in Cruise Studies

Research approach			
Analytic Hierarchy Process	1	Life Cycle Analysis	1
Bottom-Up	4	Linear and Multiple Regression	11
Case study	7	Literature review	5
Comparative analysis	1	Multiple Discriminate Analysis and Logistic Regression	4
Correlation and variance	10	N/A	1
Cost-Benefit Analysis	3	Network Models	1
Decision Analysis	5	Non-Parametric Approaches (like FDH, DEA)	1
Descriptive/exploratory	18	Optimization	2
Factor Analysis	1	Scheduling Models	1
Game Theory	3	Simulation analysis	1
Input-output model	4	Structural Equation Models	1

Source: Conduced by authors.

The research methods used in the cruise literature vary based on the goals of the research. Some utilize complex methods combining more than one approach in their research. The most common research approach was a descriptive/exploratory which contained 18 papers. This shows in the cruise research frequently using exploratory methods to describe a newly developed area and/or application. For instance of Lasserre and Pelletier (2011), authors studied the possibility of maritime transport in the Arctic. Motivations, interests, and intentions of the shipowners among shipping companies were collected through an empirical survey to discuss the feasibility, profitability and reliability. Case studies are also among the most frequent used methodology. For example, Styhre et. Al (2017), examined greenhouse gas emissions in ports, applying case studies across four continents to capture the uniqueness of the implementation of strategies at port level.

Referring to empirical analysis, common research approaches are linear and multiple regression analysis, correlation and variance, input-output for economic impacts and logistic regression. This shows the increasing correlation and trend analysis applying empirical and statistical tools. In our sample of papers, 62 of the papers used secondary data and 23 used surveys or primary data sources. For theoretically studies, we can see some game theory and optimization applications. Within cruise papers in transportation journals, the majority of papers utilize secondary data such as the AIS system in order to obtain data for their papers. The use of descriptive/exploratory methodologies, relying heavily on interviews, surveys, and questionnaires, allows for analysis of objectives that are sometimes unclear and introduction of new issues and concepts. These research approaches show the current cruise research's practical approach to industry issues and development.

3.2. Emerging Study Areas

Figure 2: Concentrated Study Areas
Source: Conduced by authors. Software: Gephi.

Figure 2 shows the major areas of study within our sample. Study areas show the target region of papers. 46 papers (51%) within our sample had a specific region of study. The primary regions that were studied are the Caribbean, the Meditation, and the South China Sea. In a regional level, Mediterranean, Jamaica, Arctic, Greeks seas, Europe, Adriatic Sea, Korea, Japan, Malaysia are some of the focuses in the literature. Port level studies can be seen in Mexican ports, Friuli Venezia Giulia, Port of Cartagena, Port of Kotor, Port of Leith, Port of Piraeus, Las Palmas Port, Spanish ports, Southampton, US homeports, Galveston, Trinidad and Tobago, Port of Bergen, Port of Copenhagen, Incheon, Bahamas and Bermuda, Copenhagen, Hong Kong, Brussels, Istanbul. The balance of regional and larger scale studies is important to see the overall growth of the cruise industry.

The subject areas are important because they show regional areas of focus in the cruise sector. This identifies areas such as Spain and the Mediterranean that had substantial research being conducted over those regions.

Developed cruise markets such as the Caribbean and Mediterranean have background knowledge and existing data that is not present in emerging markets. Developed cruise markets research typically will display more complex research methods and have a greater emphasis on policy given the challenges and obstacles they have experienced in the past. Emerging cruise markets, on the other hand, such as Asia and Australia/Pacific are on the different stages of the life cycle of cruise development. Through case studies or exploratory analysis, some lesson learned from the well-established markets can be applied. That explains why interdisciplinary approaches and interdisciplinary collaboration are needed across different regions. Differences in culture and inter-relationships between stakeholders in the Asian market in particular presents a significant issue to the cruise industry.

3.3. International Collaboration and Network Analysis

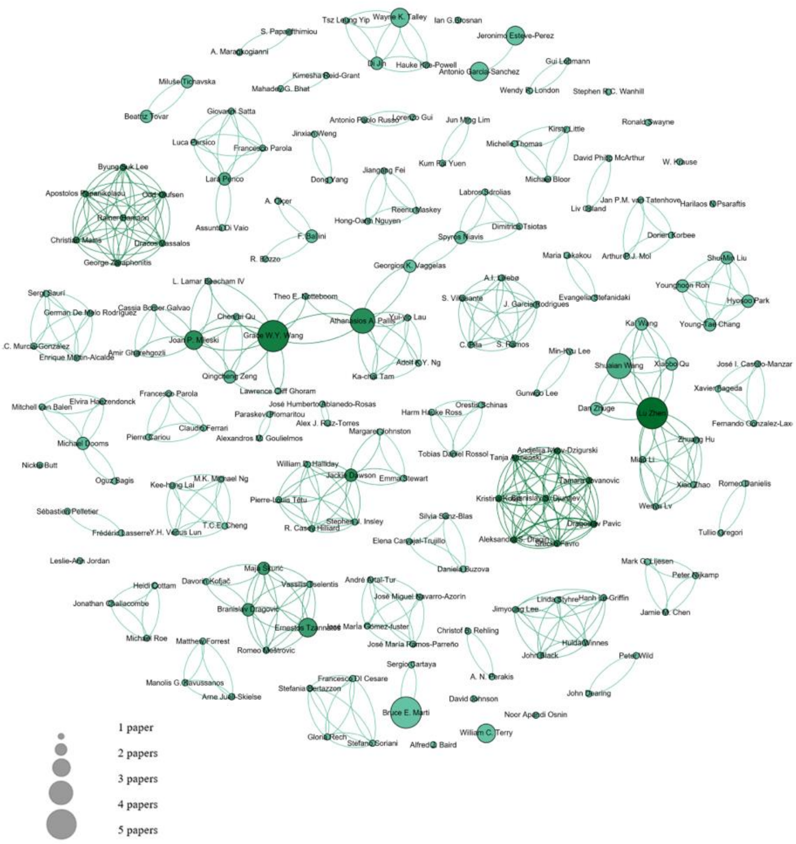

Figure 3: Network Analysis of Co-occurrence of Authorship and Collaboration
Source: Conduced by authors. Software: Gephi.

The interconnection of authorship within cruise research showed clusters within academic research (Figure 3). The network analysis was created using Gephi to show the interconnections between authors within our literature review sample. Every author was assigned a node ID. Authors who worked together were connected from one node to other nodes. The author's size is represented by the number of papers written by each author. The minimum number of papers was one which became a weight of 10 and the maximum number of papers was 5 which became 50, the weight of the papers was scaled up based on a multiple of 10, because otherwise the difference would be indistinguishable. The authors are connected to every co-author they have worked with, this displays the network of connectivity and interdisciplinary collaboration between major researchers in the cruise industry. The different clusters display the authorship in the cruise industry in a fundamental way. For example, the cluster containing Lu Zhen, Shuaian Wang and Miao Li are from Hong Kong, and appear to be major players in cruise transportation research. The connectivity to other author's shows network clusters some of which can be explained by affiliations and locations.

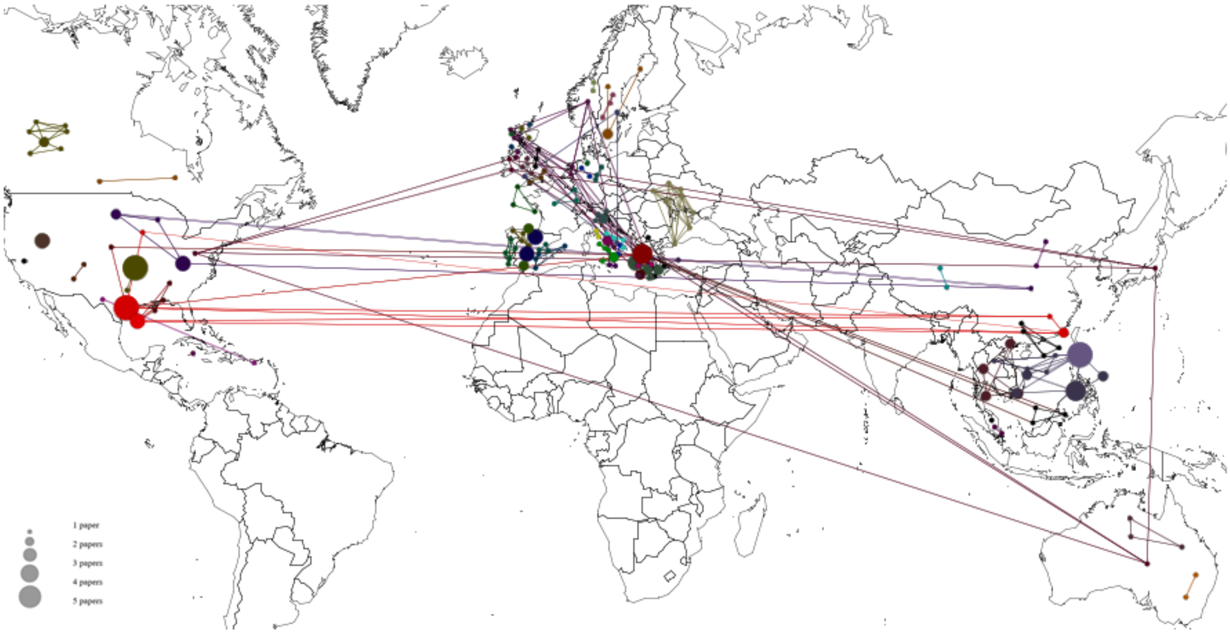

Figure 4: International Collaboration among Co-authorships
Source: Conduced by authors. Software: Gephi.

Figure 4 is a representation of the regional clustering of authorship in cruise literature. It shows the international integration that is present in the cruise research sector. The clusters show major research areas and international collaboration. This affiliation shows the regions which provide significant contributions to cruise research. Significant clusters are present in Spain, Greece, Hong Kong as well as the United States and the United Kingdom. These clusters appear near major cruise regions such as the Spain and Greece clusters are around the Mediterranean. The United States cruise is significantly related to the Caribbean and gulf cruises. The Hong Kong cluster is near the growing cruise region of the South China Sea. The United Kingdom and Scandinavian clusters are near the North Sea cruise sectors.

4. Discussions and Findings

The industry focus has shifted significantly over the past almost 40 years. Changing regional players, lines, and industry focuses shown by industry organizations such as MedCruise and Cruise Lines International Association (CLIA) represent these views from the cruise port and cruise line perspective respectively. An industry comparison was conducted between 2003 and 2018 in order to better understand the industry concerns. The source from the industry were compared with the literature review we have done in this study. Environmental issues did not appear to be a major industry concern until after 2009 with cold ironing discussions. The environmental discussion continued with until 2011 where discussion of waste management began. This is when MARPOL Annex V resolution MEPC.201(62) concerning waste and garbage disposal. The environmental literature attention reflects the industry attention as the issue grew and more importance was placed on it after 2014, the industry focus follows the environmental regulatory issues.

A large emphasis was placed from port perspective (MedCruise) on itinerates and logistics. This focus remained consistent between 2003 and 2018. In 2009, industry discussions on berth conformation cooperation in order to reduce congestion began and continued until 2019 when MedCruise released the Unified Mediterranean Cruise Ship Berth Booking and Confirmation Process. This is the current system used in the Mediterranean in order to minimize congestion through planning and confirmations. The literature does not show the increasing industry interest on berthing congestion solutions. One thing that had very little academic presence was the airport-homeport supply chain for cruise passengers and even packages of cruise-flights together.

Technology is major focus area for the cruise industry with the utilization of big data, VR, and passenger connectivity plays a significant part of onboard experience, marketing and passenger retention. The level of emphasis placed by cruise lines and industry organizations on new technological development and implementation, demonstrates a gap between industry themes and literature focuses. Competition and cooperation within the industry is clear in the relationships between the cruise lines and the cruise ports. This relationship has not significantly changed other than new ports entering and consolidation of cruise lines. Papers within transportation journals cover this topic and address the issues these relationships cause the industry. The industry consistently placed a large emphasis on maritime education with both the cruise port and the cruise line. The push for more, better trained travel agents and more efficient terminal operators is clear from both MedCruise and CLIA. Transportation journals contained no papers on cruise education in the last 38 years; this is a significant gap between the industry and academic focuses. The discussion of security, safety and risk began with International Ship and Port Security (ISPS) security standards that came into effect in 2004, the years leading up to this displayed a strong focus on port security. Safety is very important for the cruise industry not just for crew but for passengers because of the liability and potential health concerns from the increased complexity while at sea.

5. Conclusions

We conducted a comprehensive literature review of cruise research that was published in transportation journals between 2018 and 1980. This literature review consisted of 86 papers in 16 journals. These papers were collected in order to understand the evolution and trends of cruise research and identify the gaps in cruise knowledge. Cruise research has grown significantly in the past 40 years. Our sample contained a significant amount of descriptive and exploratory analysis, the cruise research appears to be identifying and exploring practical cruise issues. The cruise research has grown significantly in its environmental awareness as shown through the growth of research on environmental problems. This focus on environmental concerns shows an awareness of its reliance upon the environment and an increasing focus on sustainable cruising. The prominence of regional and port studies shows the impact of cruise on hinterland activity and the concerns surrounding this. As the cruise industry has grown the impact on hinterland economies has also grown. With the growth of new cruise sectors such as Arctic and Asian sectors, these studies are important for identifying concerns and assisting liners through an academic means.

There is a distinct lack of publications in transportation journals over cruise supply chains, rerouting, and cruise resupply in the literature sample. The cruise industry review showed a growing interest in airport-cruise value creation and potential packaged deals. The airport-cruise supply chain was not found in any cruise article in transportation journals. This shortcoming is important due to the demand for reliability and flexibility in the cruise industry. It is important to create reliable itineraries that satisfy customers while allowing for essential refueling and resupply for cruise ships. The need for flexibility in the changing climate of cruise tourism is important as a disruption such as a port strike, storm, or local instability that can disrupt cruise itinerary and resupply options. This area of research is not touched on often in recent years despite its importance. The lack of quantitative and empirical research within the sample is a clear indication that cruise research needs to use applications of empirical research along with frequent qualitative research. Cruise research within transportation journals also appears to fail to consider the importance of customer satisfaction for cruises.

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Hub Status of Primary Cities in Asia from the Perspective of International Air Transportation

Hidenobu Matsumoto[1], *and Koji Domae*[2]

[1] Graduate School of Maritime Sciences, Kobe University, Kobe, Japan
[2] College of Global Communication and Language, Kansai Gaidai University, Hirakata, Japan

Abstract

This paper assesses the competitive hub status of twelve primary cities from the perspective of international air transport on both aspects of demand and supply. Its focus of attention is Asia, where cross border competition has been witnessed among global cities for the role as a key international air traffic hub. From the demand aspect, the paper examines international air passenger movements on the segment level and, in turn, the hub status of twelve primary cities by a gravity model composed of GDP per head, population, distance and dummy variables for these twelve cities. From the supply aspect, the paper employs the NetScan connectivity model to measure and compare the connectivity developments in air transport networks of these twelve cities. The results confirm the dynamic change of the air transport city hierarchy, demonstrating a stronger presence of cities in China and a number of previously secondly ranked cities as international air traffic hubs.

Keywords: Hub status of cities, Air traffic flows, Air network connectivity, Gravity model, NetScan connectivity model, Asia

1. Introduction

Problems of hub location and network configuration are one of the main items that are frequently discussed in the published literature. These topics draw considerable attention particularly in Asia, where cross border competition has been witnessed among global cities for the role as a key international air traffic hub. Especially after the 1990's, new international airports started up one after another in many cities of this region: Shenzhen (1991), Osaka (1994), Macau (1995), Kuala Lumpur (1998), Hong Kong (1998), Shanghai (1999), Seoul (2001), Guangzhou (2004), Nagoya (2005), Tianjin (2005) and Bangkok (2006), while Tokyo, Singapore, Taipei etc. have responded by expanding their airport capacities, such as runways and terminals. Beijing will start a new international airport in 2019 and Ho Chi Minh City in the coming years. Meanwhile, three global air-freight integrators, DHL, FedEx and UPS, have been developing their hub-and-spoke networks in this region by constructing global and regional hubs. Their Asian hubs are drastically changing the urban pattern of international air cargo transport within this region. Hence, there has been a major re-alignment in hub roles, providing the potential to change the hierarchical structure of hub cities.

To date, many studies have analyzed hub-and-spoke networks. One branch of research is from the viewpoint of economic perspectives, with a focus on economies of density and scope (Caves et al., 1984; Brueckner and Spiller, 1994), hub premiums (Borenstein, 1989; Oum et al., 1995), entry deterrence (Zhang, 1995) and the role of hub-and-spoke networks in airline alliances (Oum et al., 2000; Pels, 2001). Another branch of research is the field of operations research, where the cost-minimizing approach is used to determine spatial optimization of air networks (Kuby and Gray, 1993; O'Kelly and Miller, 1994; O'Kelly and Bryan, 1998). A third branch uses the geographical approach, in which the structures, performance and spatial dimension of hub-and-spoke networks are analyzed empirically (Ivy, 1993; Shaw, 1993; Bania et al., 1998; Burghouwt et al., 2003). These studies, however, take into consideration air traffic flows purely from the demand aspect, without capturing the airline network structures, schedule coordination and its resulting hub performance from the supply aspect. Consequently, some studies have included the level of schedule coordination in the measurement of performance and structure of hub-and-spoke networks. Veldhuis (1997) analyzes Amsterdam Airport Schiphol, focusing on the quality and frequency of indirect connections. Burghouwt and Veldhuis (2006) evaluates the competitive position of West European airports in the transatlantic market from this viewpoint, followed by Burghouwt et al. (2009) and De Wit et al. (2009) which assess the competitive hub status of primary airports in East and Southeast Asia.

Reflecting these backgrounds, the main objective of this paper is to quantify the hub status of primary cities in Asia in terms of both international air traffic flows (demand-aspect) and international air network connectivity (supply-aspect). The remainder of this paper is organized as follows. The next section provides an overview of the geographical scope of this study and twelve primary cities in Asia. In Section 3, a gravity model is specified to explain international air passenger flows between cities, followed by a discussion of the results. In Section 4, after describing the NetScan connectivity model, the connectivity developments in air transport networks of these twelve primary cities are measured and compared. Finally, the paper ends with a conclusion with future work in Section 5.

2. Geographical Scope and World Cities

2.1 Study Areas

The focus of attention in this research is Asia, which has been selected as this region has witnessed the most intense cross border competition among primary cities for the role as a key international air traffic hub since the 1990's. Our research question is relevant to the dynamic change of hub status of primary cities in a region's urban hierarchy from an international air passenger traffic perspective. From this point of view, Asia is one of the best regions to be analyzed on the globe.

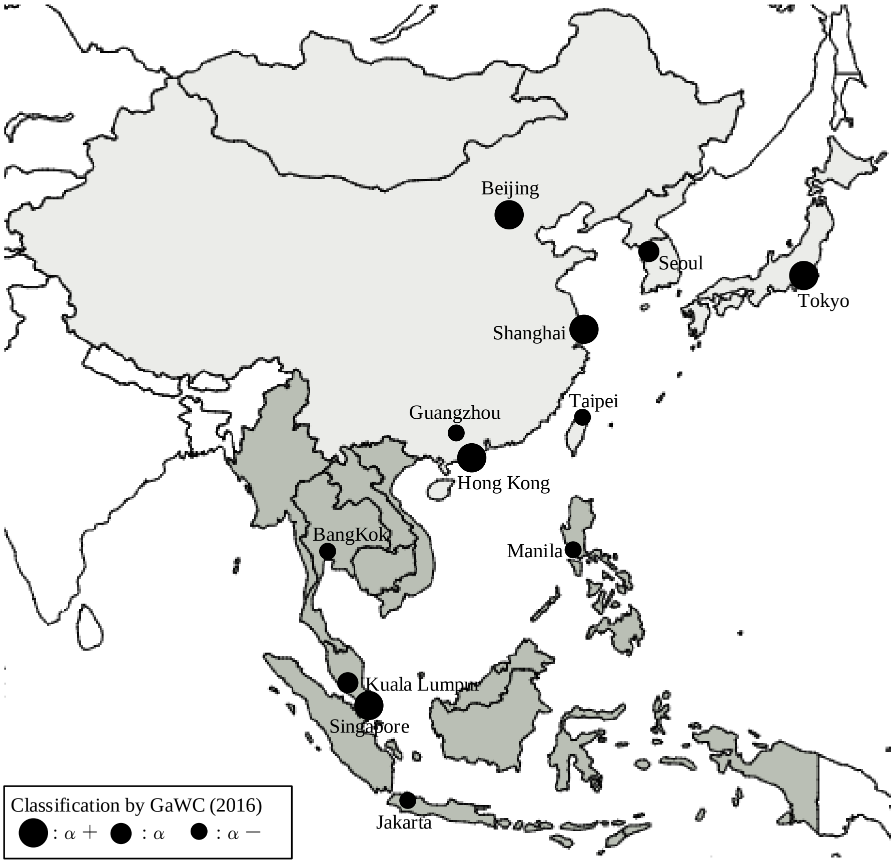


Figure 1: Countries and Global Cities in Asia

Note: East Asia comprises China, Japan, Democratic People's Republic of Korea, Mongolia, Republic of Korea and Taiwan province of China. Southeast Asia includes Brunei Darussalam, Cambodia, Indonesia, Lao People's Democratic Republic, Malaysia, Myanmar, Philippines, Singapore, Thailand, Timor-Leste and Viet Nam.

As shown in Figure 1, Asia in this paper comprises six countries and one region in East Asia and eleven countries in Southeast Asia. The figure also shows twelve primary cities in this region, which are classified above the Alpha minus category by the GaWC analysis discussed in detail in Section 2.2 below (GaWC, 2016). As mentioned earlier, some of these cities have opened a new international airport, whereas others have expanded their airport capacities, including runways or terminals.

2.2 World Cities

The Globalization and World Cities (GaWC) Research Network focuses upon research into the external relations of world cities. GaWC determines the hierarchy of cities basically every four years after 2000, based on the connections between the offices of 175 global advanced producer services (APS) firms in finance, banking, accountancy, insurance, law, consultancy or advertising across 707 cities in 2016. Measures of the number and importance of firm offices in each city are compressed into a score. Five groups are identified: Alpha, Beta, Gamma, High Sufficiency and Sufficiency. Alpha, Beta and Gamma cities are again sub-divided into three or four categories. Table 1 shows the classification of cities in Asia by GaWC above Alpha minus in 2016, which are focused on in the analyses below.

Table 1: Classification of Cities in Asia by GaWC (2016)

No.	City	Country	2000	2004	2008	2012	2016
1	Singapore	Singapore	Alpha＋	Alpha＋	Alpha＋	Alpha＋	Alpha＋
2	Hong Kong	China	Alpha＋	Alpha＋	Alpha＋	Alpha＋	Alpha＋
3	Beijing	China	Beta＋	Alpha－	Alpha＋	Alpha＋	Alpha＋
4	Tokyo	Japan	Alpha＋	Alpha＋	Alpha＋	Alpha＋	Alpha＋
5	Shanghai	China	Alpha－	Alpha－	Alpha＋	Alpha＋	Alpha＋
6	Seoul	Korea	Beta＋	Alpha－	Alpha	Alpha－	Alpha
7	Kuala Lumpur	Malaysia	Alpha－	Alpha－	Alpha	Alpha	Alpha
8	Jakarta	Indonesia	Alpha－	Alpha－	Alpha－	Alpha－	Alpha
9	Bangkok	Thailand	Alpha－	Alpha－	Alpha－	Alpha－	Alpha－
10	Taipei	Taiwan	Alpha－	Alpha－	Alpha－	Alpha－	Alpha－
11	Guangzhou	China	Gamma－	Gamma－	Beta－	Beta＋	Alpha－
12	Manila	Philippines	Beta＋	Gamma＋	Beta＋	Beta＋	Alpha－

Source: The World According to GaWC (http://www.lboro.ac.uk/gawc/gawcworlds.html).

3. Analysis of International Air Traffic Movements

3.1 Model

A gravity model is employed to analyze international air passenger flows in this section. The model is frequently used to determine the spatial orders or organization of air passenger and cargo flows (Harvey, 1951; Taaffe, 1962; Long, 1970; Wojahn, 2001; Grosche et al., 2007; Hwang and Shiao, 2011).

The idea on the gravity model in the section was first published in Matsumoto (2004), which analyzed international air traffic flows within and among the Asian, European and American regions separately over the years from 1982 to 1998. It incorporated into a gravity model GDP per head, population, distance and some city-dummy variables. In Matsumoto (2004), workload unit (WLU), a traffic measure combining passengers and cargoes, was used to reflect air traffic volume. A WLU is equivalent to one terminal passenger or a hundred kilograms of cargo handled (Doganis, 1992). Matsumoto (2007) separated passengers and cargoes in the analysis. Meanwhile, Matsumoto and Domae (2018) developed these two studies, using the extended dataset up to 2012, by including in the analysis all international air traffic flows from, to and within Asia. Unlike the previous two studies, this change led to the inclusion of international air traffic flows from/to Asia to/from other regions than Europe and America (the Middle East, Africa etc.) in the analysis. On the other hand, the effect of business connectivity between cities was explored on their air traffic connections, and, in turn, on their place in an Asian urban hierarchy by Matsumoto et al. (2016) and in a European urban hierarchy by Matsumoto and Domae (2019). The present paper develops Matsumoto and Domae (2018), which analyzed international air traffic movements up to 2012, by extending the dataset up to 2016. This will capture the effect of drastic expansion in international air passenger traffic on the hub status of cities in this region after 2012.

The dependent variables are international air passenger flows between cities (T). The explanatory variables include GDP per head (G), population (P) and distance (D). In addition, city-dummy variables (C) are embedded into the model to explore the competitive hub status of twelve primary cities shown in Figure 1. The entry rule for introducing them is their rank as a global city classified above the Alpha minus category by GaWC (2016), as discussed earlier (see Table 2 for a listing).

Table 2: City-dummy Variables

Dummy variable	C_1	C_2	C_3	C_4	C_5	C_6
City	Singapore	Hong Kong	Beijing	Tokyo	Shanghai	Seoul
GaWC (2016)	Alpha＋	Alpha＋	Alpha＋	Alpha＋	Alpha＋	Alpha
Dummy variable	C_7	C_8	C_9	C_{10}	C_{11}	C_{12}
City	Kuala Lumpur	Jakarta	Bangkok	Taipei	Guangzhou	Manila
GaWC (2016)	Alpha	Alpha	Alpha－	Alpha－	Alpha－	Alpha－

The structure of the model is as follows:

$$T_{ij} = A\frac{(G_iG_j)^{\alpha}(P_iP_j)^{\beta}\exp(\delta C_1)\exp(\varepsilon C_2)\exp(\zeta C_3)\cdots\exp(\nu\xi C_{10})\exp(\xi C_{11})\exp(o C_{12})}{(D_{ij})^{\gamma}} \qquad (1)$$

Technically, the size of ‘e’ raised to the power of a city-dummy parameter partly gives an indication of its hub status, as it accounts for international air passenger movements above those explained by the basic three factors (GDP per head, population and distance). This means that a city with this dummy has more international air passenger movements than expected, having considered its basic three factors, and this may be partly due to its hub status that attracts more international air passengers than locally generated. For example, an effect of transferring passengers is included in this value. If one flies from Osaka to Mumbai via Hong Kong, two tickets are issued: Osaka to Hong Kong and Hong Kong to Mumbai. In this case, Hong Kong functions as a hub airport and thus this value for Hong Kong becomes larger.

Of course, this dummy variable is not solely related to the hub status of cities and changes in its size result from various factors. The growth of national economies, developments in aircraft technology (e.g. longer haul aircraft), changes in the type of passengers carried (e.g., the split between business and leisure travel) or changes in bilateral air service agreements will also affect the size of city-dummy parameter.

After transforming Equation (1) into log form, ordinary least-squares (OLS) regression analysis is conducted to international air passenger flows from, to and within Asia on the segment level for the years from 2001 to 2016.

3.2 Data

City-pairs selected were those that had international air passenger movements exceeding ten thousand passengers. Since cities are the basic unit of analysis, airport numbers were aggregated in cities that have multiple international airports. We obtained international air traffic data from the International Civil Aviation Organization. As addressed in Derudder and Witlox (2005a, 2005b, 2008), the relevance of research based on this international air traffic statistics is potentially undermined because these data will be imperfect in some cases. One possible weakness in this first data is reduced by utilizing both of On-flight Origin and Destination and Traffic by Flight Stage. The data on GDP per head was taken from the World Bank, the Organisation for Economic Co-operation and Development, the United Nations and the International Monetary Fund, which was converted to US dollar at the constant 2010 prices. With regard to the population data taken from the United Nations, the concept of an urban agglomeration, rather than that of a city proper, was used, since the former is considered to be a better reflection of population in the areas surrounding airports. The distance between cities was calculated by using the website: Great Circle Mapper. The data sources are displayed in Table 3.

Table 3: City-dummy Variables

Data	Sources
International air traffic flows between cities	On-flight Origin and Destination, International Civil Aviation Organization, 1982-2016.
Real GDP per head	World Bank National Accounts Data, and OECD National Accounts Data Files (June 2018), World Bank Statistical Yearbook, Sixty Issue, United Nations World Economic Outlook Database (April 2018), International Monetary Fund
Population of urban agglomeration	World Urbanization Prospects (The 2018 Revision), United Nations Demographic Yearbook (1982-2016), United Nations
Distance between cities	Great Circle Mapper (http://www.gcmap.com/)

3.3 Results

3.3.1. Regression Results in 2016

Table 4 shows the regression results in 2016. The overall model fit is relatively good and the estimated values of parameters for each variable are significant at the 1% level, except for Jakarta.

The estimated values of parameters for the city-dummy variables are larger than GDP and population, indicating that city-specific factors are the most powerful variable in this model in explaining international air passenger flows. Meanwhile, distance is a deterrent to international air passenger flows in this region.

Table 4: Regression Results in 2016

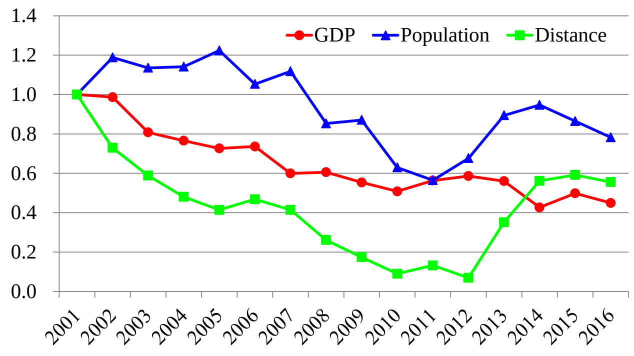
	GaWC (2016)		Unstandardized coefficients			Standardized coefficients	t-values	Sig.
			B	Hub status	Std. error			
Constant		lnA	7.44		0.57		12.99**	0.00
GDP		α	0.14		0.02	0.18	5.87**	0.00
Population		β	0.13		0.02	0.17	6.11**	0.00
Distance		γ	0.19		0.04	-0.14	5.19**	0.00
Singapore	Alpha＋	δ	0.78	2.19	0.17	0.12	4.73**	0.00
Hong Kong	Alpha＋	ε	1.24	3.44	0.12	0.30	10.58**	0.00
Beijing	Alpha＋	ζ	0.74	2.10	0.12	0.17	6.12**	0.00
Tokyo	Alpha＋	η	0.86	2.36	0.14	0.19	6.28**	0.00
Shanghai	Alpha＋	θ	0.92	2.50	0.13	0.20	7.21**	0.00
Seoul	Alpha	ι	0.92	2.50	0.11	0.24	8.45**	0.00
Kuala Lumpur	Alpha	κ	1.67	5.33	0.15	0.29	11.32**	0.00
Jakarta	Alpha	λ	0.66	1.93	0.21	0.08	3.08*	0.00
Bangkok	Alpha－	μ	1.11	3.03	0.11	0.27	9.73**	0.00
Taipei	Alpha－	ν	1.05	2.85	0.23	0.12	4.59**	0.00
Guangzhou	Alpha－	ξ	0.78	2.18	0.15	0.14	5.26**	0.00
Manila	Alpha－	ο	0.94	2.55	0.16	0.16	5.92**	0.00
Adj.R^2			0.36					
Number of observations			1,048					

Notes: ** and * indicate significance at the 1% and the 5% levels, respectively. Hub status is 'e' raised to the power of a city-dummy parameter.

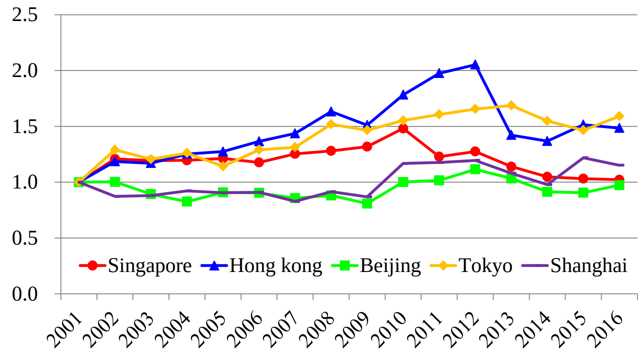
Statistics involving ‘e’ raised to the power of city-dummy parameters reveal a high hub status of Kuala Lumpur, Hong Kong and Bangkok. All of these cities opened a new international airport in the last twenty years and have had international passenger movements above those accounted for by GDP per head, population and distance. Kuala Lumpur and Bangkok are ranked in the Alpha and Alpha minus category in GaWC (2016), respectively, positioned just below the top ranked global cities. This suggests that the second ranked cities in this region have had the strongest gains in terms of international air passenger flows. Cities that have always been seen as major hubs (Tokyo, Hong Kong and Singapore) have retained their absolute supremacy in the network. The results on city-dummy variables confirm the importance of this aspect of cities outside their basic factors of GDP, population and distance, showing that decisions associated with airline operations have a major influence on the city air transport activity hierarchy.

3.3.2. Temporal Changes of City-dummy Parameters from 2001 to 2016

To examine the temporal changes in the value of parameters, the same analysis was applied to the international air passenger flows from 2001 to 2015. This will elucidate the changing importance of each explanatory variable in explaining international air passenger flows. The results are separately shown in Figure 2, according to the rank of cities by GaWC (2016), with each value divided by that for 2001. As for the city-dummy variables, they are the temporal change on the size of ‘e’ raised to the power of the estimated value of parameter.



(1) Three basic variables



(2) Alpha plus Cities

Figure 2: Parameter Size relative to that in 2001

Among the three basic variables, the analysis shows that the influence of the distance parameter drastically declined over the period analyzed, indicating that international air passengers move with less and less regard to their journey length. That may also reflect a growing complexity in connectivity in the region, where longer length connections have an importance. That change will have some implications for the development of hub-and-spoke systems in this region, as some hubs may be over-flown by longer-haul flights. That trend may also be linked to the technological innovation of aircrafts in the flight time in hours, which has allowed more point-to-point services on intra-regional routes, resulting in more direct city-to-city services within the region (O'Connor and Fuellhart, 2015).

Looking at the effectiveness of the model in groups of cities, it seems that outcomes in Hong Kong and Tokyo among cities in the larger Alpha class have become much more predominant, confirming that these two cities play a prominent role in the network of cities in this region. The strong gain of Tokyo can be definitely attributed to the resumption of international air services at Tokyo International Airport in 2010. Among other cities in the smaller Alpha classes, the model's estimates indicate the prominent presence of Kuala Lumpur, Seoul and Guangzhou. The big gains for these cities probably reflect the strength of the economy in each country, along with their new international airports which opened in 1998, 2001 and 2004, respectively.

4. Measurement of Network Quality

4.1 Model

4.1.1. Four Types of Network Connectivity

In our approach, four types of network connectivity are distinguished as described in Figure 3.

1. Direct connectivity: flights between A and B without a hub transfer

2. Indirect connectivity: flights between A and B, but with a hub transfer at H

3. Onward connectivity: connections via (with a hub transfer at) B between A and D

4. Hub connectivity: connections via (with a hub transfer at) A between C and B

The quality of an indirect connection between A and B with a transfer at hub H is not equal to the quality of a direct connection between A and B. In other words, the passenger traveling indirectly will experience additional costs due to longer travel times, consisting of transfer time and detour time. Transfer time equals at least the minimum connecting time, or the minimum time needed to transfer between two flights at hub H.

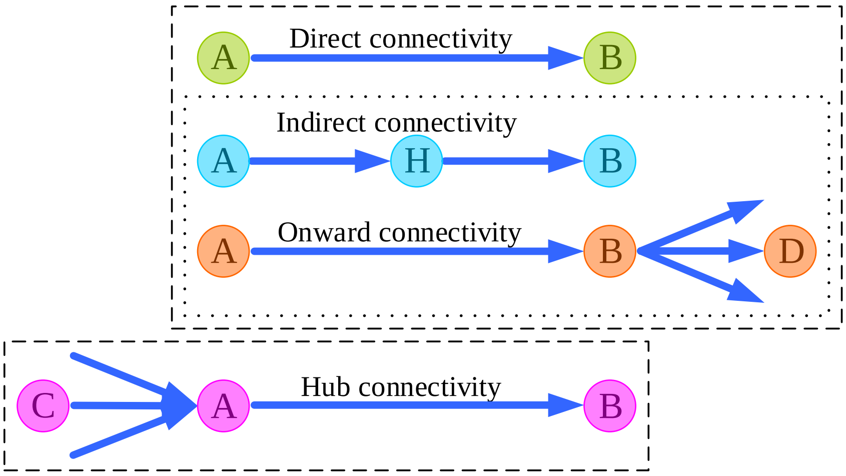


Figure 3: Four types of network connectivity
Note: This paper does not consider onward connectivity.

The measurement of indirect connectivity is particularly important from the perspective of passenger welfare; how many direct and indirect connections are available to passengers between A and B? The concept of hub connectivity is particularly important for measuring the competitive hub status of airports in a certain market; how does airport A perform as a hub in the market between C and B?

4.1.2. Concept of Connectivity Units

Many passengers transfer at hub airports to their final destinations, even in case good direct connections are available. Passengers' choices depend on the attractiveness of the available alternatives.

When measuring the attractiveness of a certain alternative, we consider frequencies and travel time. As for fare differentiation, fares on non-stop direct routes are generally higher than those on indirect routes. Fares on indirect routes are generally lower for on-line (or code-shared) connections than for interline connections. Fares on a route are generally lower if more competitors are operating on these routes. And finally, fares are 'carrier-specific' and are depending on the ability of carriers to compete on fares. Therefore, it can be concluded that fares are generally depending on the number of competitors on the route and the product characteristics, like travel time, number of transfers, kind of connection (on-line or interline) and the carrier operating on the route. So, fare differentiation is partly reflected in the route characteristics.

The route characteristics mentioned are to be operationalized in a variable indicating connectivity, expressed in so called 'connectivity units (CNU's)'. This variable is a function of frequencies, travel time and the necessity of a transfer.

4.1.3. NetScan Connectivity Model

The NetScan connectivity model, developed by Veldhuis (1997), has been applied here to quantify the quality of an indirect or a hub connection and scale it to the quality of a theoretical direct connection. The model assesses the level of direct connectivity based on the Official Airline Guide (OAG) flight schedules. Based on the direct connections, the model builds viable indirect and hub connections. The model weighs these for their quality based on transfer time and detour time involved, which results in the level of indirect and hub connectivity provided. Figure 4 shows the scheme of NetScan Model.

First, direct connections have been retrieved from the OAG flight schedules (Step 1). Then, indirect and hub connections have been constructed using an algorithm, which identifies each incoming flight at a hub airport and the number of outgoing flights that connect to it. The algorithm takes into account the minimum connecting time and puts a limit on the maximum connecting time. In our case, we assume 30 minutes between domestic connections and 45 minutes between domestic and international connections and between international connections for the minimum connecting time and 420 minutes for the maximum connecting time.

Next, NetScan assigns a quality index to every individual connection, ranging from 0 to 1 (Step 2). A non-stop direct connection is given the maximum quality index of 1. The quality index of an indirect or a hub connection will always be lower than 1, since extra travel time is added due to transfer time and detour time for the passenger. The same holds true for a multi-stop direct connection. Passengers face a lower network quality because of en-route stops compared to a non-stop direct connection. If the additional travel time of an indirect or a hub connection exceeds a certain threshold, the quality index of the connection equals 0. The threshold between two airports depends on the travel time of a theoretical direct connection between these two airports. In other words, the longer the theoretical direct travel time between two airports, the longer the maximum indirect travel time can be. The travel time of a theoretical direct connection is determined by the geographical coordinates of origin and destination airport and the assumptions on flight speed and time needed for take-off and landing. Furthermore, additional time penalties for transfer time have been incorporated into the model. Passengers generally perceive transfer time as more inconvenient than flying time, as additional risks exist of missing connections and loss of baggage.

By taking the product of the quality index and the frequency of the connection per time unit (day, week or year), the total number of connections or connectivity units (CNU's) can be derived.

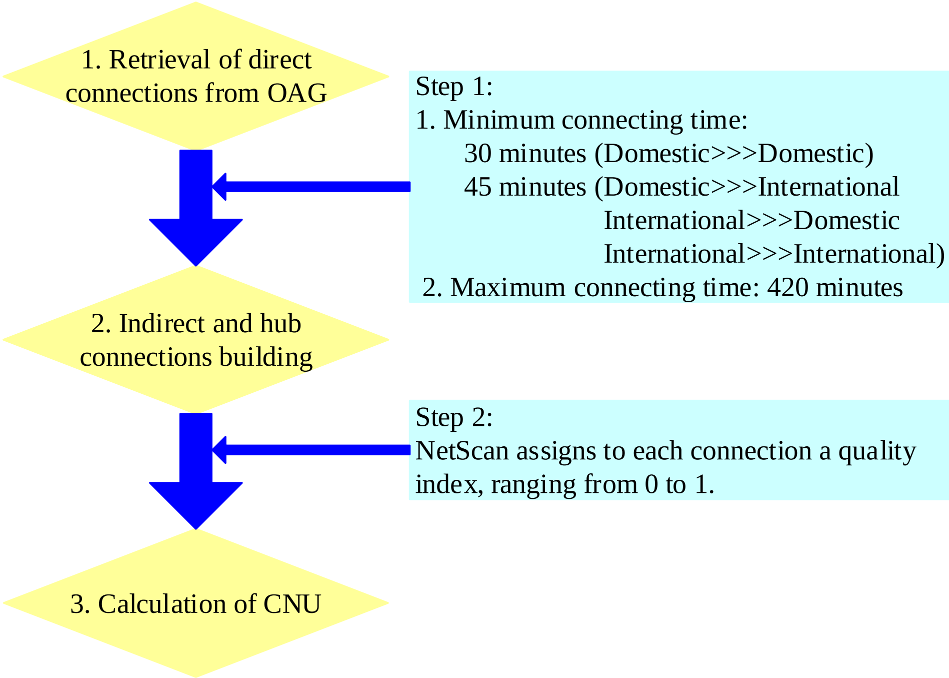


Figure 4: Scheme of NetScan connectivity model

Summarizing, the following formulas have been applied for each individual direct, indirect and hub connection (Airports Council International, 2014). The air network developments at each airport are assessed by calculating the direct, indirect and hub connectivity.

$$t_{xy}^{flight,nonstop} = (40 + 0.068 * \mathrm{gcd}\, km)/60 \tag{2}$$

$$t_{xy}^{perceived,\max} = t_{xy}^{flight,nonstop} + 5\ln(t_{xy}^{flight,nonstop} + 0.5) \tag{3}$$

$$t_{x(h)y}^{perceived,actual} = \begin{cases} t_{xy}^{flight,actual} & for\, direct\ flights \\ (t_{xh}^{flight,actual} + t_{hy}^{flight,actual}) + p_{xy} * t_h^{transfer} & for\, indirect\ flights \end{cases} \tag{4}$$

$$q_{x(h)y} = \begin{cases} 1 & if\ t_{x(h)y}^{perceived,actual} \le t_{xy}^{flight,nonstop} \\ 1 - \dfrac{t_{x(h)y}^{perceived,actual} - t_{xy}^{flight,nonstop}}{t_{xy}^{perceived,\max} - t_{xy}^{flight,nonstop}} & if\ t_{xy}^{flight,nonstop} < t_{x(h)y}^{perceived,actual} < t_{xy}^{perceived,\max} \\ 0 & if\ t_{x(h)y}^{perceived,actual} \ge t_{xy}^{perceived,\max} \end{cases} \tag{5}$$

where,

$t_{xy}^{flight,nonstop}$: nonstop flight time between airports X and Y in hours

gcd km : great-circle distance in kilometers

$t_{xy}^{perceived,\max}$: maximum allowable perceived travel time between airports X and Y in hours

$t_{x(h)y}^{perceived,actual}$: actual perceived travel time between airports X and Y (via H) in hours

$t_{xy}^{flight,actual}$: actual travel time between airports X and Y in hours

$t_{h}^{transfer}$: transfer time at hub H in hours

p_{xy} : penalty for transfer time (= $= 3 - 0.075 t_{xy}^{flight,nonstop}$)

$q_{x(h)y}$: quality index.

4.2 Data and Study Airports

The data used in this analysis are from the OAG flight schedules for the third week of September in 2001, 2005, 2009, 2013 and 2017. In this study, only online connections are considered as viable connections. In other words, the passenger transfer has to take place between flights of the same airline or the same global airline alliance partners. For the years 2004 and 2007, three global airline alliances are distinguished: Oneworld, SkyTeam and Star Alliance. For the year 2001, an additional alliance, Wings Alliance, is also distinguished, which submerged into SkyTeam in 2004. In addition, actual codeshare agreements between airlines are also considered when building connections.

The airports, selected and analyzed in our study, are twenty-one airports in the twelve primary cities classified above the Alpha minus category by GaWC (2016), discussed in Section 2.2: Tokyo (Narita International Airport (NRT), Tokyo International Airport (HND)), Seoul (Incheon International Airport (ICN), Gimpo International Airport (GMP)), Peking (Beijing Capital International Airport (PEK), Beijing Nanyuan Airport (NAY)), Shanghai (Shanghai Pudong International Airport (PVG), Shanghai Hongqiao International Airport (SHA)), Guangzhou (Guangzhou Baiyun International Airport (CAN)), Hong Kong (Hong Kong International Airport (HKG)), Taipei (Taoyuan International Airport (TPE), Taipei Songshan Airport (TSA)), Manila (Ninoy Aquino International Airport (MNL)), Bangkok (Suvarnabhumi Airport (BKK), Don Mueang International Airport (DMK)), Kuala Lumpur (Kuala Lumpur International Airport (KUL), Sultan Abdul Aziz Shah Airport (SZB)), Singapore (Singapore Changi Airport (SIN), Seletar Airport (XSP)) and Jakarta (Soekarno–Hatta International Airport (CGK), Halim Perdanakusuma International Airport (HLP)).

Since cities are the basic unit of analysis, airport numbers were aggregated in cities that have multiple airports. The analysis considers the connectivity between or via these cities and cities worldwide.

4.3 Results

4.3.1. Total Network Connectivity

Figure 5 shows the total network connectivity split up in direct, indirect and hub connectivity in the twelve primary cities in 2017. This figure reveals the competitive status of these twelve cities in Asia from a connectivity perspective.

As for direct connectivity, Chinese cities definitely provided many direct connections: Shanghai (6,723 CNU), Beijing (6,198 CNU), Guangzhou (4,364 CNU) and Hong Kong (3,308 CNU). Tokyo was the second largest city in this region with regard to direct connectivity and accommodated 6,309 direct flights in this year. Furthermore, Bangkok (5,553 CNU), Jakarta (5,513 CNU), Kuala Lumpur (4,435 CNU), Seoul (4,138 CNU) and Singapore (3,477 CNU) offered more than 3,000 direct flights. Indirect connectivity was remarkable at Tokyo (15,460 CNU), Shanghai (11,705 CNU), Beijing (11,000 CNU) and Singapore (10,561 CNU), followed by Hong Kong (8,739 CNU), Bangkok (8,040 CNU) and Seoul (7,234 CNU). With respect to hub connectivity, Tokyo, Beijing and Hong Kong were in the first tier, with 18,571 CNU, 16,750 CNU and 14,520 CNU, respectively. Singapore (12,077 CNU), Bangkok (11,539 CNU) and Seoul (10,052 CNU) were in the second tier. Indirect and hub connectivity at Guangzhou and Jakarta, in general, were not so high, compared with direct connectivity.

Narita International Airport has lost its competitive status over the last decades against the emerging airports in this region, but looking at the connectivity on the city basis, Tokyo has retrieved its supremacy after the resumption of international air services at Tokyo International Airport in 2010.

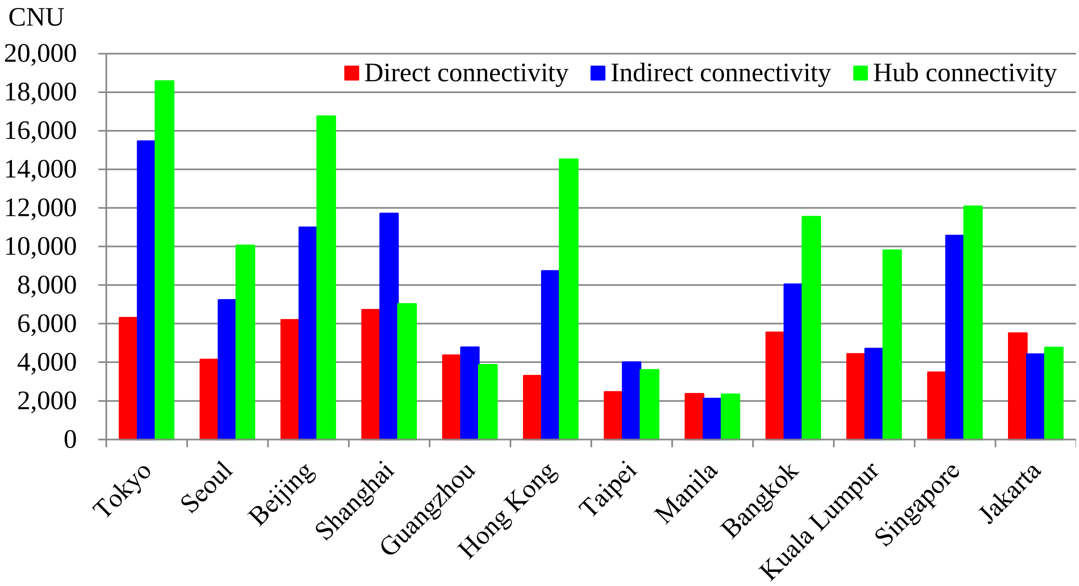


Figure 5: Direct, Indirect and Hub connectivity at Primary Asian Cities in 2017

4.3.2. Hub Connectivity Developments

Figure 6 describes the hub connectivity developments between 2001 and 2017 at the twelve primary cities in Asia. The most striking growth of hub connectivity developments has been found at the three cities in Mainland China: Guangzhou (5,630%), Shanghai (5,013%) and Beijing (1,104%). This was partly because these three cities had very low levels of hub connectivity in 2001. The high growth of hub connectivity at Tokyo (423%) can be again due to the resumption of international air services in 2010 at Tokyo International Airport.

As discussed earlier, Seoul (2001), Guangzhou (2004) and Bangkok (2006) opened a new international airport during the years analyzed, in addition to Kuala Lumpur (1998), Hong Kong (1998) and Shanghai (1999). In this way, the construction of a new international airport has a major influence on the hub connectivity developments.

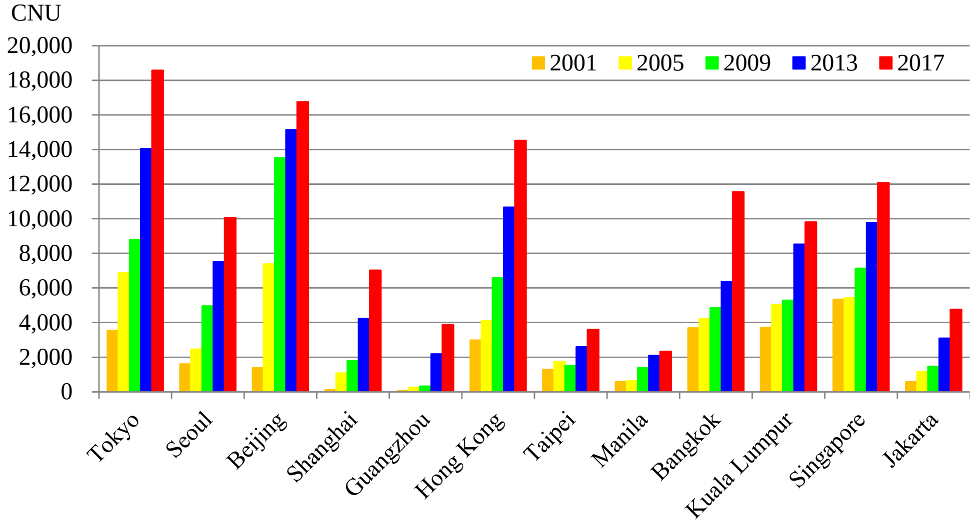


Figure 6: Hub Connectivity Developments at Primary Asian Cities between 2001 and 2017

5. Discussion and Conclusion

This paper assessed and quantified the competitive hub status of twelve primary cities in Asia from the perspective of both international air traffic flows (demand-aspect) and international air network connectivity (supply-aspect). This region has witnessed intense cross border competition among these cities for the role as a key international air traffic hub. From the demand aspect, the paper examined international air passenger movements on the city level by a gravity model composed of GDP per head, population, distance and dummy variables for these twelve cities over the years from 2001 to 2016. From the supply aspect, the paper employed the NetScan connectivity model to measure and compare the connectivity developments in air transport networks of these twelve cities over the period from 2001 to 2017.

The main contribution of the current paper is to capture the dynamic change of air transport city hierarchy within Asia, where the construction of new international airports, along with the intense economic development, has changed the relative rank of a number of cities. The research has demonstrated a stronger presence of cities in China and a number of previously secondly ranked cities as international air traffic hubs during the period of analysis, which is the significant implication for the planning and development of airports with this region. These results refine our understanding of the way the economic development and construction of a new airport actually shape the air transport hierarchy.

In future, the research will need to open up further to include other variables. An important consideration relates to the impact of air cargo movements on the hub status of cities, something that has been outside the agenda of the present paper. Air cargo links could continue to re-shape the hierarchy of cities beyond the patterns detected in the current research.

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Dynamic Interdependence and Spillovers of Market Volatility over Distance: Evidence from Bunker Fuel Markets

Xiaoxia Li[1] ,and Tsz Leung Yip[1]

[1]Department of Logistics and Maritime Studies, The Hong Kong Polytechnic University, Hong Kong
Email: [1]xiaoxia.li@connect.polyu.hk

Abstract

The ship fuels are known as bunker fuels, and bunker fuel prices vary from port to port. Since global bunker markets are linked with each other by international trade and ocean transportation, shocks to one bunker market will transmit to other bunker markets. Previous studies focus on volatility spillovers in financial markets. This study is to explore the volatility spillovers in bunker markets, and the logarithm of bunker prices data in 12 markets runs from January 2002 to May 2017. Volatility spillovers in bunker markets are analyzed by using the two-step approach. Firstly, the series of volatilities are specified by the dynamic conditional correlation GARCH (DCC-GARCH) model. Secondly, spillover indices, which Diebold and Yilmaz (2009) propose, are derived from variance decompositions based on 10-step-ahead forecasts. We examine volatility spillovers among bunker markets in Asian, European, American and international region, respectively. Our analysis provides evidence of bidirectional volatility spillovers among different bunker markets and further quantifies the spillovers effects. We find that the Singapore market (the central market) is regarded as a net transmitter of shocks to other markets and the magnitude of Singapore market transmitting volatility decreases in general if the geographical distance between two markets increases. But there are some abnormal spillovers that one distant market receives more volatility from the central market than one nearby market. We suggest that it is attributed to the closer intra-market trade ties between the central market and the distant market. Thus, for stakeholders in bunker markets, Singapore bunker market should receive more attention to better manage bunker price risks. Our analysis is important to understand the global market organization of bunkers and its related industries.

Keywords: Shipping, bunker fuel, Volatility

1. Introduction

The shipping industry carries a huge load of the world trade. Bunker fuel has being used in the shipping industry increasingly from the 1950's since it is the primary power source for the vessel engine. In maritime industry fuel oil is considered one of the most crucial costs, of which the cost may be up to approximately 70% of the carriers cost.

Bunker fuel is known as ship fuel. Seaborne transportation carries more than 80% of global trade volume, and bunker fuel cost accounts of the majority of international transportation cost. Global bunker fuel market had the trading value of $97,203 million in 2016, and is expected to develop with a CAGR (compound annual growth rate) of 9.6% between 2017 and 2023, reaching $142,489 million. Bunker fuel could be classified as type, residual fuel oil and distillate oil (divided into marine gas oil and marine diesel oil). Residual fuel oil is the thickest, heaviest part left over after refineries have processed all the more valuable fuels from the crude source. It has high viscosity, requiring pre-heating before being poured into vessel engines and specific temperature for storage and pumping. The cost of transporting bunker oil from a distant refinery is extremely high due to the excessive weight of bunker fuel. Thus, bunker fuel is mainly stored at major ports or some refineries close to the port for bunkering easily and economically. Also, it produces high concentration of pollutants, such as sulphur.

The most commonly used bunker fuel at deep sea or at international transportation are the residual fuel oil, the Intermediate Fuel Oils 180 and 380 (hereinafter IFO 180 and IFO 380). IFO 180 is are composed of 98% of residual oil and 2% of distillate oil. A combination of 88% of residual oil and 12% of distillate oil is IFO 380. Due to the higher content in distillate oil, IFO 380 is more expensive than IFO 180. This study only takes example for IFO 380 to investigate dynamic volatility spillovers of bunker fuel markets. Therefore, in this study bunker fuel market (hereinafter bunker market) is specific to the bunker market trading IFO 380, and bunker fuel is specific to IFO 380.

Bunker fuel prices vary widely from market to market. The shipping costs and bunker fuel rates are affected by various inclusive charges including crude oil charges. Namely, even though all bunker fuel are extracted from crude oil and changes in crude oil prices have a straight and immediate effect on bunker price, there are also other numerous factors which affect the pricing of bunker fuel, such as speculation in the crude oil market, refining priorities and capacity constraints, inherent difficulties for vessel operators in storing fuel or hedging fuel risk. Though bunker fuel is traded at different price at all ports over the world, the majority of trading volume of bunker fuel is centered on limited and busy ports. Generally, primary bunkering locations are those along major trading routes and around choke points, for instance the port of Singapore and Fujairah. Thus, this work studies 12 bunker markets.

Bunker fuel makes the global shipping industry move and powers seaborne trade. As the main fuel consumptions of vessels, bunker fuel price directly impacts on costs and earnings of running a ship or a ship company. The higher bunker rate makes the increase of expenses for operating a ship, while the lower bunker price could decrease the costs and increase the earnings of conducting ships and companies. For instance, IFO380 prices in Singapore and other global hubs rose almost 15% in early 2013, while freight rates headed in the opposite direction. In the worse situation with lower freight rates and higher oil prices, bunker fuel cost can easily account for up to 70% of daily ship operating costs. It definitely burdens the shipping companies.

If the prices of an asset fluctuate dramatically over a long period of time, it has a higher volatility. If the prices of an asset do not fluctuate dramatically but change slowly or steadily over a short time period, then it has a lower volatility. The volatility could be explained as the risk in asset price, and the higher volatility reflects more unstable markets. The higher the volatility is, the larger the risk of bunker fuel markets are. High price volatility implies more uncertainty and risk, and hence sudden and large shifts in bunker price volatility would hurt international trade, regional markets and economic growth. Since global bunker markets are linked with each other by international trade and ocean transportation, shocks to one bunker market will transmit to other bunker markets. Meanwhile, the price volatility of one bunker market also acts in response to that of other markets and then the bunker market become more volatile. This motivates stakeholders with price exposure to explore the volatility of bunker markets around the world and the dynamic spillovers among bunker markets as so to manage bunker market risk.

Bunker market risk management has become a crucial issue in recent years. The interest on this specific asset class, bunker fuel, has been pronounced due to the dramatically larger price volatility after the 2000s. Shipowners, charterers and bunker suppliers are exposed to global fluctuations of bunker prices, which is closely associated with costs and earnings of their enterprises. It is well known from previous literatures that part of the volatility of bunker markets sources from shipping freight market and crude oil market. But it is also required to be explored that under economic integration how the volatility of global bunker markets spills over mutually. Therefore, it is of utmost importance for ship owners, operators and shipping banks alike to have a deep understanding of the volatility properties of bunker market and volatility spillovers between different markets. This study concentrates on exploring the volatility over distance among bunker markets and on how volatility of regional bunker markets reacts with each other.

The objective of this study is to find out static and dynamic independence and spillovers of the volatility among global bunker markets, explore the volatility spillovers of global bunker markets over distance and scrutinize whether there exists a net volatility transmitter from one market to other markets in different regions and over the world. Specifically, this study is firstly to capture the volatility series of bunker markets and to analyze the properties of the market volatility. Secondly, spillover index are derived from variance decomposition, which is proposed by Diebold and Yilmaz (2009). Based on this approach and spillover index, we examine dynamic volatility spillovers among bunker markets in Asian, European, American region and international scale, respectively. And then, we examine whether there exists a powerful bunker market in each region. Thirdly, the static and dynamic volatility spillover effects among global bunker markets are studied, including total, directional and net (pairwise) volatility spillovers. It is investigated if there is a strong bunker market which mainly transmits volatility to other markets other than receives. And we also study how shocks to one market spill over to other markets in term of geographical distance. Namely, whether market volatility from one market will have a larger effect on geographically neighboring market.

The rest of the paper is organized as follows. Section 2 displays the literatures review. Section 3 describes the related data. Section 4 discusses the econometric methodology used. Section 5 reports the results and findings. Section 6 concludes this paper.

2. Literature Review

The issue of information transmission between financial markets is widely investigated by numerous papers. Specifically, it focuses on how information from one future market is transmitted to another spot (futures) market. Empirical research of information transmission is researched by the price discovery and volatility spillovers. Although price discovery is of significance to study information transmission, our research doesn't consider it because the price discovery is frequently employed to explore futures markets (Chan, 1992; Ghosh, 1993). Thus, we only analyze volatility spillovers among bunker markets to discuss information transmission.

Tao & Green (2012) documents that there exists volatility spillovers hypothesis when a news shock to whichever market will enlarge volatility in all markets. Thus, the key of exploring volatility spillovers is investigating how shocks to one market lead to the changes of volatility in other markets. Most studies employ GARCH-family models to explore the volatility spillovers in financial markets, and in recent years the study of volatility spillovers is introduced into shipping freight markets. However, there is little research on information transmission and the volatility spillovers in bunker fuel markets.

2.1. Volatility spillover

The study of Drobetz et al. (2012) explores whether incorporating macroeconomic factors or asymmetric effects into GARCH model, could better explain the volatility in shipping freight markets. Namely, by comparing the three specifications, GARCH-X, EGARCH and EGARCH-X, it confirms that both macroeconomic forces and asymmetric effects have a significant influence on the volatility in the tanker freight market and could be incorporated into conditional variance equation.

Tao and Green (2012) adopt DCC-TGARCH-M to exploring the contemporaneous relationships between volatilities. Then, they study volatility spillovers between spot and futures markets by the Cross-Correlation Function (CCF) for testing causality-in-variance between two markets proposed by Cheung and Ng (1996). They find that the existence of significant volatility asymmetries in both the FTSE100 spot index and index futures prices: negative volatility news shocks have a significantly larger effect on the conditional variance in each market than do positive shocks. The CCF tests suggest that variance shocks in each market are impounded more-or-less simultaneously in both markets.

2.2. Spillover index

Diebold and Yilmaz (2009) proposed the spillover index approach, which could measure the contributions of shocks to variables to the forecast error variances of all variables in model. The dynamics of spillovers and spillover plots could be obtained by using rolling-window estimation. Based on the approach in Diebold and Yilmaz (2009), Diebold and Yilmaz (2012) extend their method from two aspects. Firstly, they further assess the directional and net spillovers by decomposing total spillovers and identifying the transmitters and recipients of spillovers. Secondly, they identify that forecast-error variance decompositions are unrelated to the ordering of the variables in employing a generalized vector autoregressive framework.

After Diebold and Yilmaz (2009), Antonakakis et al. (2016) introduce the spillover index to explore the dynamic spillovers(interdependences) between spot and futures markets volatilities. Also, they use robustness checks to support their findings. Tsouknidis (2016) uses the DCC-MGARCH (the dynamic conditional correlation multivariate GARCH) model to capture the dynamic volatility spillovers over time and across shipping freight markets. The volatility spillovers in this paper are decomposed to be the total, directional, net and net pairwise one. Dynamic spillover effects across petroleum spot and futures volatilities, trading volume and open interest are explored by Magkonis and Tsouknidis (2017), with the approach of the D&Y spillover index.

In order to fuel cost controlling and risk hedging, market participants, such as shipowners and charterers, need to know co-movement of global bunker markets and the sensitivity of bunker markets to changes of volatility in other markets induced by exogeneous shocks. For instance, once a fixture is settled for shipping between Singapore and Hong Kong, changes of bunker price in those two markets affect fuel costs and profits made from this fixture. Thus, it is necessary to figure out the dependence among bunker markets and how shocks to one market affects other markets. This study is mainly drawn attention on by how the volatility of global bunker markets are related to each other. It examines that to what extent markets' economic and geographical relations affect volatility spillovers among main bunker markets as well as market co-movement.

Previous studies do not consider volatility spillovers in bunker markets and the contribution of distance to volatility transmission. Namely, shocks to one bunker market spill over to other bunker markets in term of geographical distance. Also, the spillover index method is not introduced into analyze volatility spillovers in bunker markets before. This research constructs the spillover index, proposed by Diebold and Yilmaz (2012), in bunker markets to examine how information in one bunker market is transmitted to other markets and if the magnitude of spillovers from one market to different markets is variant in terms of the distance between two markets.

3. Data

3.1. Data sources

Bunker fuel prices vary from market to market. Since global bunker markets, located in different geographical positions, are linked with each other by international trade and ocean transportation, shocks to one bunker market probably transmits to other bunker markets and contributes to the fluctuations of other bunker markets. Most previous studies focus on volatility spillovers in financial markets. This study focuses on exploring how the volatility spillovers among bunker fuel markets and initiatively considers the 'distance' variable into spillovers of market volatility. The data employed in this study can be accessed by Clarksons Shipping Intelligence Network (SIN). This study takes example for IFO380, one of main marine fuel oils for international vessels, to explore volatility of bunker fuel and volatility spillovers among bunker markets. Thus, the bunker price quoted in this research is the price of IFO380 bunker fuel. And monthly IFO380 bunker prices data in 12 markets run from December 2001 to May 2017. All bunker price data is transformed in logarithm. And the 12 bunker markets are separated into three regions, Asia, Europe and America, respectively. Asia region includes the Singapore, Hong Kong, Japan and Korea market; Europe region covers the Rotterdam, Gibraltar, Genoa and Fujairah market; and America region embraces the Houston, Philadelphia, Panama and Los Angeles market. Due to the data limit, the data of bunker fuel price in Gibraltar market runs from January 2008 to May 2017. Except Gibraltar market, there are total 185 observations in each bunker market.

The economic rationale for bunker markets selected in this study is that those markets trade the great majority of bunker fuel. The Singapore Port in Asia Pacific is currently the largest port of trade volume of bunker fuel in the world. The Port of Fujairah is also a large bunkering port, which occupy the important share of bunker trading volume in global market. Europe has a large amount of the busiest trading routes in the world. The Port of Rotterdam and Gibraltar located in choke positions are highly appealing and busy bunkering destinations. Additionally, the port of Fujairah is classified as one port in Europe region in this study. The reason behind is as follows. There are a large number of busy routes from Persian Gulf to Red Sea and Mediterranean Sea, and frequent ocean transportation as well as international trade makes the linkage between Fujairah port and other European ports tighter and closer.

Since there exist unit roots among the bunker price of Singapore, Hong Kong, Japan, Korea Rotterdam, Gibraltar, Genoa, Fujairah, Houston, Philadelphia, Panama and Los Angeles, the 12 original series are not stationary. By analyzing Johansen's cointegration tests (Johansen, 1988; Johansen and Juselius, 1990), it shows that all the 12 prices have mutually cointegration relationships in the long term. And all the time-series are integrated of order one. To make the original data stationary and eliminate a unit root, those original series are transformed by the first-order difference. The differenced data are examined by stationary test and Granger-causality test (Granger, 1986). Granger causality test is a technique for determining whether there exits the causality between two variables. And Augmented Dickey-Fuller test (Dickey and Fuller, 1979) for testing unit roots shows that the t-statistics value of the first-order difference price is smaller than the critical value, which illustrates that the transformation series are stationary and significant. Namely, all series of differenced price are stationary and do not have a unit root. With the Augmented Dickey-Fuller (ADF) test, all the first-order difference data could be used into the subsequent analyses. Though the volatility of the differenced price measures the volatility of price changes over time, it also reveals the volatility of prices in different bunker markets. And we denote DS, DHK, DJP, DKR, DR, DGI, DGE, DFUJ, DH, DPH, DPAN and DLA as the first-order difference (changes) of bunker price of Singapore, Hong Kong, Japan, Korea, Rotterdam, Gibraltar, Genoa, Fujairah, Houston, Philadelphia, Panama and Los Angeles, respectively.

3.2. Descriptive statistics of bunker market volatility

As Table 1 and Figure 2 shows, the descriptive statistics and plots of monthly price series in 12 markets are analyzed. The trends are similar in the plots of price changes in 12 ports, and it is difficult to directly find out the relationship of bunker price changes among different regional markets. So does the Figure 3, which plots market volatility series of 12 bunker markets.

Table 8: Descriptive Statistics of 12 prices at Bunker markets

	DS	DHK	DJP	DKR
Mean	1.043946	1.050649	1.250649	1.104054
Median	1.870000	1.630000	1.370000	2.870000
Maximum	90.25000	95.62000	101.7000	123.7500
Minimum	-187.7800	-177.0700	-207.0000	-210.3000
Std. Dev.	33.38843	33.06552	33.82533	33.76874
Skewness	-1.981611	-1.673186	-1.967819	-1.661439
Kurtosis	13.01898	11.16743	14.85153	12.89397
Jarque-Bera	894.8374	600.5190	1202.099	839.6862
Probability	0.000000	0.000000	0.000000	0.000000
Sum	193.1300	194.3700	231.3700	204.2500
Sum Sq. Dev.	205120.8	201172.4	210524.2	209820.4
Observations	185	185	185	185

	DR	DGI	DGE	DFUJ
Mean	0.981081	-1.442857	1.085838	1.068919
Median	4.100000	2.275000	4.230000	3.580000
Maximum	85.74000	97.50000	89.50000	88.00000
Minimum	-180.3700	-192.5000	-179.5500	-176.3000
Std. Dev.	32.24923	39.26894	32.48209	33.31348
Skewness	-1.664488	-1.528030	-1.674532	-1.802689
Kurtosis	10.18469	8.593538	10.17460	11.51943
Jarque-Bera	483.3272	189.5935	483.2440	659.6751
Probability	0.000000	0.000000	0.000000	0.000000

(Continued) Table 9: Descriptive Statistics of 12 prices at Bunker markets

	DR	DGI	DGE	DFUJ
Sum	181.5000	-161.6000	200.8800	197.7500
Sum Sq. Dev.	191362.4	171167.5	194135.8	204200.9
Observations	185	112	185	185

	DH	DPH	DPAN	DLA
Mean	0.991892	1.091892	1.002054	1.211459
Median	3.250000	3.750000	3.500000	2.050000
Maximum	91.75000	102.1300	112.0000	103.6000
Minimum	-178.5000	-185.9000	-169.3000	-201.4000
Std. Dev.	33.64485	33.80100	33.62620	34.46655
Skewness	-1.574663	-1.458742	-1.342862	-1.675492
Kurtosis	10.33786	9.400746	9.584729	11.83351
Jarque-Bera	491.5024	381.4181	389.8240	688.0458
Probability	0.000000	0.000000	0.000000	0.000000
Sum	183.5000	202.0000	185.3800	224.1200
Sum Sq. Dev.	208283.6	210221.4	208052.8	218581.5
Observations	185	185	185	185

Note: DS/DHK/DJP/DKR/DR/DGI/DGE/DFUJ/DH/DPH/DPAN/DLA = the first difference of bunker price at Singapore/HongKong/Japan/Korea/Rotterdam/Gibraltar/Genoa/Fujairah/Houston/Philadelphia/Panama/Los Angeles port
Observation period: January 2002 to May 2017

4. Empirical Model and Methodology

For fuel cost controlling and risk hedging, market participants, such as shipowners and charterers, need to know co-movement of global bunker markets and the sensitivity of those markets to exogeneous shocks. For instance, once a fixture is settled for shipping between Singapore and Hong Kong, changes of bunker price in those two markets affect fuel costs and profits made from this fixture. Thus, it is necessary to figure out the dependence among bunker markets and how shocks to one market affects other markets. This study is mainly drawn attention on by how global bunker markets are related to each other. This study examines that to what extent markets' economic and geographical relations affect their bunker market co-movements, by investigating how market volatilities spill over among main bunker markets.

Numerous studies on market volatility and market interdependence focus on financial markets. In this study, volatility spillovers in bunker markets are quantitatively analyzed by using a two-step approach. Firstly, the series of volatilities are specified by the dynamic conditional correlation GARCH (DCC-GARCH) model, which is proposed by Engle (2002), to explore and capture the volatility in bunker markets. Secondly, spillover indices, which are proposed by Diebold and Yilmaz (2009), are derived from variance decompositions based on 10-step-ahead forecasts. Based on this approach, we examine dynamic volatility spillovers among bunker markets in Asian, European, American region and international scale, respectively.

Volatility spillover hypothesis is that shocks in one market will transmit to other related markets and increase their market volatilities (Tao & Green, 2012). Previous papers adopt GARCH-family models to exploring the volatility spillovers in various cash and futures markets. Our study constructs the spillover index in bunker markets to investigate the volatility spillovers over distance according to the approach of Diebold and Yilmaz (2009,2012). Specifically, the generalized Vector Autoregression (VAR) model of Koop, Pesaran, and Potter (1996) and Pesaran and Shin (1998), called KPPS, is adopted to explore the volatility spillovers among regional markets, which mainly concentrates on variance decompositions and distills information transmission. The

VAR of KPSS produces variance decompositions which are invariant to the ordering of variables. Specifically, the spillover index is calculated by using the forecast error variance decomposition method of the VAR model. It could appraise the contributions of shocks to one market to the forecast error variances of both the market and other markets in the model. Namely, the spillover index derived by this approach could reflect how much of volatility transmits among bunker markets.

Orthogonal innovations are necessary in order to calculate variance decompositions, but innovations of this study are correlated. Using Cholesky factorization to identify, the orthogonality could be achieved and meanwhile variance decompositions are related to the orderings of the variables in the model. As mentioned above, the VAR framework of KPSS avoids this problem. This approach does not orthogonalizes shocks. Oppositely it allows the correlated shocks and employs the observed distributions of errors to consider the correlated shocks. Since the shocks to each variable are not orthogonalized, the sum of contributions to the forecast error variance is not always equal to one. Namely, the sum of raw elements in variance decomposition table is not always equal to one.

First of all, the framework of the generalized VAR is given by,

$$\boldsymbol{V_t} = \sum_{i=1}^{n} \boldsymbol{\beta_i V_{t-i}} + \boldsymbol{\varepsilon_t}, \quad (1)$$

where $\mathrm{V_t} = (\mathrm{V_{1,t}}, \mathrm{V_{2,t}}, \dots \mathrm{V_{M,t}})$ is a vector of M endogenous variables, $\beta_i, i = 1 \dots n$, are M × M parameter matrices and $\boldsymbol{\varepsilon_t} \sim (0, \Sigma)$ is a vector of disturbances that have independent distribution over time; $t = 1, \dots, T$ is denoted as the time; $i = 1 \dots n$ is the lag order. The moving average representation is

$$\boldsymbol{V_t} = \sum_{j=0}^{\infty} \boldsymbol{P_j \varepsilon_{t-j}}, \quad (2)$$

where $\boldsymbol{P_j}$ is M × M parameter matrices, and $\mathrm{P_j} = \beta_1 \mathrm{P_{j-1}} + \beta_2 \mathrm{P_{j-2}} \dots + \beta_n \mathrm{P_{j-n}}$.

Variance decompositions could decompose the forecast error variances of each variable into parts attributed to the various shocks. According to Diebold and Yilmaz (2012), the ij entry of the H-step-ahead forecast error variance decomposition is $\theta_{ij}(H)$,

$$\theta_{ij}(H) = \frac{\sigma_{jj}^{-1} \sum_{h=0}^{H-1} (e_i' P_h \Sigma e_j)^2}{\sum_{h=0}^{H-1} (e_i' P_h \Sigma P_h' e_i)} \quad (3)$$

Σ is the (estimated) variance matrix of the error vector $\boldsymbol{\varepsilon}$, σ_{jj} the (estimated) standard deviation of the error term for the j^{th} equation and e_i a selection vector with one as the i^{th} element and zeros otherwise.

M × M matrix $\theta(\mathrm{H}) = [\theta_{ij}(\mathrm{H})]_{i,j=1 \dots M}$, in which the main diagonal elements represent the own contributions of shocks to the market j to its own forecast error variance; and the off-diagonal elements show the cross contributions of shocks to the market i to the forecast error variance of market i, $i \neq j$, which means that the off-diagonal ones could be employed to illustrate possible spillovers.

Each element in M × M matrix $\theta(\mathrm{H}) = [\theta_{ij}(\mathrm{H})]_{i,j=1 \dots M}$, is normalized by the row sum, as following,

$$\tilde{\theta}_{ij}(H) = \frac{\theta_{ij}(H)}{\sum_{j=1}^{M} \theta_{ij}(H)}, \quad (4)$$

then, $\sum_{j=1}^{M} \tilde{\theta}_{ij}(H) = 1$, $\sum_{i,j=1}^{M} \tilde{\theta}_{ij}(H) = M$.

Thus, the total volatility spillovers (TVS) could be obtained by

$$TVS(H) = \frac{\sum_{i,j=1;i\neq j}^{M} \tilde{\theta}_{ij}(H)}{\sum_{i,j=1}^{M} \tilde{\theta}_{ij}(H)} \tag{5}$$

The directional spillovers received by market i from all other markets j are

$$DVS_{FROM}(H) = \frac{\sum_{i,j=1;i\neq j}^{M} \tilde{\theta}_{ij}(H)}{\sum_{i,j=1}^{M} \tilde{\theta}_{ij}(H)} \tag{6}$$

The directional spillovers transmitted by market i to all other markets j as

$$DVS_{TO}(H) = \frac{\sum_{i,j=1;i\neq j}^{M} \tilde{\theta}_{ij}(H)}{\sum_{i,j=1}^{M} \tilde{\theta}_{ij}(H)} \tag{7}$$

Net spillovers from market i to all other markets j are

$$NVS_i = DVS_{TO}(H) - DVS_{FROM}(H) \tag{8}$$

which gives the information that the market i is a net transmitter or receiver.

The net pairwise spillovers focus on the interdependence of pairwise markets, by denoting

$$NPVS_{ij}(H) = \frac{\tilde{\theta}_{ij}(H)}{\sum_{i,j=1}^{M} \tilde{\theta}_{ij}(H)} - \frac{\tilde{\theta}_{ji}(H)}{\sum_{i,j=1}^{M} \tilde{\theta}_{ij}(H)} \tag{9}$$

Based on the derived spillovers index, this study examines static and dynamic volatility spillovers among bunker markets in Asian, European, American region and international scale, respectively. In the first subsection, the volatility spillovers in regional markets are studied. Global bunker markets are separated as three regions: Asia region, Europe region and America region. According to geographical locations, Singapore, Hong Kong, Japan and Korea market (Rotterdam, Gibraltar, Genoa and Fujairah market/Houston, Philadelphia, Panama and Los Angeles market) belongs to Asia region (Europe region/America region). It is intended to explore whether there exists a central market in each region, mainly transmitting volatility to other markets within the region in term of geographical distance. After the first subsection of obtaining the three central bunker markets, the volatility spillovers among the three central markets are discussed. Namely, it is examined if there exists a dominated market which is still spilling over volatility to others among the three markets. Finally, the volatility spillovers among the dominated market and other markets over the world are investigated. It attempts to analyze that how shocks to Singapore market transmits volatility to global bunker markets over geographical distance.

Additionally, static and dynamic volatility spillovers are analysed, including total, directional, net (pairwise) spillovers.

5. Empirical Findings

The volatility spillovers in bunker markets are analysed by using the two-step approach. Firstly, the volatilities series of 12 bunker markets are obtained from the dynamic conditional correlation GARCH (DCC-GARCH) model. Secondly, the spillover indices are derived from variance decompositions of the generalized VAR model. Based on BIC (Schwarz Bayesian Information Criterion), the optimal lag length for the VAR models in Houston, Philadelphia, Panama and Los Angeles market is the second-order lag, and the optimal lag length Singapore, Hong Kong, Japan, Korea, Rotterdam, Gibraltar, Genoa and Fujairah market is the first-order lag. Section 5.1 shows the results of volatility spillovers over distance in regional markets. Section 5.2 presents the estimation results of volatility spillovers among three central markets. Section 5.3 reports the results of volatility transmissions from the dominated market to others in term of geographical distance.

5.1 Volatility spillovers in three regions

5.1.1 Static spillovers

In this part, the volatility spillovers over distance in regional markets are explored. We separate global markets as three regions: Asia, Europe and America region. Asia region includes the Singapore, Hong Kong, Japan and Korea market; Europe region covers the Rotterdam, Gibraltar, Genoa and Fujairah market; and America region embraces the Houston, Philadelphia, Panama and Los Angeles market.

Table 10: Volatility Spillovers in Asia region

Spillover Table

	DS	DHK	DJP	DKR	From Others
DS	49.5	14.8	6.9	28.8	50.5
DHK	47.4	18.3	5.3	29.0	81.7
DJP	44.2	13.0	10.1	32.7	89.9
DKR	46.9	17.1	1.8	34.2	65.8
Contribution to others	138.5	44.9	13.9	90.6	287.9
Contribution including own	188.0	63.2	24.0	124.8	72.0%

Note: S denotes Singapore market; HK, Hong Kong market; JP, Japan market; KR, Korea market.

Table 11: Volatility Spillovers in Europe region

Spillover Table

	DR	DGI	DGE	DFUJ	From Others
DR	64.8	19.2	5.4	10.7	35.2
DGI	60.1	23.5	4.9	11.5	76.5
DGE	62.0	21.0	6.6	10.3	93.4
DFUJ	60.8	20.8	4.6	13.8	86.2
Contribution to others	182.9	61.0	14.9	32.5	291.3
Contribution including own	247.7	84.5	21.5	46.3	72.8%

Note: R denotes Rotterdam market; GI, Gibraltar market; GE, Genoa market; FUJ, Fujairah market.

Table 12: Volatility Spillovers in America region

Spillover Table

	DH	DPH	DPAN	DLA	From Others
DH	76.5	3.8	18.8	0.8	23.5
DPH	70.5	4.4	24.0	1.1	95.6
DPAN	67.1	2.3	29.8	0.8	70.2
DLA	66.9	2.5	22.1	8.5	91.5
Contribution to others	204.5	8.7	64.9	2.7	280.8
Contribution including own	281.1	13.1	94.6	11.2	70.2%

Note: H denotes Houston port; PH, Philadelphia market; PAN, Panama market; LA, Los Angeles market.

The results in Table 2 to 4 give the evidence that the total volatility spillovers in each region vary similarly with one shock in each region. The values of the total volatility spillovers in three tables are around 70%. The total spillover index indicates that around 70 percentage of the total volatility in each region sources from spillovers when markets are shocked by news. In Table 2, shocks to Singapore market lead to transmitting 138.5 volatilities to other three markets, which explains 48% of the total volatility spillovers in Asia market. In Table 3, shocks to Rotterdam market result in spilling over 182.9 volatilities to other three markets, which occupies 63% of the total spillovers in Europe region. In Table 4, shocks to Houston market contribute to transmitting 204.5 volatilities to other three markets, which accounts for 73% of the total volatility spillovers in America region.

The directional volatility spillovers in regional markets consist of the spillovers to other markets from one market, denoted as ‘Directional To’, and the spillovers from other markets, denoted as ‘Directional From’. If the difference between ‘Directional To’ and ‘Directional From’ spillovers of one market, named as net (volatility) spillovers, is positive, it means that the market transmits much more volatility to others rather than receives, and that the market has the larger power to affect others rather than to be affected. From the tables in this subsection, Singapore (Rotterdam/Houston) market could transmit much more volatility to other three markets in the region of Asia (Europe/America). Namely, shocks to Singapore market incline to have extremely large contributions to both Singapore and other three regional markets, whereas shocks to Hong Kong/Japan/Korea market tend to have tiny influence on itself but also Singapore market. It indicates that Singapore market has a volatility lead effect to Hong Kong/Japan/Korea market in Asia. The situation in Europe and America region is similar to Asia region. Thus, Singapore (Rotterdam/Houston) market is regarded as the regional central market in Asia (Europe/America) when discussing volatility spillovers. Additionally, if there are only two markets in one region and the difference between ‘Directional To’ and ‘Directional From’ spillovers, named as net pairwise (volatility) spillovers, is positive, it means that one market transmits much more volatility to the other one rather than receives, and that the former market has the larger power to affect the other one rather than to be affected.

On the basis of ocean transportation routes, the geographical distance from Singapore (Rotterdam/Houston) to other regional markets ranks by increase as follows. The rank is Hong kong, Japan and Korea in Asia, Gibraltar, Genoa and Fujairah in Europe, and Philadelphia, Panama and Los Angeles in America. From the three tables above, as the geographical distance increases from the regional central market to another regional market, the regional central market transmits less volatility to the remoter market within the same region. The three Spillover Table are the static analysis of the volatility spillovers in regional markets.

5.1.2 Dynamic spillovers

From Figure 2, 3 and 4, we discover that the Singapore (Rotterdam/Houston) market is considered as a net transmitter of shocks to other markets over time in the region of Asia (Europe/America). It reconfirms that Singapore (Rotterdam/Houston) market is the regional central market in Asia (Europe/America).

Figure 3: Spillover Plots in Asia

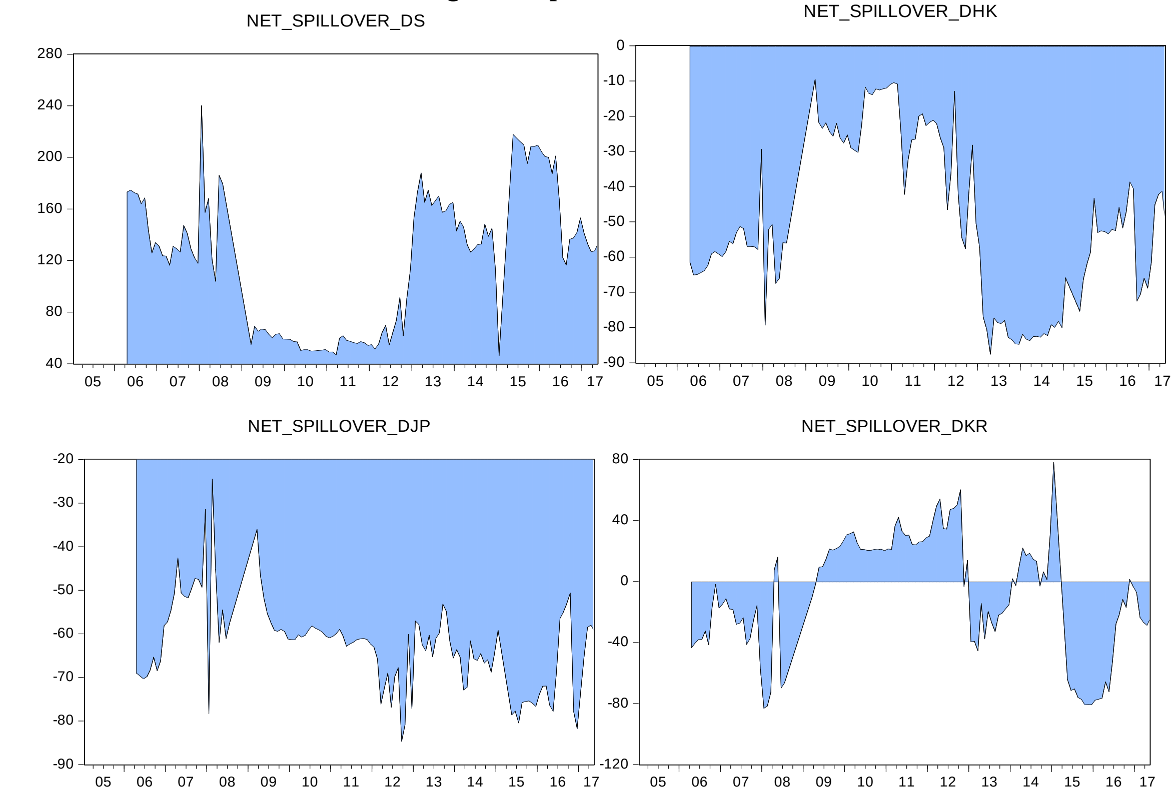


Figure 4: Spillover Plots in Europe

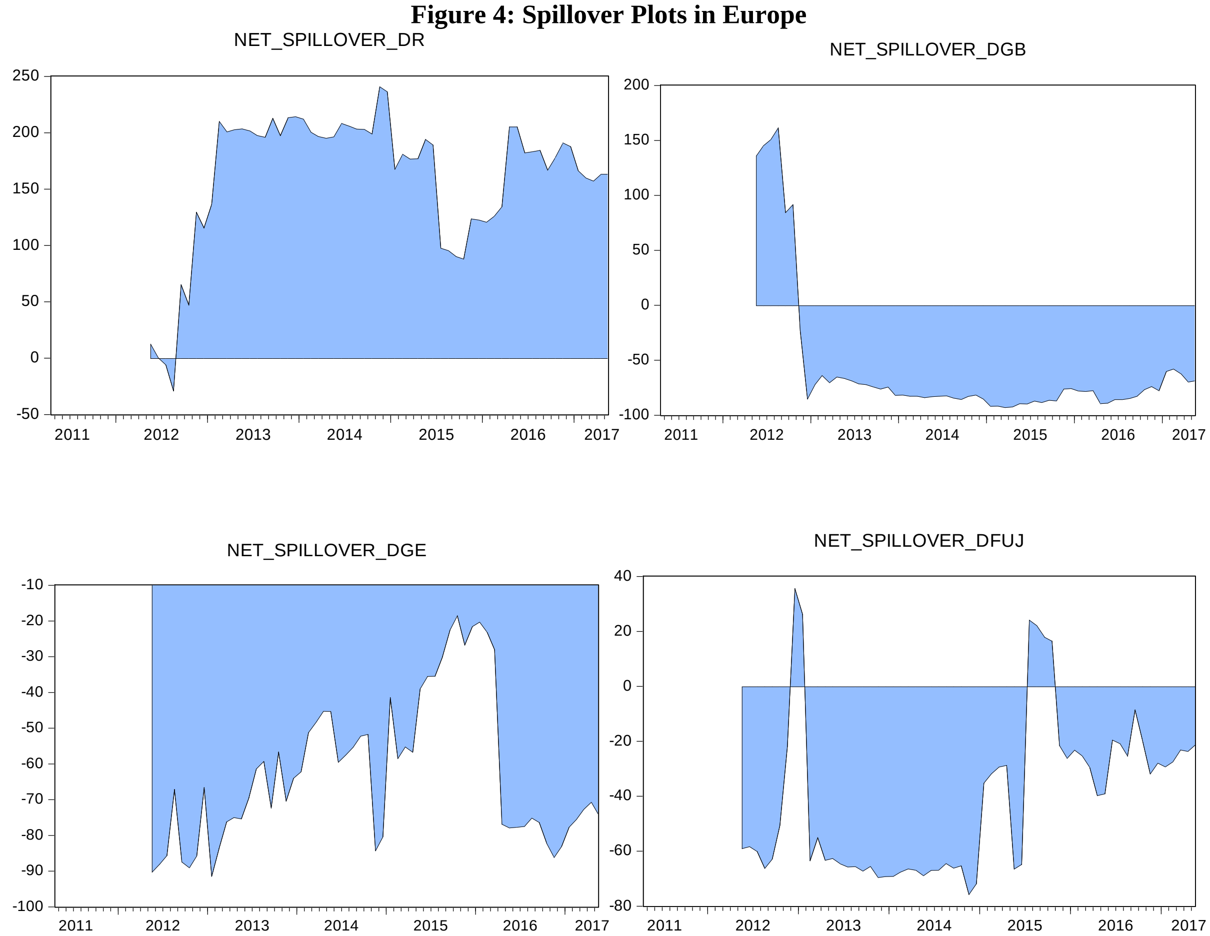
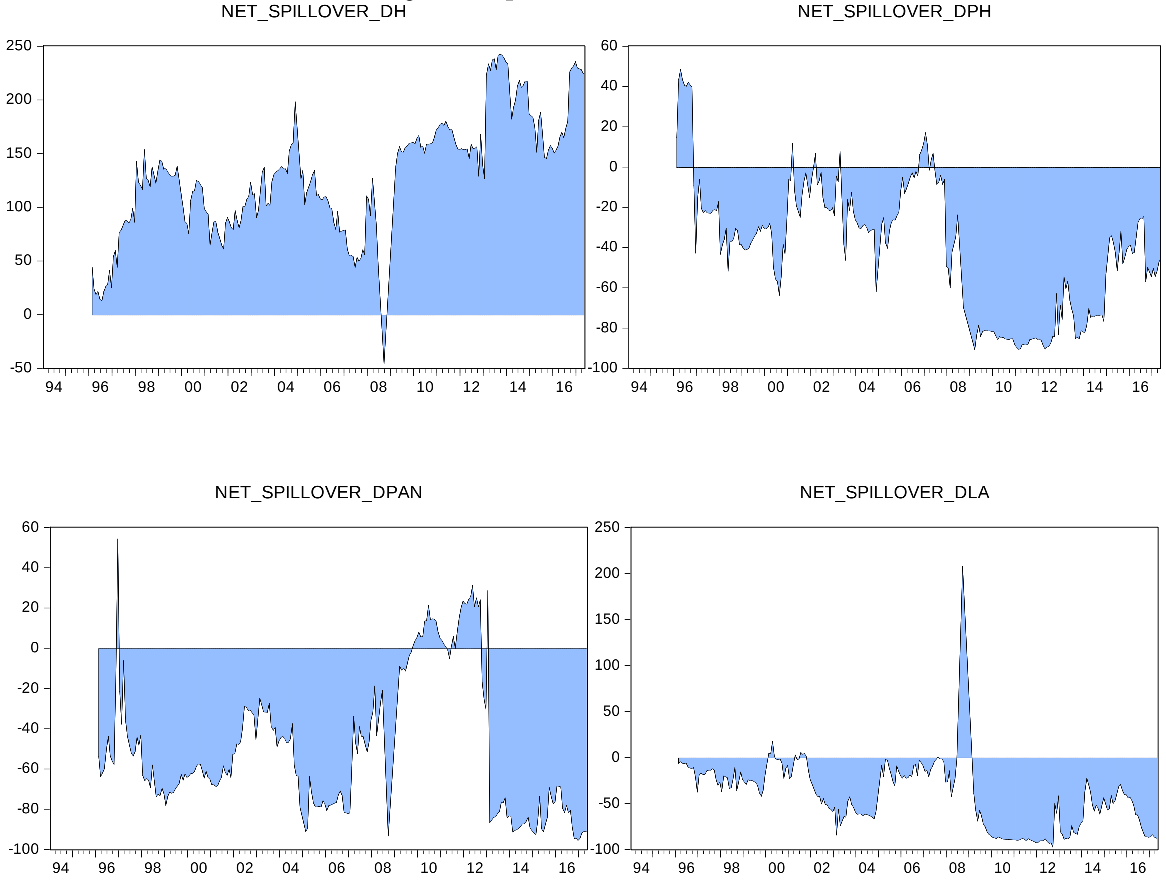


Figure 5: Spillover Plots in America



5.2 Volatility spillovers among three central markets

From Section 5.1, we know that Singapore, Rotterdam and Houston market are the central bunker markets, which spill over the volatility to other regional markets rather than receive. In this section, the spillover relationship among the three central markets are discussed.

Table 13: Spillovers among 3 bunker ports

Spillover Table

	dS	dR	dH	From Others
dS	92.7	0.8	6.5	7.3
dR	91.6	3.5	4.9	96.5
dH	91.5	0.9	7.6	92.4
Contribution to others	183.1	1.7	11.4	196.3
Contribution including own	275.8	5.2	19.0	65.4%

Table 5 shows that the total spillover index is 65.4% among Singapore, Rotterdam and Houston market. It indicates that 65.4 percent of the volatility in the three markets sources from the transmissions. Also, Singapore market still dominates the other two markets in terms of spillovering volatilities. Because the volatility from Singapore market contributing to others is 183.1, but the volatility transmitted from others to Singapore market is only 7.3. Thus, Singapore market has a definite volatility lead effect not only in Asian regional markets but also among the three central markets.

5.3 Volatility spillovers in a global scale

5.3.1 Net spillovers

In this subsection, we explore the volatility spillovers over distance between the dominated market and other markets. Section 2 finds that Singapore market is a dominated market. Thus, this paper analyzes that how shocks to Singapore market transmits volatility to global bunker markets in term of geographical distance.

In Table 6, the total volatilities transmitted are up to 292.2, and 73.1% of the total volatilities among the dominated market and other markets comes from the spillovers.

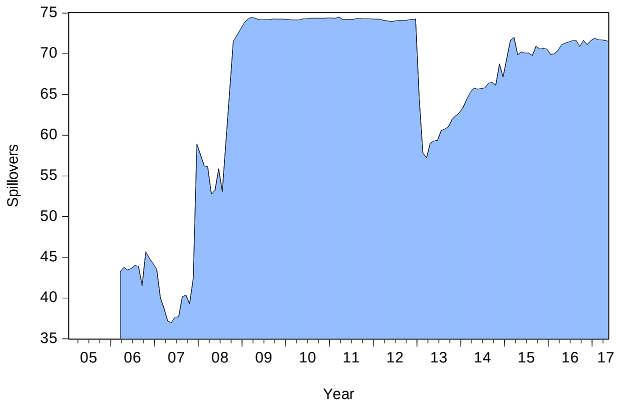
Table 14: Volatility spillovers between dominated market and other markets

Spillover Table

	DS	DHK	DGE	DPAN	From Others
DS	97.7	0.8	1.4	0.1	2.3
DHK	96.3	2.1*	1.6	0.1	97.9
DGE	94.2	1.7	3.9	0.2	96.1
DPAN	92.1	2.2	1.7	4.0	96.0
Contribution to others	282.6	4.6	4.7	0.3	292.2
Contribution including own	380.3	6.7	8.6	4.4	73.1%

* denotes that this value is abnormal in this matrix of Spillover Table.

Figure 6: Dynamics of total spillovers

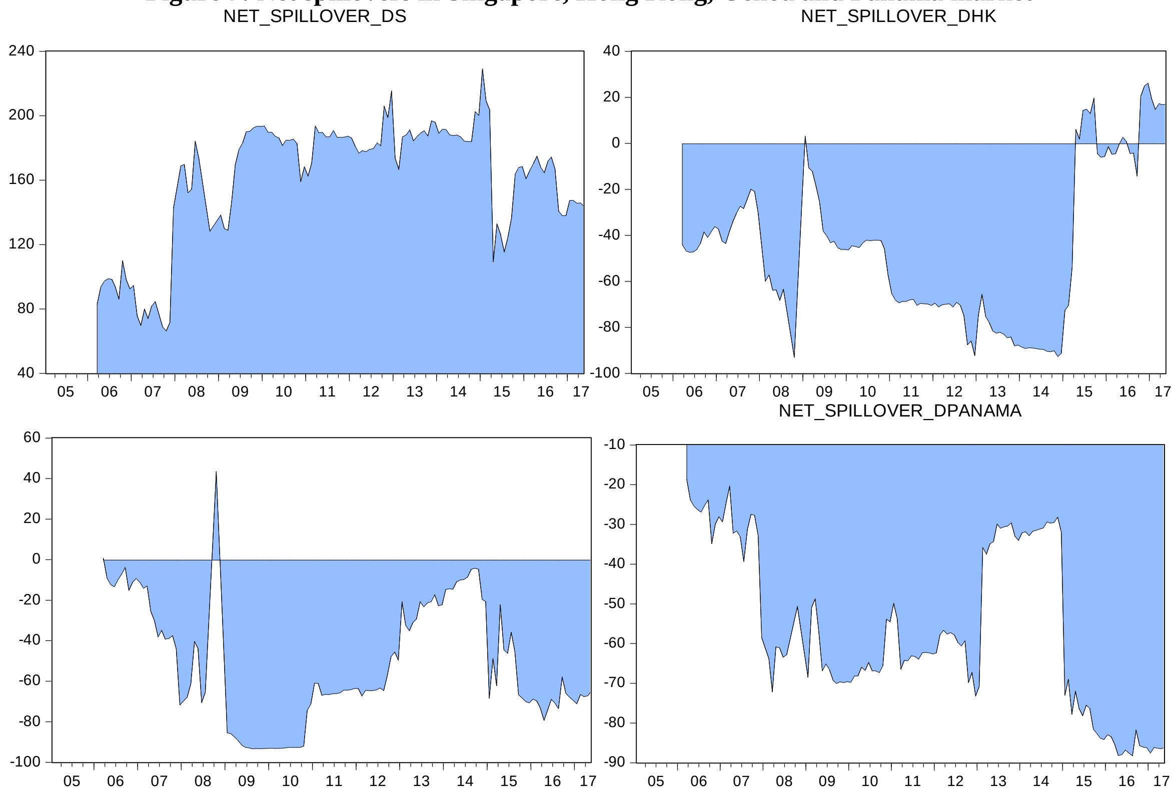


Note: The unit of spillovers in vertical axis is numerical value; it is appropriate for all the vertical axis of figures related to 'spillovers' in this report.

By using 50-month rolling samples, the dynamic total spillovers between Singapore market and other markets are generated as Figure 5. Volatility spillover index began to rise from the late of 2007, reached the peak at the mid of 2008 and then it lasted until 2013. At March 2013 it dropped dramatically. After that, it began to climb gradually. During the mid of 2008 to the end of 2012, the spillover became more stable and also higher. Since all bunker markets are closely related to crude oil market and freight rate markets, the economic linkages make them have a correlation and a co-movement and make them react with each other. Shocks to the changes of volatility in one market probably contribute to transmit the volatility into other markets and make other markets volatile. The increase in volatility spillovers is closely linked with that bunker markets become financialized and that the relationship among markets become tight. While the sharp drops of spillovers reflect that global economy is in inactive situation and that the linkage between markets recedes and weakens.

Directional spillovers in Table 6 show that there exists a leader in bunker markets, Singapore market, which dominates the rest of markets in transmitting the volatility. Specifically, shocks to Singapore market will exert a large effect not only on the volatility of itself but also on that of other bunker markets. However, the asymmetries of directional spillovers in Singapore market incline to increase after 2008. This section proves that there exist bilateral spillovers between dominated markets and other distance-related markets. And the net spillovers of one market is equal to ‘Directional to’ minus ‘Directional from’ spillovers. It explores the feature of a market, ‘receive volatility more or transmit volatility more’. Positive values of the net spillovers illustrate that the market is a net transmitter of volatility, and negative values mean that the market is a net receiver of volatility.

Figure 7: Net spillovers in Singapore, Hong Kong, Genoa and Panama market

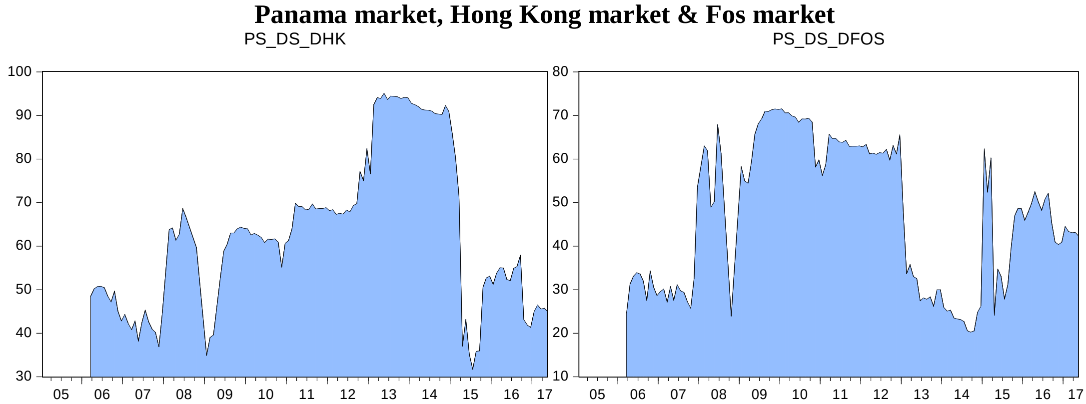


From figure 7, Singapore market is always playing a role as a net transmitter of volatility during all periods; Hong Kong market became a net transmitter of volatility from a net receiver since the mid of 2015; Whereas Genoa market was mainly a net receiver of volatility and became a net transmitter during 2008; Panama market is a net receiver of volatility during all periods.

5.3.2 Net pairwise spillovers

Net pairwise spillovers indicate the volatility spillover between two specific markets. Positive value means that one of two markets is a net transmitter of volatility and the other is a net receiver of volatility.

Figure 8: Singapore market & Hong Kong market, Singapore market & Fos market, Singapore market & Panama market, Hong Kong market & Fos market



(Continued) Figure 8: Singapore market & Hong Kong market, Singapore market & Fos market, Singapore market & Panama market, Hong Kong market & Fos market

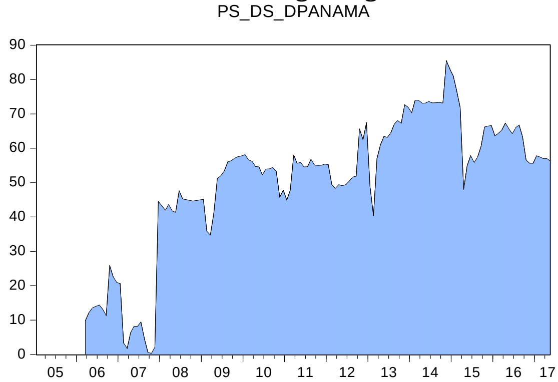


Figure 9: Hong Kong market & Genoa market, Hong Kong market & Panama market

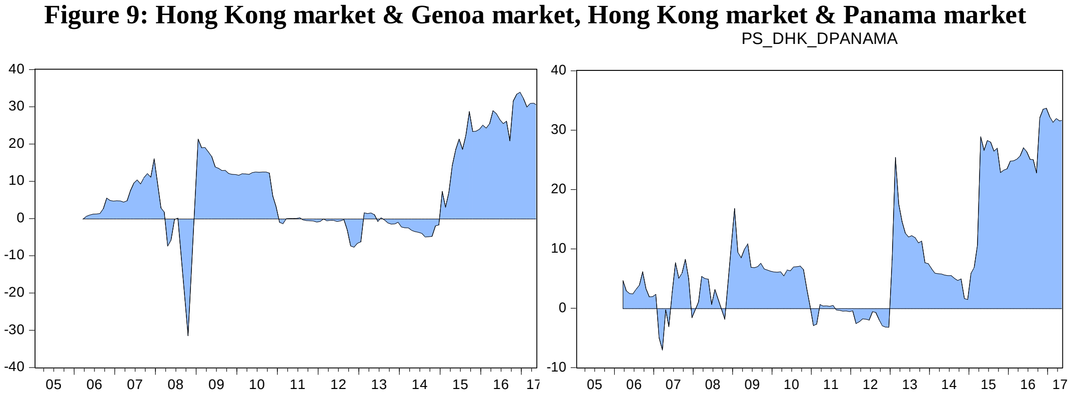
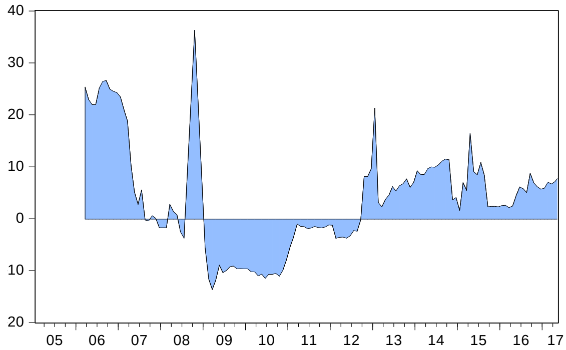


Figure 10 Genoa market & Panama market



Overall, Figure 8,9 and 10 show that Singapore market has a unitary volatility lead effect to other markets over the world. The reaction between bunker markets are closely related to international economy, which significantly impacts the volatility spillovers and interdependences. This paper offers a possible explanation as following. When global economy and international trade is in good condition, volatility spilling over markets is relatively at high level. While global markets are affected by shocks and are in bad condition, volatility transmission drops sharply. Unlike the vehicles in the land, vessels are driven on the sea to every corner over the world. The key feature of bunker fuel markets is that vessels always select those locations or ports to bunkering, in which the rates of bunker fuel are relatively cheaper and more competitive. Thus, bunker fuel markets are closely related to the development and the globalization of the world economy. When the world economy grows and the international trade expands rapidly, the consumption of bunker fuel would be increasingly larger.

6. Conclusions

The volatility could be explained as the risk in bunker fuel, and the higher volatility reflects the more unstable markets. The higher the volatility of bunker fuel markets is, the riskier the markets and the asset (bunker fuel) are. This directly damages the profits of stakeholders. Thus, it is of significance to figure out the volatility features in bunker markets and examine how the volatility of one market impacts on and spills over to other bunker markets. This study suggests that bunker fuel markets spill over volatilities to each other in the international scale.

In this study, volatility spillovers in bunker markets are analyzed by using the two-step approach. Firstly, the series of volatilities are specified by the dynamic conditional correlation GARCH (DCC-GARCH) model. Secondly, spillover indices, which are proposed by Diebold and Yilmaz (2009), are derived from variance decompositions based on 10-step-ahead forecasts. Based on this approach, we examine dynamic volatility spillovers among bunker markets in Asian, European, American region and international scale, respectively. Our analysis provides evidence of bidirectional and asymmetric volatility spillovers among different bunker markets and quantifies the static and dynamic interdependence of volatility in bunker markets, including total, directional and pairwise volatility spillovers. Furthermore, we discover that the Singapore (Rotterdam/Houston) market is considered as a net transmitter of shocks to other markets in the region of Asia (Europe/America). We denote Singapore (Rotterdam/Houston) market as the regional central market in Asia (Europe/America). And normally as the geographical distance increases from the regional central market to another regional market, the regional central market transmits less volatility to the remoter market within the same region. Afterwards, we find that, the Singapore market, which is also the central market from the respective of the globe, is regarded as a net transmitter of shocks to other markets and the magnitude of Singapore market transmitting volatility decreases in general if the geographical distance between two markets increases. But there are some abnormal volatility spillovers that one more distant market receives more volatility from the central market than one more neighboring market does. We suggest that it is attributed to the closer inter-market trade ties between the central market and the distant market.

Also, this study provides the new evidences on information transmissions among different bunker markets and quantify the volatility spillovers effects. Furthermore, the interdependence and spillovers of volatilities are bidirectional and dynamic in all bunker markets. It is found that Singapore market has a unitary volatility lead effect to other markets and mainly transmits volatility to other markets other than receives in global main bunker markets. The power of spillovers in Singapore market is extremely strong, and the scope of its volatility spillovers is also broad. Thus, for each player and stakeholders in bunker fuel markets, shocks to Singapore market as well as itself should be paid more attention to in order to better make profits and hedge risk. Our analysis is important to understand the global market organization of bunkers and its related industries.

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New Developments of Seaworthiness —— In Aspect of the Rotterdam Rules

Shengyun Ding

Law School, Dalian Maritime University, China
Email: shengyunding@dlmu.edu.cn

Abstract

It is an essential obligation of shipowners to provide a seaworthy ship in the contract of affreightment at common law. More exactly, if there is no express provision in the contract of affreightment, the obligation may be considered as an implied one. Moreover, this obligation is absolute, which means that 'the ship will be fit for the purpose intended'. In the case *Steel v State Line Steamship Co*, Lord Blackburn stated that in marine contracts providing a seaworthy ship can be properly considered as warranty. However, if the contract of affreightment is governed by the Hague-Visby Rules, the obligation can be reduced from an absolute obligation to an obligation that only needs to exercise due diligence.

Under the Rotterdam Rules, the obligation of seaworthiness has changed a lot. More precisely, it provides an increased obligation on the carrier to exercise due diligence to ensure the vessel is seaworthiness. The following discussion will be divided into three sections. The first section will discuss the new development of seaworthiness by comparing with the common law and Hague-Visby rules. The second section will analyse the problems presented in the Rotterdam Rules and whether these developments are satisfactory. Finally, the conclusion will be made according to the analysis above.

1. Introduction

Nowadays, many standard forms of charterparties contain express provisions to require seaworthiness of the vessel. For instance, Tanker Voyage Charter Party (" ASBATANKVOY") states that ' the vessel,…, shall, with all convenient dispatch, proceed as ordered to Loading Port(s) named in accordance with Clause 4 hereof, or so near thereunto as she may safely get (always afloat), and being seaworthy'[1]. No matter the obligation of seaworthiness is expressed or implied, it is absolute at common law. However, according to Article III rule 1 of the Hague-Visby Rules, the requirements of seaworthiness contain three aspects: firstly, the physical condition of the vessel should be seaworthy. Secondly, the vessel should be properly manned and equipped.[2] Thirdly, the vessel should be cargoworthiness.[3] In addition, the Hague-Visby Rules do not require a continuing obligation of seaworthiness. A vessel does not need to be seaworthy all through the voyage. The carrier only needs to due diligence to make the vessel seaworthy 'before and at the beginning of the voyage'[4].

In December 2008, the UN General Assembly formally adopted the 'United Nations Convention on Contracts for the International Carriage of Goods Wholly or Partly by Sea', to be known as the 'Rotterdam Rules'.[5] The Rotterdam Rules aims to modernise the existing international rules (such as the Hague Rules, Hague-Visby Rules and the Hamburg Rules) relating to the contract of maritime carriage of goods. Under the Rotterdam Rules, the obligation of seaworthiness has changed a lot. More precisely, it provides an increased obligation on the carrier to exercise due diligence to ensure the vessel is seaworthiness.[6]

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[1] Tanker Voyage Charter Party (" ASBATANKVOY"), Part II 1. See also the New York Produce Exchange Form 1946, line 21-24.
[2] See the Court of Appeal case *Manifest Shipping Co Ltd v Uni-Polaris Shipping Co Ltd & Anor (The Star Sea)*, [1997] C.L.C. 481.
[3] Sea the case *Ben Line Steamers Ltd v Pacific Steam Navigation Co (The Benlawers)*, [1989] 2 Lloyd's Rep. 51.
[4] of The Hague-Visby Rules, Article III rule1
[5] Professor Michael F. Sturley, *A New Convention for the Carriage of Goods by Sea-The Rotterdam Rules*, edited by Professor D Rhidian Thomas, (Witney: Lawtext Publishing Limited, 2009), p 1-2.
[6] The Rotterdam Rules, Article 14.

2. Duration of obligation: from 'before and at the beginning of the voyage' to a continuous obligation.

The obligation for shipowners to provide a seaworthy ship does not mean that the vessel should be perfect. The test of seaworthiness was set up in the case *McFadden v Blue Star Line*, Channell J stated that a vessel a 'must have that degree of fitness which an ordinarily careful and prudent owner would require his vessel to have at the commencement of her voyage having regard to all the probable circumstances of it.'[7] This test can be considered as the 'prudent owner' test. Moreover, as mentioned above, the requirement for the shipowner to provide a seaworthy vessel not only includes the physical condition of the vessel but also includes cargoworthiness. Moreover, the vessel should be properly manned and equipped. More specifically, in the case '*The Arianna*', Webster J stated that a vessel can be considered as an unseaworthy vessel if 'there is something about it which endangers the safety of the vessel or its cargo or which might cause significant damage to its cargo or which renders it legally or practically impossible for the vessel to go to sea or to load or unload its cargo.'[8] That is to say, the shipowner should ensure that the vessel is seaworthy during his obligation period.

2.1 Duration of the obligation under common law

Under the common law, in the case of voyage charter, the obligation to provide a seaworthy ship starts at the time of sailing and discharges if the vessel is seaworthy at the time of sailing. That is to say, it does not matter whether the vessel is seaworthy during the preliminary voyage or at an intermediate port.[9] Consequently, As Channell J Stated in *McFadden v Blue Star Line*[10], the obligation is not a continuing one in the case of voyage charter. Besides, when there is a consecutive voyage charter, the obligation starts at the time of the sailing of each charter.[11] Moreover, in the case of *Biccard v. Shepherd*[12], the court illustrated the principle of the division of a voyage into stages, and the obligation of seaworthiness only attaches at the commencement of each stage for seaworthiness for that stage. Furthermore, in the case of time charter, the situation is different from that in voyage charter, although some of the standard forms require that the shipowner maintain the vessel 'in a thoroughly efficient'[13]During the voyage, it is not the obligation of seaworthiness. At common law, the obligation attaches 'only at the time of delivery of the vessel under the charter party'[14]In time charter.

Furthermore, the obligation to provide a cargoworthy vessel is another issue for shipowners. One of the leading cases of this issue is *McFadden v Blue Star Line*. More exactly, in this case, after the goods were on board and safely loaded, the ship's engineer had occasion to open a sluice-door in a watertight bulkhead in the lower part of the ship. He then shut the sluice-door but failed to screw it down so tightly as to make it watertight. Unfortunately, the water came in and damaged the cargo.[15] Channel J stated that 'I think the warranty is that at the time the goods are put on board she is fit to receive them and to encounter the ordinary perils that are likely to arise during the loading stage; but that there is no continuing warranty after the goods are once on board that the ship shall continue fit to hold the goods during that stage and until she is ready to go to sea.'[16] That is to say, the obligation of cargoworthiness starts from the commencement of loading and discharges when the vessel finishes loading. There is no continuing obligation of cargoworthiness.

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[7] *McFadden v Blue Star Line*, [1905] 1 K.B. 697, p 706.
[8] *Athenian Tankers Management SA v Pyrena Shipping (The Arianna)*, [1987] 2 Lloyd's Rep. 376, p 389.
[9] See the case *Stanton v Richardson*, (1875) LR 9 CP 390.
[10] *McFadden v Blue Star Line*, [1905] 1 K.B. 697, p 703. Channell J stated that the warranty is 'a warranty only as to the condition of a vessel at a particular time, namely, the time of sailing; it is not a continuing warranty in the sense of a warranty that she shall continue fit during the voyage.'
[11] John F Wilson, *Carriage of Goods by Sea*, 6th edition, (England: Pearson Education Limited), p12. See also the case Adamastos Shipping v Anglo-Saxon Petroleum [1958] 1 Lloyd's Rep 73.
[12] *Francois Louis Charl Biccard, and Others, Trustees of the Commercial Marine and Fire Assurance Company v John Shepherd, and Others, Trustees of the Namaqua Mining Company*, (1861) XIV Moore 471.
[13] NYPE 93, Clause 6.
[14] John F Wilson, *Carriage of Goods by Sea*, 6th edition, (England: Pearson Education Limited), p 12.
[15] *McFadden v Blue Star Line*, [1905] 1 K.B. 697, p 697.
[16] Ibid, p704.

2.2 Duration of the obligation under the Hague-Visby Rules

Under COGSA 1971, the Hague-Visby Rules have the force of law.[17] According to Article III rule 1 of the Hague-Visby Rules, the carrier is bound to exercise due diligence to make the ship seaworthy, properly manned and equipped and cargoworthy 'before and at the beginning of the voyage'.[18] In the case of *Maxine Footwear Co Ltd v Canadian Government Merchant Marine*, Lord Somervell stated that 'before and at the beginning of the voyage means the period from at least the beginning of the loading until the vessel starts on her voyage.'[19] That is to say, the carrier's obligation is from the beginning of loading until the vessel sailed. Hence, at last, the court held that the carrier was liable because he failed to exercise due diligence to provide a seaworthy ship. Therefore, the carrier cannot rely on Article IV rule 2 to discharge from liability. Moreover, this case has solved another question about seaworthiness: There is no need to consider the 'stage' doctrine under Hague-Visby Rules. The doctrine of stages only has been laid down to the absolute warranty of seaworthiness at common law.[20] Therefore, the doctrine set up by *Biccard v. Shepherd*[21], which divided a voyage into stages and the obligation of seaworthiness only attaches at the commencement of each stage for seaworthiness for that stage, does not apply under the Hague-Visby Rules. So in the *Leesh River Tea Co v British India Stream Nav Co*[22], the court held that the vessel was not unseaworthy when it was calling at an intermediate port[23]Although a storm valve cover plate was removed by an unknown person.

Moreover, in the case of a newly constructed vessel, the principle is the same. In '*the Happy Ranger*'[24]case, although the hook had never been tested to 250 tonnes when the shipowner manufactured the ship, the shipowner was still not responsible for any negligence of others prior to the delivery of a ship. The vessel was seaworthy because after the delivery date the shipowner had exercised due diligence to make the vessel seaworthy within the meaning of the Hague-Visby Rules.[25] That is to say, if the newly constructed vessel has a latent defect because of the negligence of the owner, the shipowner is not liable if he exercises due diligence at the time of the delivery of the vessel.

However, when the Hague-Visby Rules do not have the force of law, the situation will be different. In '*The Imvros*'[26]case, the charterparty was under NYPE form, and it also required that the charterer had an obligation to load and secure the cargo under the captain's supervision and to his satisfaction. The charter failed to do so. The court held that the owner was not liable for two reasons: firstly, the Hague-Visby Rules do not have the force of law so the shipowner can avoid liability for damage through exemption clauses. Secondly, the obligation to load and lash was expressly placed on the charter, although it should be under the captain's supervision. The shipowner was not liable for unseaworthiness because of the supervision of the captain. Hence, the duration is not absolute when the Hague-Visby Rules do not have the force of law. It may depend on express clauses of the charterparty.

2.3 Duration of the obligation under the Rotterdam Rules

The relevant provision about seaworthiness in the Rotterdam Rules is Article 14, which provides that: 'the carrier is bound before, at the beginning of, and during the voyage by sea to exercise due diligence to ...' It is evident that the Rotterdam Rules have changed the seaworthiness obligation of the carrier to a continuous one. More precisely, the obligation is not only to provide a seaworthy ship before and at the beginning of the voyage

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[17] Carriage of Goods by Sea Act 1971, Section 1 (2).
[18] The Hague-Visby Rules, Article III rule 1.
[19] *Maxine Footwear Co Ltd v Canadian Government Merchant Marine*, [1959] AC 589, p 603.
[20] Ibid, p 600-604.
[21] *Francois Louis Charl Biccard, and Others, Trustees of the Commercial Marine and Fire Assurance Company v John Shepherd, and Others, Trustees of the Namaqua Mining Company*, (1861) XIV Moore 471.
[22] *Leesh River Tea Co. Ltd. and Others v British India Steam Navigation Co. Ltd*, [1967] 2 Q.B. 250.
[23]. See also Part 3.1 of this article.
[24] *Parsons Corp v CV Scheepvaartonderneming Happy Ranger (The Happy Ranger)*, [2006] 1 Lloyd's Rep. 649.
[25] Ibid.
[26] *Transocean Liners Reederei GmbH v Euxine Shipping Co Ltd (The Imvros)*, [1999] C.L.C. 928.

by sea, but also to keep the vessel in that condition during the voyage by sea. The reasons why the Rotterdam Rules made this extension of the seaworthiness duty are as followed:

Firstly, it seems that it is difficult for the carrier to keep the vessel seaworthy during the whole voyage, especially when the vessel is on the high sea. The carrier may have difficulties in connecting with the vessel. Nevertheless, with the development of technology, the carrier can use advanced communication systems to build up a permanent communication with the vessel. Moreover, a modern tracking system can be used to track the vessel when it is at high sea. Hence, the situation in the 21st century is different from that in 20th century[27]. It is no need to restrict the period of seaworthiness obligation to the time before and at the beginning of the voyage.

Secondly, if the carrier only has an obligation to provide a seaworthy ship before and at the beginning of the voyage, it cannot fulfil the requirement of the International Safety Management (ISM) Code. For instance, Article 5.2 of the ISM Code illustrates that 'The Company should ensure that the safety management system operating on board the ship contains a clear statement emphasising the master's authority. The Company should establish in the safety management system that the master has the overriding authority and the responsibility to make decisions concerning safety and pollution prevention and to request the Company's assistance as may be necessary.' This provision implies that the carrier should keep the vessel seaworthy on the whole voyage. Article 14 of the Rotterdam Rules is consistent with the ISM Code.

Finally, the Hague-Visby Rules is criticised for being too carrier-friendly[28]. For instance, in case of voyage charter, the period to provide a seaworthy ship is from the beginning of the loading until the vessel starts on her voyage. It seems that this period cannot meet the requirement of the recent development of carriage of goods by sea. Moreover, in order to solve this problem, the Rotterdam Rules decided to be more 'pragmatic'.[29] The extension of seaworthiness duty of carrier enhances the carrier's obligation and allocates risk on the carrier.

However, the problem arises when Article 14 and Article 21 are looked at together. Article 21 of the Rotterdam Rules states that 'delay in delivery occurs when the goods are not delivered at the place of destination provided for in the contract of carriage within the time agreed.' Moreover, according to Article 17 of the Rotterdam Rules, the carrier is liable for 'loss of or damage to the goods, as well as for delay in delivery…' When the carrier finds that the vessel is unseaworthy during the voyage, it may be liable because of delay if the carrier orders the master to call at a port for repairing; otherwise, he may be liable because of unseaworthiness of the vessel[30] if he ignores the unseaworthiness of the vessel. Hence, it is tough for the carrier to balance Article 14 and Article 17, 21.

Although the duration of the obligation of seaworthiness has been extended, it does not mean that the carrier can avoid responsibility by delegating his obligation to his employees or the independent contractor. Just like the case '*The Muncaster Castle*'[31], the carrier cannot delegate his liability under the Rotterdam Rules. Moreover, in Article 14 of the Rotterdam Rules, it is unclear that 'when the voyage by sea ends and whether the seaworthiness obligation is one to be observed during the unloading operation'[32].

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[27] Professor Stephen Girvin, *A New Convention for the Carriage of Goods by Sea-The Rotterdam Rules*, edited by Professor D Rhidian Thomas, (Witney: Lawtext Publishing Limited, 2009), p 105.
[28] See n.11.
[29] See n.9.
[30] Yvonne Baatz, *The Rotterdam Rules: a practical annotation*, (London: Informa Maritime Law, 2009), p 14-04 to 14-06.
[31] *Riverstone Meat Co Pty Ltd v Lancashire Shipping Co Ltd (The Muncaster Castle)*, [1961] 2 W.L.R. 269. In this case, 'a fitter employed by independent ship repairers carelessly refixed the inspection covers of storm valves of a ship with the result that cargo shipped under the Hague Rules was damaged by sea water.' The carrier still had the obligation to check the fitter's work. The court held that the carrier was liable for unseaworthiness of the vessel.
[32] See n. 39, p 14-02.

3. The nature of the obligation: from 'absolute obligation' to 'due diligence.'

Whether the duty of seaworthiness should be an absolute obligation or need to exercise due diligence? The situation has changed from common law to the Hague-Visby Rules.

3.1 Seaworthiness as an absolute obligation at common law

According to the House of Lords case '*Steel et Al. v The State Line Steamship Company*'[33], the duty of the carrier to provide a seaworthy ship was an absolute one. In this case, Lord Chancellor enunciated the absolute obligation of seaworthiness. The vessel went to sea in an unseaworthy condition because of the negligence of the crew, and then the vessel came across the perils of the sea. Lord Chancellor stated that 'if they provided a seaworthy ship, tight, staunch and strong, well-manned and equipped for the carriage of goods, they say that, in consequence of the manner in which the clause of excepted risks is conceived, they are free from all other liability.'[34] Hence, even though no express clause requires the owner to provide a seaworthy ship, this obligation is implied and absolute. However, at common law, the absolute obligation can be excluded by an express clause in the contract of affreightment. Moreover, the express clause must be clear enough to exclude the obligation of seaworthiness. For instance, in the '*Nelson Lines (Liverpool) Ltd v James Nelson & Sons Ltd*'[35] case, the clause 'The owners not being liable for any damage or detriment to the goods which is capable of being covered by insurance, or which has been wholly or in part paid for by insurance' was held not effective and clear enough to exclude liability which resulted from unseaworthiness.

However, the absolute obligation at common law has two disadvantages: Firstly, although it is not easy to exclude the obligation of seaworthiness by an express clause, it does not mean that it is impossible to do that. In '*The Irbenskiy Proliv*'[36] case, a clause stated that loss or damage 'arising or resulting from: unseaworthiness (whether or not due diligence shall have been exercised by the carrier, his servants or agents or others to make the vessel seaworthy).' In this case, the court held that this clause was clear and sufficient enough to exclude all liability for unseaworthiness. That is to say, after this case, all clauses like that will be considered sufficient enough to exclude the obligation of seaworthiness. The significant role of seaworthiness in the charterparties cannot be protected although it is an absolute obligation. Secondly, if there was no exclusive clause in the contract of affreightment, the absolute obligation of seaworthiness seems to be too strict for shipowners. Hence, the obligation of seaworthiness at common law can be considered as an 'all or none' obligation. More specifically, if there is no efficient exclude clause, the obligation is absolute; if there is an efficient exclude clause, there is no obligation. This kind of obligation cannot meet the requirement of recent carriage of goods by sea.

3.2 The 'absolute obligation' is replaced by 'exercise due diligence'

As mentioned above, it is not suitable to consider the duty of the carrier to provide a seaworthy ship as an absolute duty. Since Hague and Hague-Visby Rules, the absolute obligation is replaced by an obligation to exercise due diligence. Under the Hague Rules, in *The Fjord Wind*[37] case, it was a voyage charterparty and the vessel grounded because of engine problems. Although the maintenance work was done by two representatives of the engine manufacturers at Durban, the shipowner was liable because he was in breach of the seaworthiness obligation. The court held that the owner was liable for two reasons: firstly, the obligation for the owner to provide a seaworthy ship at each stage of the voyage was the same, so the owner should exercise due diligence before and at the beginning of each stage of the voyage; secondly, the owner was liable if he cannot prove that the representatives at Durban had exercised due diligence. Similarly, in '*The Amstelslot*[38]' case, the court held that the carrier was not liable because the survey of the ship had been conducted with due diligence. Hence,

[33] *Steel et Al. v The State Line Steamship Company,* (1877-78) L.R. 3 App. Cas. 72.
[34] Ibid p 83.
[35] *Nelson Lines (Liverpool) Ltd v James Nelson & Sons Ltd,* [1908] AC 16.
[36] *Mitsubishi Corp v Eastwind Transport Ltd (The Irbenskiy Proliv),* [2005] 1 Lloyd's Rep. 383.
[37] *Eridania SpA (formerly Cereol Italia Srl) v Oetker (The Fjord Wind)*, [2000] C.L.C. 1376.
[38] *Union of India v NV Reederij Amsterdam (The Amstelslot)*, [1963] 2 Lloyd's Rep. 223.

although there is a latent defect which makes the vessel unseaworthy, the carrier is not liable if the carrier and its employers have exercised due diligence to make the vessel seaworthy. In addition, from this case, it is obvious that although the obligation is delegated to an independent contractor, the duty cannot be delegated[39]. That is to say, the carrier will remain to be liable because it does not exercise due diligence to provide a seaworthy ship. Hence, under the wording of the Hague-Visby Rules, the duty of due diligence has been interpreted to be 'a non-delegable duty which excludes only latent defect'.[40]

However, according to Article IV rule 2 of the Hague and Hague-Visby Rules, the provision states that 'neither the carrier nor the ship shall be responsible for loss or damage arising or resulting from (a) Act, neglect, or default of the master, mariner, pilot, or the servants of the carrier in the navigation or the management of the ship.'[41]This provision not only gives the owner the chance to avoid responsibility because of his employees' negligence in navigation or the management of the ship but also provides the owner with a chance to avoid the obligation of seaworthiness. More specifically, the owner can exclude the liability of unseaworthiness when the owner exercises due diligence to employ a master, mariner, pilot, or the servants. For instance, if the owner employs a master with legal qualification, the owner can be considered that he has exercised due diligence. Hence, even if the vessel is unseaworthiness because of the negligence of the master, the owner is not liable.[42]

Similarly, under the Rotterdam Rules, it is a duty for the carrier to exercise due diligence to ensure that the vessel is seaworthy[43]. However, the Rotterdam Rules have removed the provision which is in Article IV rule 2 (a) of the Hague-Visby Rules. This significant change means that the carrier cannot escape from liability when damages happen during the voyage because of the negligence errors of the master and crew. The reasons of the deletion of 'nautical fault' exception are: firstly, the 'nautical fault' exception is considered not justified and there is 'no parallel in other fields of law relating to contract'.[44] Secondly, according to CMI, the 'nautical fault' exception is the first one of the carrier's traditional exceptions, 'as provided in the Hague or Hague-Visby Rules. There is considerable opposition to the retention of either.'[45] In addition, in the report of the Working Group III, it stated that a number of delegations believed that the general exception based on error in navigation should be maintained and a considerable change should take place in order to change 'the existing position regarding the allocation of the risks of sea carriage between the carrier and the cargo interests, which would be likely to have an economic impact on insurance practice'. [46] However, this view was not accepted by most of the delegations because if the charges of insurance raise there will be an enormous rise in the whole transportation cost[47]. Therefore, it is necessary to remove the 'nautical fault' exception in the Rotterdam Rules in order not to keep the stability of the whole transportation system. Hence, the removal of the 'nautical fault' exception may bring significant influence to the obligation of seaworthiness. Moreover, many cases which were decided under the Hague-Visby Rules may be revered if the Rotterdam Rules come into force.

Since the duration of the seaworthiness obligation has changed by the Rotterdam Rules, the duty of due diligence should be treated differently between when the vessel is at port and when the vessel is at sea. The reason is: although the technology is developing, the communications at sea between the carrier and the master of the vessel sometimes are not as easy as at port. Moreover, the 'nautical fault' exception is removed under the Rotterdam Rules. Hence, the duty of seaworthiness which imposed on the carrier seems to be heavier than that

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[39] See the case *Gesellschaft Burgerlichen Rechts and Others v Stockholms Rederiaktiebolag Svea the Brabant*, [1967] 1 Q.B. 588, p 603.
[40] See n. 39, p 14-02.
[41] The Hague-Visby Rules, Article IV rule 2.
[42] See also the case *The Satya Kailash*, in this time charter case, the Oceanic Amity was chartered by the owner of the Satya Kailash to light the vessel. The damage was caused by the negligence of the master of the Oceanic Amity. At last, the court held that the owner of the Satya Kailash was not liable and he can rely on the exception of Article IV rule 2. *Seven Seas Transportation Ltd v Pacifico Union Marina Corp* (The Satya Kailash and The Oceanic Amity), [1984] 2 All E.R. 140.
[43] The Rotterdam Rules Article 14.
[44] Si yuzhuo and Henry Hai Li, *The New Structure of the Basis of Liability for the Carrier*, p 7.
[45] The Report of Working Group III, A/CN.9/WG.III/WP21, paragraph 69.
[46] The Report of Working Group III (Transport Law), (A/CN.9/525), paragraph 36.
[47] Si yuzhuo and Henry Hai Li, *The New Structure of the Basis of Liability for the Carrier*, p 10.

under Hague-Visby Rules. Hence, in practice, it is reasonable for the court to treat 'due diligent at sea' less strict than 'due diligence at port'[48].

4. Burden of proof

4.1 Burden of proof before the Rotterdam Rules

Generally, according to the common law principle, the burden of proof of unseaworthiness should be set upon the party alleging it. However, in many cases the court may assist the alleging party by inferences drawn. Thus seawater in hold will normally be treated as *prima facie* evidence of unseaworthiness by the court.[49] However, in the case of *International Packers London Ltd v Ocean Steam Ship Co Ltd*[50], The vessel shipped cargo under bills of lading which incorporated the rules scheduled to the Australian Sea-Carriage of Goods Act 1924. During the voyage, the tarpaulins were stripped off the hatch covers over one of the holds and water entered and the cargo damaged. The court held that the owner was not liable, because the loss was not caused by unseaworthiness but by the negligence of the crew.[51] After proving the unseaworthiness of the ship, the cargo owner should then to prove that the unseaworthiness caused the loss of the cargo. In '*The Europa*', this case stated that 'if unseaworthiness in the carrying ship is relied on by the cargo owner, he must prove that it was the cause of the damage.'[52] That is to say, the owner may still not liable because the loss is not caused by unseaworthiness, although the vessel is proved to be unseaworthiness.

When the contract of affreightment is governed by the Hague-Visby Rules, the burden of proof of seaworthiness relates to the exercise of due diligence[53]. According to Article IV rule 1, the carrier can escape from liability even though the vessel is unseaworthiness. Moreover, the rule 1 continues that 'whether loss or damage has resulted from unseaworthiness the burden of proving the exercise of due diligence shall be on the carrier or other person claiming an exception under this article.' It is clear that the burden of proof of exercise of due diligence will set on the carrier only if the other party can establish that the vessel was unseaworthiness and his loss or damage was caused by the unseaworthiness of the vessel. For instance, in the case of 'The *Kamsar Voyager*[54]', the carrier was held liable for two reasons: firstly, 'the risk of breakdown could have been avoided by adhering to the cylinder service interval set by both the engine builders and the vessel managers. Although the damage to the vessel was caused by the fitting of an incompatible spare piston rather than the cracking of the original piston, the presence on board of the incompatible piston constituted unseaworthiness'[55]. Secondly, the carrier failed to prove that the piston suppliers had exercised due diligence. Another key point of the burden of proof is the time. In the case '*The Hellenic Dolphin*'[56], cargo was damaged by seawater which gained access to the hold. However, no evidence was provided to the court about when the seawater came into the hold. More exactly, the time for the vessel being unseaworthiness was unsure and the carrier was only liable for the unseaworthiness of the vessel 'before or at the beginning of the voyage'. Hence, at last, the carrier can rely on the exception clause by a peril of sea.

Consequently, the phases of the shifting of the burden of proof are as followed: at the beginning, the cargo owner should prove that the vessel is unseaworthiness and the loss or damage is caused by the unseaworthiness of the vessel. Then if the carrier cannot provide other proof, it will be liable. Otherwise, the carrier has two choices: one is that the carrier can prove the loss or damage is not caused by the fault of the carrier or the fault

[48] Diego Esteban Chami, The Obligations of the Carrier (2009), p 5. Available at: http://www.rotterdamrules2009.com/cms/index.php?page=text-speakers-rotterdam-rules-200, accessed 16 September 2010.
[49] John F Wilson, *Carriage of Goods by Sea*, 6th edition, (England: Pearson Education Limited), p13.
[50] *International Packers London Ltd v Ocean Steam Ship Co Ltd*, [1955] 2 Lloyd's Rep. 218.
[51] See also the examples: *Elder, Dempster and Company, Limited and Others v Paterson, Zochonis and Company*, [1924] A.C. 522.
[52] *The Europa*, [1908] P. 84, p 84.
[53] The Hague-Visby Rules, Article III rule 1.
[54] *Guinomar of Conakry v Samsung Fire & Marine Insurance Co Ltd (The Kamsar Voyager)*, [2002] 2 Lloyd's Rep. 57.
[55] Ibid.
[56] *The Hellenic Dolphin*, [1978] 2 Lloyd's Rep. 336.

of any person for whom he is liable[57]; and the other one is that the carrier can prove the loss or damage is caused by a reason listed in Article IV rule 2. Again, the claimant may win if he can successfully prove that the exception peril is caused by the fault of the carrier or other relevant people, or the loss or damage is not caused by the exception peril.

However, this kind of burden of proof may bring about some problems: it is precisely that it is complicated for the cargo owner to prove the time when unseaworthiness happens, because the cargo owner may never go onto the vessel and know nothing about the voyage at sea[58]. On the contrast, the carrier, as the only party to know about the full facts of the voyage, only has to prove that he has exercised due diligence after the other party has established that the vessel is unseaworthy and loss is caused by unseaworthiness. The burden of proof is so heavy for the cargo owner.

4.2 Burden of proof under the Rotterdam Rules

Under this section, Article 14 (seaworthiness obligation) should be read together with Article 17 (Basis of liability). Comparing with the Hague-Visby rules, burden of proof under the Rotterdam Rules has changed in detail. Under Article 18, the carrier may be liable for the fault of '(a) any performing party; (b) the master or the crew of the ship; (c) employees of the carrier or a performing party; (d) any other person that performs or undertake to perform any of the carrier's obligation under the contract of carriage, to the extent that the person acts, either directly or indirectly, at the carrier's request or under the carrier's supervision or control.'[59]. Comparing with Hague-Visby Rules, this added provision makes it clear that the carrier may be liable because of the fault of the 'relevant persons' who are mentioned in Article 18 of the Rotterdam Rules. Moreover, in Hague-Visby Rules, the carrier may escape from liability when loss or damage is caused by the master or crew during the voyage or in the management of the ship.[60] However, Article 17 and 18 make it clear that 'nautical fault' exception is removed and the carrier may be liable for the fault caused by his master and crew. Hence, in the Rotterdam Rules, the carrier is liable for loss, damage or delay caused by the fault of himself and persons mentioned in Article 18.

4.2.1 The first step of burden of proof under the Rotterdam Rules

As common law and Hague-Visby Rules, the initial burden of proof rests on the person who alleges it. According to Article 17 rule 1, in order to establish that the carrier is liable for the loss, damage or delay, the claimant should prove that 'the loss, damage, or delay, or the event or circumstance that caused or contributed to it took place during the period of the carrier's responsibility as defined in chapter 4.' After the claimant successfully builds up the initial burden of proof, the carrier is presumed at fault[61]. However, the carrier has a chance to provide evidence against the proof having been provided by the claimant in the initial burden of proof. In order not to be liable or to relieve his liability for the loss, damage or delay, the carrier should alternatively prove that: (a) 'the cause or one of the causes of the loss, damage or delay is not attributable to its fault or the fault of any person referred to in article 18'[62]. (b) the causation of the loss, damage or delay is on the list of the exception perils, which is mentioned in Article 17 rule 3.

Moreover, if the carrier can successfully provide that 'the cause or one of the causes of the loss, damage, or delay is not attributable to its fault or the fault of any person referred to in article 18'[63], then the carrier may relieve part or all liability caused by the loss, damage or delay. Then the burden of proof comes to an end. There is no need for the claimant to provide further evidence. However, if the carrier chooses to prove that the causation of the loss, damage or delay is on the list of the exception perils, which is mentioned in Article 17 rule 3, the burden of proof will go on to the second step.

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[57] The Hague-Visby Rules, Article IV rule 1.
[58] John F Wilson, *Carriage of Goods by Sea*, 6th edition, (England: Pearson Education Limited), p 189-190.
[59] The Rotterdam Rules, Article 18 (Liability of the carrier for other persons).
[60] The Hague-Visby Rules, Article IV rule 2 (a).
[61] Si yuzhuo and Henry Hai Li, *The New Structure of the Basis of Liability for the Carrier*, p 2.
[62] The Rotterdam Rules, Article 17 rule 2.
[63] Ibid.

4.2.2 The second step of burden of proof under the Rotterdam Rules

According to Article 17 rule 4 and rule 5, the claimant may provide further evidence in order to maintain that the carrier is liable for the loss, damage and delay. Moreover, the claimant has three choices to maintain the carrier's liability[64]:

Firstly, the claimant may prove directly that the causation of the loss, damage or delay is not on the list of the exception perils, which is mentioned in Article 17 rule 3. After that, as the provision states in Article 17 rule 4(b): 'if the claimant proves that an event or circumstance not listed in paragraph 3 of this article contributed to the loss, damage, or delay, and the carrier cannot prove that this event or circumstance is not attributable to its fault or to the fault of any person referred to in the article 18', the carrier will be given a chance to illustrate that the loss, damage or delay is not attributable to its fault and the loss, damage or delay is not attribute to the fault of any person for whom the carrier is responsible according to article 18. It the carrier cannot do so, and then the carrier will lose.

Secondly, the claimant may choose to agree that the causation of the loss, damage or delay is indeed on the list of the exception perils, which is mentioned in Article 17 rule 3, but it is the carrier (or the person for whom the carrier is responsible) who causes the exception perils in article 17 rule 3. If the claimant can prove this successfully there is no chance for the carrier to provide any counter-proof and the carrier is certainly liable for the loss, damage or delay.

Thirdly, although the carrier may rely on article 17 rule 3, the claimant would win if he can provide the evidence required by rule 5(a). More exactly, the carrier is also liable if the claimant proves that 'the loss, damage or delay was or was probably caused by or contributed by (i) the unseaworthiness of the ship; (ii) the improper crewing, equipping, and supplying of the ship; or (iii) the fact that the holds or other parts of the ship in which the goods are carried, or any containers supplied by the carrier in or upon which the goods are carried, were not fit and safe for reception, carriage and preservation of the goods.'[65] That is to say, if the claimant can prove that the loss, damage or delay is caused by unseaworthiness (broad definition), the carrier is likely to be liable even if the causation of the loss, damage or delay is indeed on the list of the exception perils, which is mentioned in Article 17 rule 3. However, the carrier would again have chance to prove that 'none of the events or circumstances referred to subparagraph 5(a) of this article caused the loss, damage or delay; or it complied with its obligation to exercise due diligence pursuant to article 14.'[66] That is to say, the carrier is given a chance to give contrary evidence unless it is liable due to the unseaworthiness of the vessel.

Consequently, as mentioned above, the steps of the burden of proof about unseaworthiness are different between the Rotterdam Rules and the Hague-Visby Rules. More exactly, under the Hague-Visby Rules if the claimant alleges that the loss of or damage to the goods was caused by unseaworthiness, then he has the burden of proving his allegation. After that, the carrier has to prove that he exercise due diligence to provide a seaworthy vessel. While under the Rotterdam Rules, the burden of proof of the claimant seems to be is lighter[67], because (a) he has different choices to discharge the burden of proof. (b) he does not need to be certain that the loss, damage or delay is caused by unseaworthiness. According to article 17 rule 5 (b), he only needs to prove that the loss, damage or delay was or was 'probably' caused by or contributed to unseaworthiness. The burden of proof about seaworthiness under the Rotterdam Rules need not be certain but probable. It is obvious that this kind of burden of proof is more reasonable since not only the claimant but also the carrier understands clearly that what burden of proof they should bear on each step of the process. In addition, it is fair that the claimant only needs to prove 'probable' unseaworthiness, because he cannot take part in all steps of the voyage[68].

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64 Si yuzhuo and Henry Hai Li, *The New Structure of the Basis of Liability for the Carrier*, p 10.
65 The Rotterdam Rules, Article 17 rule 5(a).
66 The Rotterdam Rules, Article 17 rule 5(b).
67 Francesco Berlingieri, *A Comparative Analysis of The Hague-Visby Rules, The Hamburg Rules and The Rotterdam Rules* (2009), p 9.
68. However, the 'probable causation' may bring some problems, which is discussed in Part 8 below.

5. Effect of breach

From the case 'H*ong Kong Fir v Kawasaki*'[69], it is clear that the shipowners' obligation to provide a seaworthy ship was neither a condition nor a warranty but an innominate term. Diplock L.J believed that it was insufficient to frustrate the contract of a 24-month time charterparty because of only five months' absence. That is to say, breaching the obligation of providing a seaworthy vessel does not necessarily make the contract to be frustrated. Moreover, Diplock L J stated that the test should be whether the breach deprived a party of 'substantially the whole benefit which it was intended that he should obtain from the contract.'[70]

Furthermore, remedies for the charterer in the event of the breach of the obligation to provide a seaworthy ship should be discussed in two different situations[71]. The first situation is that the breach is discovered before the sail of the vessel. Under this situation, the charterer may choose to discharge his liability if the circumstance deprives him of 'substantially the whole benefit which it was intended that he should obtain from the contract.' However, if the effect of the breach is not very severe, the charterer may not discharge his liability but only get remedies in damage. For instance, in the abovementioned case 'The *Hong Kong Fir*'[72], the court held that it was not severe enough for a 24-month's charterparty to have 5-month's repair, so the charterer cannot discharge his liability. However, in some standard form of time charterparties, the charterer may discharge from liability without considering how severe the breach is by an express provision.[73] The other situation is that the breach is discovered after the sail of the vessel. Although the breach is discovered after the sail of the vessel, the charterer also has the same right as that in the first situation. However, in the case of voyage charter, it is very difficult for the charterer to repudiate the charter, as when the vessel reaches the destination the contract is complete. Hence, it is meaningless for the charterer to repudiate the contract.

Where the contract of affreightment is governed by Hague or Hague-Visby Rules, the obligation of the carrier to exercise due diligence to provide a seaworthy ship is considered to be an 'overriding obligation'[74] In the case '*Maxine Footwear v. Canadian Government Merchant Marine*'[75], a fire started in the ship owing to the negligence of one of the ship's officers, which made the ship unseaworthy. Hence, the carrier was not entitled to immunity under the Hague Rules Art.IV. That is to say, if the carrier cannot fulfil the obligation to exercise due diligence to provide a seaworthy ship, it cannot be entitled to immunity under the 'exception perils' of Article IV of the Hague-Visby Rules. However, 'the carrier's obligation of care for the goods shall be subject to the exemptions, which means that if a single event that causes the cargo loss or damage relates to both the carrier's obligation of care for the goods and an exemption on which the carrier is entitled to rely, then the carrier's exemption shall prevail over his obligation of care for the goods carried'[76]. That is to say, if the carrier breaches the obligation of care of goods, it may still escape from liability by relying on the 'exception perils'. Consequently, under the Hague-Visby Rules, as an 'overriding obligation', seaworthiness must be proved in the first place. After that, the carrier is entitled to rely upon the exemptions.

However, as mentioned above, Article 17 rule 5 of the Rotterdam Rules states that the carrier is also liable, 'notwithstanding paragraph 3 of this article…' More exactly, paragraph 3 contains the exemptions. Moreover, The Working Group III stated that 'the issue of the seaworthiness of the ship would become relevant only in an actual claim for cargo damage, i.e. when the cargo claimant could prove unseaworthiness as a cause of damage to rebut the carrier's invocation of one of the excepted perils.'[77] Hence, it is clear that the carrier's exemption

[69] *Hongkong Fir Shipping Co. Ltd. v Kawasaki Kisen Kaisha Ltd*, [1962] 2 Q.B. 26.
[70] Ibid, p 69.
[71] John F Wilson, *Carriage of Goods by Sea*, 6th edition, (England: Pearson Education Limited), p14.
[72] See n.78.
[73] See *Cheikh Boutros Selim El-Khoury v Ceylon Shipping Lines (The Madeleine)*, [1967] 2 Lloyd's Rep. 224. In this case, the time charterparty had a cancelling provision. The court held that the cancelling provisions, which required the shipowner to provide a seaworthy vessel by the cancelling date, can be considered as an express warranty.
[74] Anthony Diamond QC, The Rotterdam Rules, Lloyd's Maritime and Commercial Law Quarterly [2009] L.M.C.L.Q 445, p 468.
[75] *Maxine Footwear Co v Canadian Government Merchant Marine*, [1959] 3 W.L.R. 232.
[76] Si yuzhuo and Henry Hai Li, *The New Structure of the Basis of Liability for the Carrier*, p 10.
[77] The Report of Working Group III (Transport Law), (A/CN.9/544), para.117.

and the obligation of seaworthiness are independent from each other. In addition, seaworthiness obligation does no longer have the chance to collide with the exemptions. That is to say, under the Rotterdam Rules, the carrier need not prove that it has exercised due diligence to provide a seaworthy vessel before it relies upon the exemptions. Thus, breaching of the obligation of seaworthiness does not lead the carrier to lose his right on exemptions, although it will be liable because of the breaching.

6. Other Changes

Neither the Hague rules nor the Hague-Visby Rules contains a provision about containers, although containers become one of the most crucial transfer tools in the carriage of goods by sea. The Dutch case '*NDAL v. Delta Lloyd & Others*'[78] was a leading case to answer the question 'are containers packaging or part of the vessel?' In this case, the court held that 'containers are not packaging but should be treated in the same manner as a part of the vessel in which goods are carried.'[79] Similarly, In Article 14(c) of the Rotterdam Rules, it also contains that the carrier is liable to make the vessel cargoworthiness and 'containers supplied by the carrier in or upon which the goods are carried' should also be cargoworthy. According to the report of the Working Group III, it stated that 'when the container was provided by the carrier, it should be qualified as part of the ship's hold, and that the same obligation that the carrier had for the ship and the care of the holds should apply to those containers once the containers were loaded on board a ship'[80]. This change in seaworthiness will make the Rules suit the development of carriage of goods by sea.

7. Problems presented in the Rotterdam Rules

Firstly, the obligation is not only to provide a seaworthy ship at the beginning of the voyage by sea, but also to keep the vessel in that condition during the voyage by sea.[81] However, according to Article 17 rule 3, the carrier is not liable for the excepted perils. Then, if the excepted perils make the ship unseaworthy during the voyage, the problem will be: should the carrier be liable for the unseaworthiness of the ship or can the carrier rely on Article 17 rule 3 to escape from liability? If the answer to the first question is yes, then once the ship suffers a peril of sea which makes the ship unseaworthiness, the claimant may be liable because of Article 17 rule 5. If the answer to the second question is yes, then in this circumstance the event 'will result both in the carrier being provisionally relieved from liability under art 17.3 and also in the carrier being provisionally liable for the loss under art 17.5(a).'[82] For instance, when there is a fire on broad during the voyage, which certainly causes the ship unseaworthy, Article 17 rule 3 and Article 17 rules 5 will come together in dealing with the carrier's liability.

One of the solutions is that the claimant may need to prove that 'the unseaworthiness of the ship was caused prior to or independently of the excepted peril'[83]. However, this solution may also bring some shortcomings: (a) this solution will increase the burden of proof of the claimant indirectly, since according to Article 17 rule 4 the claimant has to prove the excepted peril is caused by the fault of the carrier, otherwise, according to Article 17 rule 5 the claimant may have to prove that the loss, damage or delay is caused by the unseaworthiness of the vessel prior to or independent of the excepted peril. However, one of the aims of the Rotterdam Rules is to change the 'carrier-friendly' Rules to the 'pragmatic' Rules. The burden of proof for the claimant will be even heavier than that in the Hague-Visby Rules. (b) this solution may make the burden of proof more complicated and confusing. In practice, it will be very difficult to prove whether the unseaworthiness of the vessel happens before or independent of the excepted perils since the duration of the obligation of seaworthiness is extended to the whole voyage and the condition of the vessel is very difficult to understand, especially for the claimant.

Secondly, the continuing obligation of keeping the vessel seaworthy 'before, at the beginning of and during the voyage by sea' also brings some problems. More exactly, making the seaworthy obligation a continuing one

[78] *Nile Dutch Africa Line B.V ("NDAL") v. Delta Lloyd Schadeverzekering N.V and others*, NJ2008.505; SES2008, 46.
[79] David Martin-Clark's 'a legal case notes website for industry professionals, lawyers and other advisers, and students'< http://archive.onlinedmc.co.uk/ndal_v__delta_lloyd_&_others.htm> accessed 17 September 2010.
[80] Ibid, para 152.
[81] The Rotterdam Rules, Article 14 rule 1.
[82] See n. 83, p 476.
[83] Ibid, p 476.

‘affected the balance of risk between the carrier and the cargo interests in the draft instrument’[84], which is agreed by the Working Group III. The carrier’s risk will be higher than that in the Hague-Visby Rules, which only requires the carrier to provide a seaworthy vessel ‘before and at the beginning of the voyage’.

This extension of the seaworthiness obligation may cause some problems: (a) when a vessel becomes unseaworthiness during the voyage by sea, the carrier should make it seaworthy according to the Article 14 of the Rotterdam Rules. However, the claimant may complain that the loss, damage or delay is more severe during the time of making the vessel seaworthy again. For instance, the unseaworthiness of the vessel maybe not influence the cargo. However, the claimant may suffer a loss because of delay when the carrier spends time on making the vessel seaworthy again. Similarly, the situation of the carrier is in a dilemma. As mentioned above, when the carrier finds that the vessel is unseaworthy during the voyage, he may be liable because of delay if he orders the master to call at a port for repairing; otherwise, he may be liable because of unseaworthiness of the vessel if he ignores the unseaworthiness of the vessel. Hence, it is very hard for the carrier to balance Article 14 and Article 17, 21[85]. However, this problem may be solved by setting up a different test of ‘due diligence’. More specifically, the duty of due diligence can be tested differently when the ship is at port and when the ship is at sea.[86] When the ship is at port, the test of ‘due diligence’ should be the same as that in the Hague-Visby Rules, since the duration of the obligation is the same (before and at the beginning of the voyage). When the ship is at sea, ‘the assessment of the due diligence to keep the ship seaworthy during the voyage and when the ship is at sea, should be less strict than to make the ship seaworthy at port’[87] Therefore, if the carrier realises that further loss, damage or delay may be caused by making the unseaworthy ship seaworthy again during the voyage, it is reasonable that the carrier can choose to maintain the condition of the vessel. Hence, the assessment of the due diligence can be whether the carrier takes all reasonable steps to make the ship seaworthy and stop the cargo from being damaged. Consequently, although it will be complicated in practice, this solution can solve this problem correctly. (b) When under Hague/Hague Visby Rules, the duration of the obligation of seaworthiness is the same as that in the Marine Insurance Act.[88] While in the Rotterdam Rules, the obligation is extended to the whole period of the voyage. Although the Rotterdam Rules does not collide with the Marine Insurance Act, the differences should be distinguished carefully at voyage charter. More exactly, the carrier in a voyage charter should keep the vessel seaworthy during the whole voyage. Otherwise, it will be liable under the charter party. An insured in a voyage policy only need to make sure that ‘at the commencement of the voyage the ship shall be seaworthy for the particular adventure insured'[89], otherwise, he is in breach of the insurance contract. Besides, in practice, it is the court that should make it clear ‘when the voyage by sea ends and whether the seaworthiness obligation is one to be observed during the unloading operation’.[90]

Finally, according to Article 17 rule 5, the claimant only needs to prove that the loss, damage or delay ‘was or was probably’ caused by unseaworthiness. This provision is considered to lessen the claimant’s burden on proving.[91] However, as mentioned above, when the claimant established that the loss, damage or delay is probably caused by unseaworthiness of the vessel, the carrier can then prove that ‘none of the events referred to in paragraph 5(a) of this article caused the loss damage or delay’[92] That is to say, the burden of proof of the claimant is not final, which can be pulled down by the carrier’s further proofing. In addition, ‘the burden in civil issues in common law countries is normally to prove a case on a balance of probabilities.[93] Hence, this provision does not necessarily lessen the burden of the claimant. However, ‘the Working Group was reminded that the

[84] Provisional redraft of the articles of the draft instrument considered in the Report of Working Group III on the work of its twelfth session (A/CN.9/544), footnote 55.
[85] See n. 39, p 14-07.
[86] Ibid, p 14-03
[87] Diego Esteban Chami, The Obligations of the Carrier (2009), p 5. Available at: http://www.rotterdamrules2009.com/cms/index.php?page=text-speakers-rotterdam-rules-2009 accessed 17 September 2010.
[88] In Section 38 of the MIA, it states that ‘in a voyage policy there is an implied warranty that at the commencement of the voyage the ship shall be seaworthy for the particular adventure insured.’
[89] Ibid.
[90] See Part 3.3 of this article.
[91] See Part 5.2.2 of this article.
[92] The Rotterdam Rules, Article 17 rule 5 (b).
[93] See n. 83, p 476.

phrase chosen was intended to compromise language in order to render acceptable the whole of article 14'[94] According to this situation, Anthony Diamond QC recommends in his article that in the first the burden of proof rests on the claimant and then rests on the carrier like a tennis match; finally, 'the court would find the relevant facts after all the evidence has been given, so that it will rarely matter where the onus of proof originally lay.'[95] This solution may properly solve this problem in practice since it is clear to follow.

8. Conclusion

As mentioned above, comparing with the Hague-Visby Rules, the Rotterdam Rules about seaworthiness has changed a lot and not all the changes are satisfactory.

Firstly, the Rotterdam Rules have changed the seaworthiness obligation of the carrier to a continuous one. It is suitable for the carriage of goods by sea in the 21st century and consistent with ISM (International Safety Management) Code. However, a continuous obligation could probably cause further loss, damage or delay, which, in practice, may be solved by setting up different assessment of the due diligence when the ship is at port and when the ship is at voyage. Secondly, the Rotterdam Rules have removed the provision which is in Article IV rule 2 (a) of the Hague-Visby Rules. This significant change means that the carrier cannot escape from liability when damages happen during the voyage because of the negligence errors of the master and crew. This change is more suitable for the modern transport system and avoids the Rotterdam Rules to become carrier-friendly rules. Thirdly, in the Rotterdam Rules, it is obvious for both the claimant and the carrier what should they do in each step of proofing. However, it also brings problems, which will 'result both in the carrier being provisionally relieved from liability under art 17.3 and in the carrier being provisionally liable for the loss under art 17.5(a)'[96] and makes the claimant confused about the 'probable causation'. Finally, in the Rotterdam Rules, the carrier need not prove that it has exercised due diligence to provide a seaworthy vessel before it relies upon the exemptions.

Consequently, the development in the Rotterdam Rules about the obligation of seaworthiness is like a double-edged sword. It brings both advantages and disadvantages. The developments about the duration, due diligence and 'probable causation' can be considered satisfactory, since although all of them have problems, at last, they could find reasonable solutions. However, the burden of proof, which result both in the carrier being provisionally relieved from liability under art 17.3 and also in the carrier being provisionally liable for the loss under art 17.5(a)'[97], is still hard to resolve. It will cause difficulties in practice.

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System Dynamic Modelling of the Intermodal Transportation System in Guangdong-Hong Kong-Macao Greater Bay Area

Huiling Zhong[1], *Dan Cheng*[2], *and Yimiao Gu*[3]

[1,2,3]Department of Logistics Engineering, School of Economics and Commerce, South China University of Technology, Guangzhou, China.
Email: [1]hlzhong@scut.edu.cn
[2]ecchengdan@mail.scut.edu.cn
[3]guymcheers@scut.edu.cn

Abstract

With heavy pressure and pollution caused by the irrational structure of intermodal transportation system, the development of the container port cluster in Guangdong-Hong Kong-Macao Greater Bay Area is restricted. Aiming to problems of the intermodal transportation system in this area, in this study, a complex System Dynamic (SD) model with multi-dimensional nonlinear dynamic prediction function is established with four subsystems: Guangzhou Port Subsystem, Shenzhen Port Subsystem, Hong Kong Port Subsystem, and Hinterland Subsystem. The proposed model is employed to simulate the dynamics of transportation demand as well as the capacity shortage of different transportation modes, subject to providing useful policy suggestions for port government in intermodal transportation system construction and investment. The results reveal that: 1) demand for waterway intermodal transportation begins to exceed the demand for highway in Guangzhou Port since 2019 due to the vigorous development of waterway intermodal transportation system; 2) demand for railway and waterway intermodal transportation maintains steady and rapid growth in Shenzhen Port during 2017-2021; 3) the shortage problem of intermodal transportation capacity in both Guangzhou Port and Shenzhen Port mainly lies on the waterway.

Keywords: System Dynamics; Intermodal Transportation System; Container Port Cluster; Guangdong-Hong Kong-Macao Greater Bay Area

1. Introduction

The Guangdong-Hong Kong-Macao Greater Bay Area (hereinafter referred to as Greater Bay Area) is a unique and special area in China, which comprises the two Special Administrative Regions of Hong Kong and Macao, and the nine municipalities of Guangzhou, Shenzhen, Zhuhai, Foshan, Huizhou, Dongguan, Zhongshan, Jiangmen and Zhaoqing in Guangdong Province, as shown in Figure 1. There are three of the world's top ten busiest container ports and five billion-ton ports in this area, with Shenzhen Port ranking 3rd, Hong Kong Port ranking 5rd, followed by Guangzhou Port ranking 7th in 2016. Apart from the three main ports, the container throughput of other container ports in this area is relatively small, accounting for only 16.03% of the total in the Greater Bay Area. With Hong Kong being an international shipping center, Guangzhou Port and Shenzhen Port are both container hub port, and the other container ports are feeder ports.

The development in container shipping industry has a direct impact on port development and regional transportation network, especially on the intermodal transportation system (Guan, 2009). Unlike other mega city-regions of the country, such as the Yangtze River Delta, the intermodal transportation system in the Greater Bay Area has three main characteristics. In terms of transportation modes, the three main modes railway, highway and waterway in the Greater Bay Area are well-developed, forming a comprehensive transportation system. Besides, various intermodal transportation modes such as combined transport of sea and rail are developing rapidly as well. As for connectivity, it’s noted that cities in the Bay Area are closely connected. Good examples are the Hong Kong-Zhuhai-Macau Bridge and the Guangzhou-Shenzhen-Hong Kong High-

Speed Railway. With well-developed cross-boundary transportation networks and facilities, there are frequent contacts between the container ports and the hinterland, which further improve the transport connectivity within the Greater Bay Area and create favorable conditions for extending the hinterland's potential and its competitiveness. In terms of transport network, the highly overlapped transportation terminals and the highway, railway and waterway networks in the hinterland can be shared in common by ports in the Greater Bay Area.

However, some structural problems exist in intermodal transportation system in the Greater Bay Area apparently. Intermodal transportation network and connectors, especially the highways, are under increasing pressure to keep pace with the ever growing container volume. For example, nearly 90% of the containers are transported by highway in Shenzhen Port. The excessive reliance on highway transport results in severe traffic congestion in the port city, which is not conducive to the healthy development. In railway development, the Greater Bay Area lags far behind other regions in the world. The Railway Access to the Port in Nansha of Guangzhou City and the project of 600 km of inter-city railways (NDRC, 2005) is still under slow construction, the railway transportation capacity between port and the hinterland is insufficient currently. In terms of waterway, the inland waterway transportation is seriously lagging behind. It is estimated the current transportation volume in waterway only accounts for about 10% of the total volume in Guangdong Province, indicating that the natural advantage in inland river has not been fully developed. Such problems reduce the efficiency of container flow and eventually being a detriment to regional economic well-being and economic competitiveness.

Aiming to problems mentioned above, it is urgently required to improve the layout of highway, railway and waterway networks, and enhance the connectivity of various modes of transport, as well as to improve transportation infrastructure within and outside cities to make intermodal transport more convenient. As the intermodal transportation system is a complex system, it is critical to study various influencing factors and the mechanism of the system. A quantitative model system that combines the container port, infrastructure investment, transportation network, and the hinterland is needed to optimize the intermodal transportation system structure in the Greater Bay Area.

Figure 1: Map of Guangdong – Hong Kong – Macau Greater Bay Area

2. Literature Review

There is a rich literature in the area of intermodal transportation system optimization. The earliest notion about inland intermodal network optimization can be found in the literature of Shen (1995), in which Shen presented a decision support system to solve the planning problem concerning the multiperiod distribution of empty containers for a shipping company using network optimization models. After that, thousands of papers have been making further research with mathematical analysis models on the following three main fields: the intermodal transport network design(Arnold, 2004; Groothedde, 2005), container terminal operation(Kozan, 2000), network traffic distribution(Nijkamp et al. 1999) and the shortest path problems (Ziliaskopoulos, 2000; Lozano, 2001; Beuthe, 2001; Boussedjra, 2004).

Although mathematical analysis models are powerful tools, system simulation modeling method has been one of the most effective modeling methods in this field. The complexity of the intermodal transportation system lies on the fact that it is a comprehensive reflection of the transportation and logistics problems (Ballis and Golias, 2004). Mathematical analysis models with time constraints are only applicable to deterministic models, which can't solve problems under the condition of the random system and dynamic factors (Macharis and Bontekoning, 2004). Zhang et al., (2005) proposed a modeling methodology of the complex container terminal logistics system by using the computer simulation package. Parola and Sciomachen (2005) present a discrete event simulation modelling approach related to the logistic chain as a whole, which aims to evaluate a possible future growth of the container flows. Jin and Wang (2006) proposed a modelling approach for a simulation model of intermodal transportation system of ports in high-level architecture distributed federation simulation environment to decrease difficulty and complexity in modelling. Corté et al., (2007) run a simulation model of resource allocation and logistics activities in the port to assess whether the port infrastructure can meet the needs of normal logistics activities. Wang et al., (2008) established a system dynamic model of the urban transportation system to analyze the impacts of different policy scenarios on urban development and transportation system.

System dynamics (SD) is a powerful methodology for obtaining insights into problems of dynamic complexity and policy resistance (Georgiadis and Besiou, 2008), which is based on the establishment of the urban dynamics model and the world model by Forrester et al. (1961) and "The Limits to Growth" theory by Meadows (Meadows et al., 1972). SD simulation enables exploring "what-if" scenarios and policy tests (Richardson and Otto, 2008), which is often used to investigate the relationship between the behaviors of a system overtime and its underlying structure and decision rules (Wolstenholme, 1990). Focusing on the optimization of the overall system rather than subsystems, this model is better at reflecting the nonlinear dynamic changes of a system than traditional models, and can analyze the complexity, nonlinearity and feedback loop structures that are inherent in physical and nonphysical systems (Forrester, 1994).

From above literature, SD model is proved to be an effective method in optimizing the intermodal transportation system. However, few literature can be found about SD's application in intermodal transportation system of the container port cluster in the Greater Bay Area. And most of previous researches do not distinguish different kinds of transportation modes separately and are biased to short-term and static planning, which cannot well reflect the reality or adjust timely to the change of external factors beyond the system. In order to fill this gap, a complex SD model has been developed for simulating the mechanism of interaction between various factors and the development trend of intermodal transportation system in the Greater Bay Area. This paper first defines the intermodal transport system framework, considering five subsystems. Then, the causal feedback relationship among variables in the system is analyzed, and a flow chart connecting the subsystems is established to model the intermodal transport system. Finally, the model is validated in terms of historical behavior and future prediction. According to the simulation results, useful policy suggestions for intermodal transportation system optimization are put forward.

3. Description of Model

SD model must be established with a closed-system boundary, within which the system interactions take place that gives the system its characteristic behavior (Forrester, 1969). Therefore, it is fundamental to determine where the boundary is and illustrate the components and subsystems. Considering the impact of economic development and infrastructure investment only, the impacts of other factors of high uncertainty, such as urban development, are neglected. The model is formulated and simulated using a professional SD software package "Ventana simulation environment personal learning edition (Vensim PLE)".

3.1 System Structure

The structure of a SD model is highlighted by the causal loop diagrams which capture the major feedback mechanisms (Yuan, 2011). As shown in Figure 2, there are five subsystems with positive (+) and negative (-) feedback loops between various variables in the intermodal transportation system in Greater Bay Area, and only main casual feedback loops are analyzed.

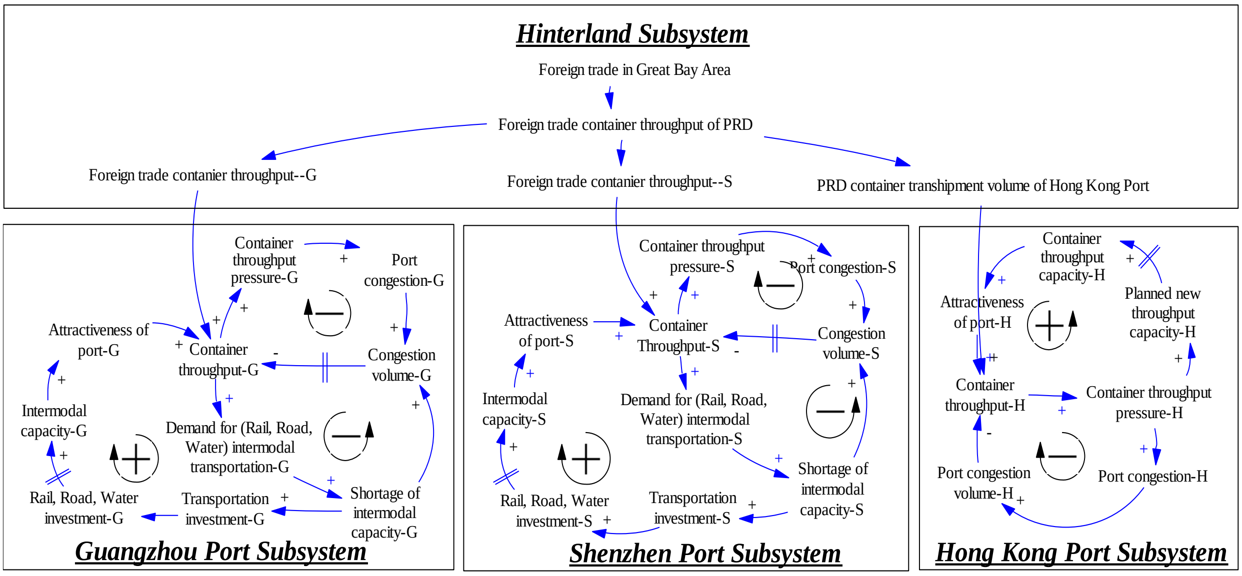


Figure 2: Causal-loop diagram of intermodal transportation system in Greater Bay Area

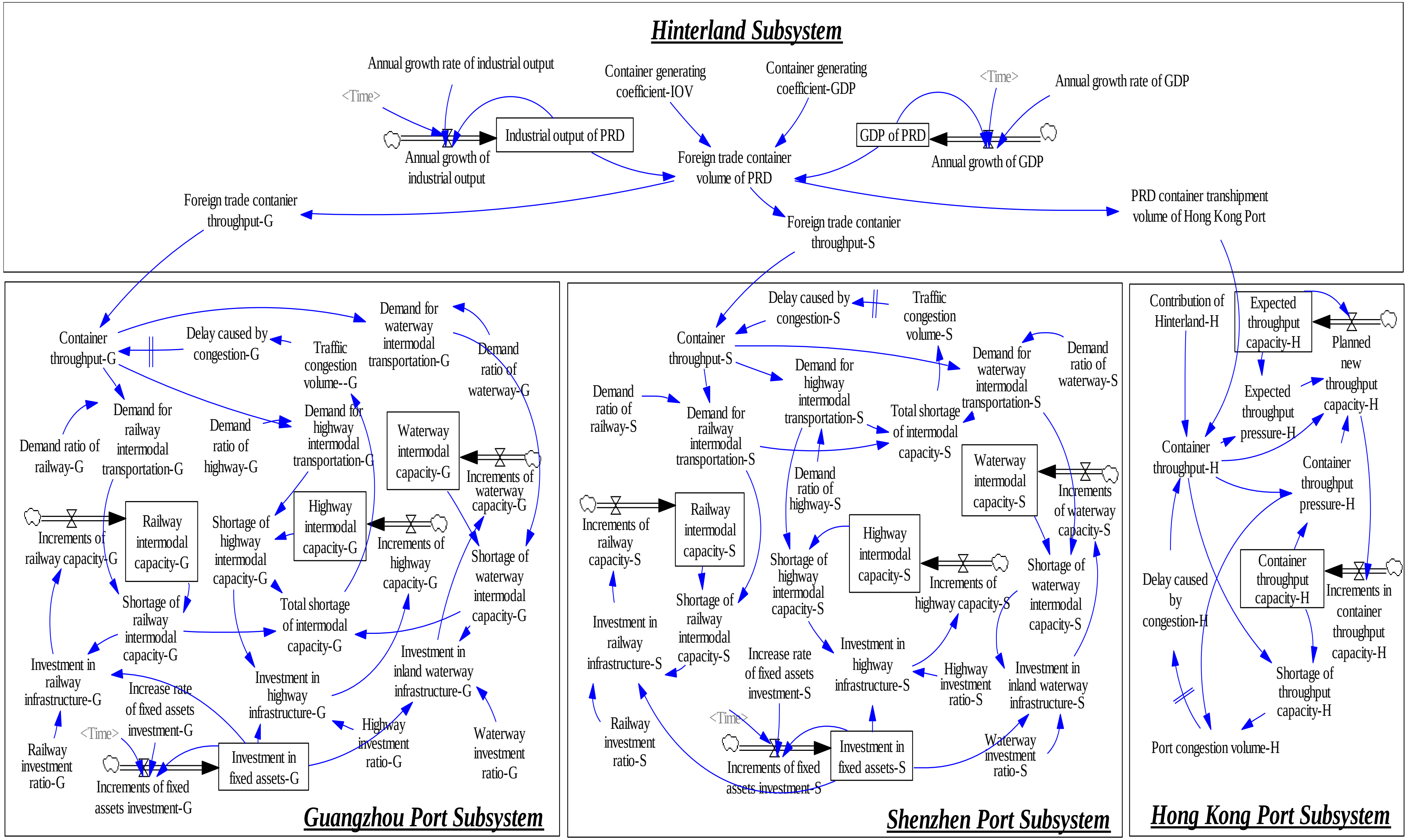
(1) Guangzhou Port Subsystem
Variables in Guangzhou Port Subsystem can be divided into three categories: container port, transportation network, and infrastructure investment. Taking transportation network as an example, with container throughput continuously growing, the volume of containers needed to be transported in various modes of railway, highway and waterway is also increased, making the shortage in intermodal capacity worse. The congestion volume, which is caused by the shortage, prevents the container throughput from further growing. So a negative feedback loop between container throughput and transportation network is formed. Analysis of Shenzhen Port Subsystem is the same as above for the reason that the two ports adopt same system structure.

(2) Hong Kong Port Subsystem
In the Hong Kong Port Subsystem, no concrete subdivision of different transportation modes will be made. As a free port and international ship finance center, the strength of Hong Kong Port is in providing high value-added maritime services rather than developing intermodal transport system. There are two feedback loops in the Hong Kong Port Subsystem. Taking the negative one for an example, the increase in container throughput will bring intensified pressure on the container port, as a result, new throughput capacity is required to solve the dilemma. With a period of time delayed, the new capacity can be transformed into real throughput capacity as well as to promote the attractiveness of Hong Kong Port, leading to an increase in the future container throughput.

(3) Hinterland Subsystem
Containers generated from the hinterland are transported to port by intermodal transportation network for export. The foreign trade container volume from the hinterland to container ports has an extremely important influence on the intermodal transportation process. As the direct hinterland, Pearl River Delta region produces most of the foreign trade containers handled in the Greater Bay Area. So, this paper adopts economic data of the PRD as the factors influencing the production of foreign-trade containers in the area. The two main factors, GDP and industrial output in the PRD, can be determined by the optimal subset of multivariate linear regression.

Base on the analysis of four subsystems, after the factors connecting the subsystems are examined, an overall system dynamic simulation model is developed by integrating the subsystems, as shown in Figure 3.

Figure 3: SD model of the intermodal transportation system of port cluster in Greater Bay Area



3.2 Parameters and Data

Parameters in the model are composed of stocks, flows and auxiliaries, which are shown in Appendix A with the description, type and unit. The study period of this model starts from 2007, ends in 2021, and the modeling time step is one year. The data of all parameters are mainly collected from Guangdong Statistical Yearbook, the Year book ports of China combined with government documents.

4. Model Validation

Model validation is composed of unit consistency test, model structure test and model performance test. The unit consistency test is done automatically by Vensim package. In terms of structure test, it is required to check whether the developed model reflects the real system well or the model equations meet the physic laws. The model performance test can be conducted by comparing the simulation values with the actual values of important parameters. In this paper, the throughput of Guangzhou Port, Shenzhen Port and Hong Kong Port are chosen as the three verifying variables to validate the model, and the results are shown in Figure 4a, Figure 4b and Figure 4c.

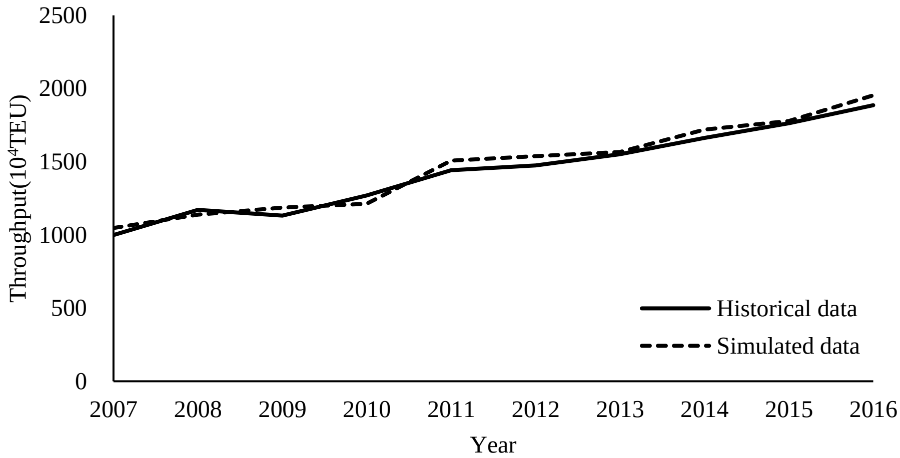


Figure 4a: Comparison between simulated data and actual data of throughput of Guangzhou Port

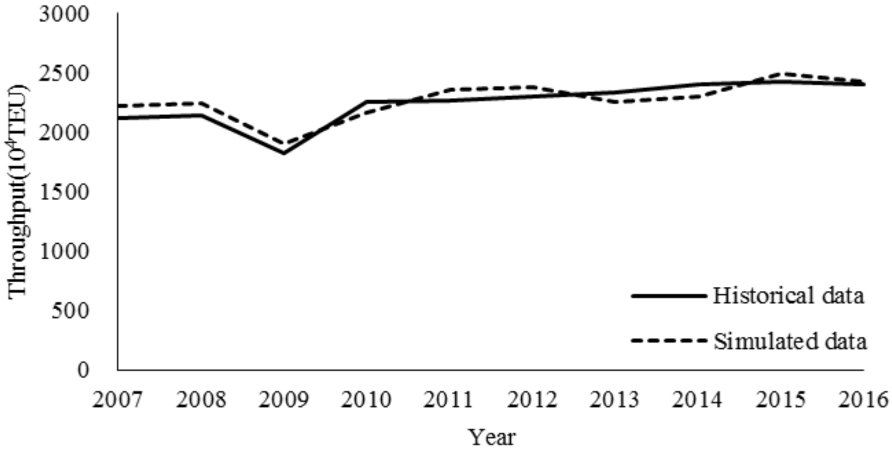


Figure 4b: Comparison between simulated data and actual data of throughput of Shenzhen Port

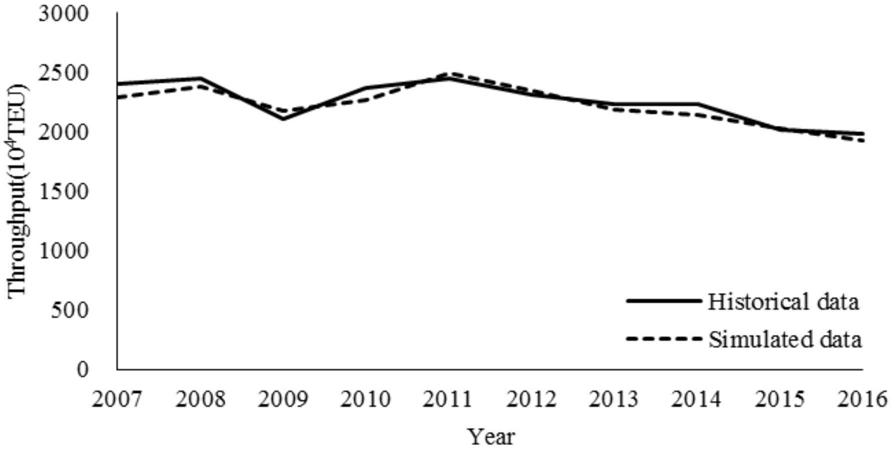


Figure 4c: Comparison between simulated data and actual data of throughput of Hongkong Port

If the deviation of simulated data and actual data is within 5%, the model and the test results is valid (Sterman, 1984). The average error of Guangzhou Port, Shenzhen Port and Hongkong Port is less than the acceptable maximum value of 5%, indicating that there is little difference between the simulated throughput and actual throughput of three container ports and the model is effective.

5. Simulation Results and Discussion

The SD model was run to simulate the years from 2007 to 2021, which is divided into two parts. The first part from 2007 to 2016 is used for historical analysis and the rest for future prediction. The simulation results are discussed in following paragraphs.

5.1 Demand for different intermodal transportation modes

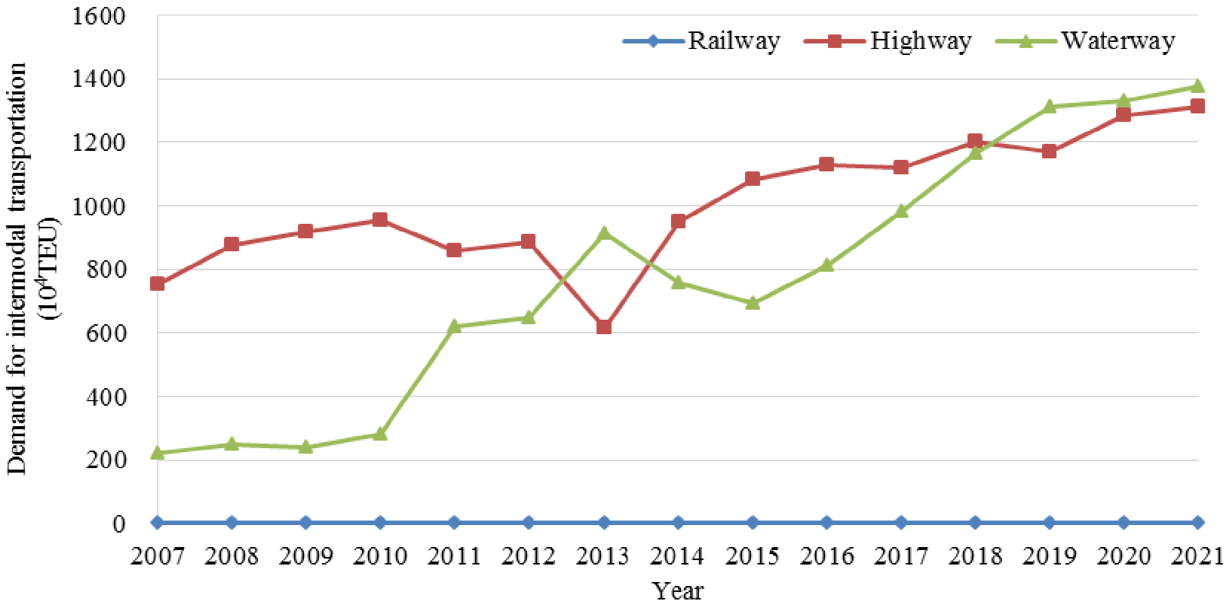


Figure 5: Simulation results of the demand for intermodal transportation modes in Guangzhou Port

(1) Demand Analysis of Historical Period of Guangzhou Port

As shown in Figure 5, the demand for highway intermodal transportation was generally greater than that of the waterway and railway in 2007-2016, except for the demand for waterway intermodal transportation exceeds that of highway in 2013. In addition, the development of waterway intermodal transportation has accelerated since 2011, and the gap between the demand for waterway and highway transportation has gradually narrowed. This is mainly because the launching of new South China Common Feeder Service connecting Beijiao of Shunde Port, Xintang of Guangzhou Port, Zhongshan Port, and Gaoming of Foshan Port to Guangzhou Port in 2011, which has greatly cleared the waterway of Guangzhou Port and enhanced the attractiveness in cargo and radiation capacity of Guangzhou Port. As a result, demand for waterway intermodal transportation was greatly promoted and increased by 46.6% compared with the previous year.

(2) Demand Analysis of Prediction Period of Guangzhou Port

The results suggest that the demand for highway intermodal transportation is higher than that of the waterway in 2017 and 2018. However, since 2019, demand for waterway intermodal transportation will begin to exceed the demand for highway while the demand for railway maintain steady and rapid growth. This is mainly due to the vigorous development of the railway and waterway intermodal transportation system. In terms of railway intermodal transportation, it is predicted by the model the demand for railway intermodal transportation in 2021 is expected to increase by 131% compared with 2017. In terms of waterway intermodal transportation, it is predicted by the model the demand for waterway intermodal transportation in 2021 is expected to increase by 70% compared with 2016.

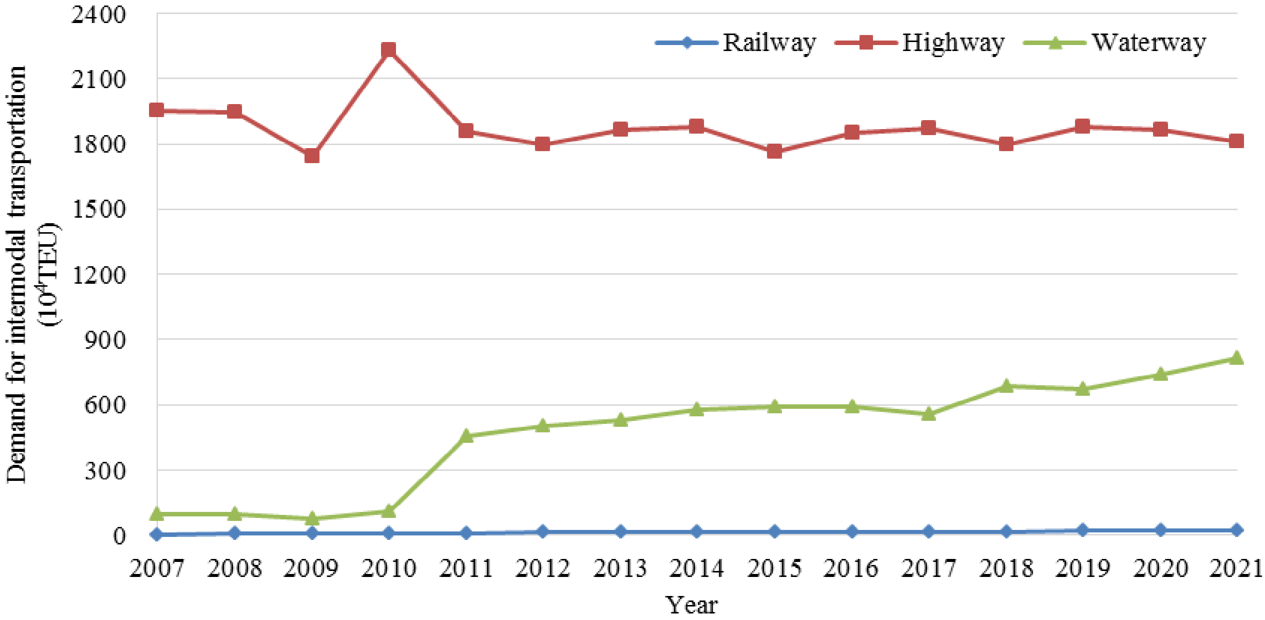


Figure 6: Simulation results of the demand for intermodal transportation modes in Shenzhen Port

(3) Demand Analysis of Historical Period of Shenzhen Port

The simulation results of Shenzhen Port (as shown in Figure 6) illustrate that the demand for highway intermodal transportation had always been dominating during 2007-2016, far exceeding that of the waterway and railway. The results also show that the growth rate of demand for waterway intermodal transportation in Shenzhen Port accelerated significantly in 2011. This was mainly due to the opening of a number of provincial barge routes in Yantian International and Dachan Bay in 2011, which further improved the attractiveness of Shenzhen Port to feeder ports in barge container transportation network in Pearl River.

(4) Demand Analysis of Prediction Period of Shenzhen Port

The results from this study suggest that, in 2017-2021, except for the slow decline in the demand for highway intermodal transportation, the demand for railway and waterway intermodal transportation will maintain steady and rapid growth. The rapid growth in demand for railway intermodal transportation is due to the vigorous promotion of sea-rail combined transportation. It is predicted by the model that the demand for railway intermodal transportation in 2021 is expected to increase by about 59.42% compared with 2016. In terms of waterway intermodal transportation, it is predicted by the model that the demand for waterway intermodal transportation in 2021 is expected to increase by about 37.62% compared with 2016.

5.2 Shortage of Intermodal Capacity in Different Intermodal Transportation Modes

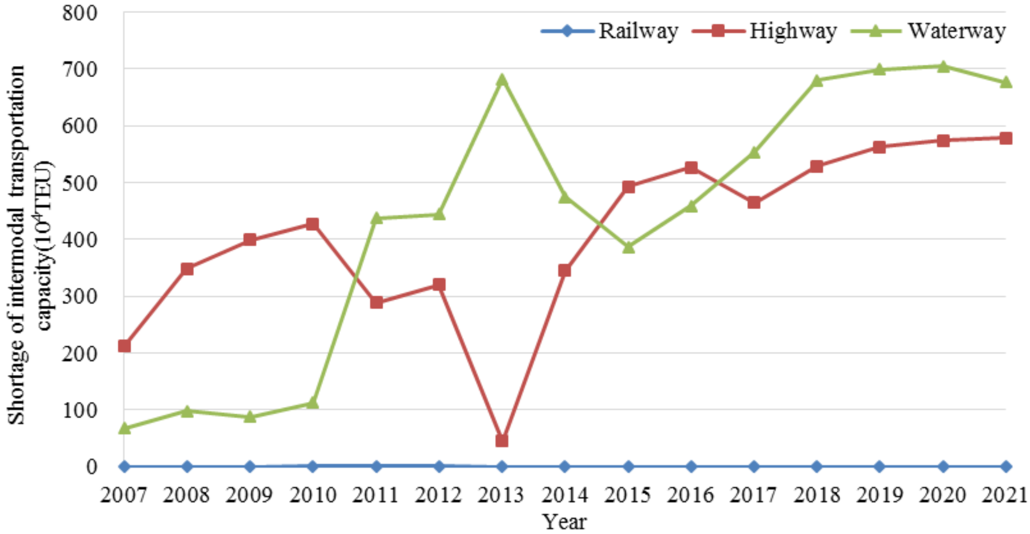


Figure 7: Simulation results of the shortage of intermodal transportation capacity in Guangzhou Port

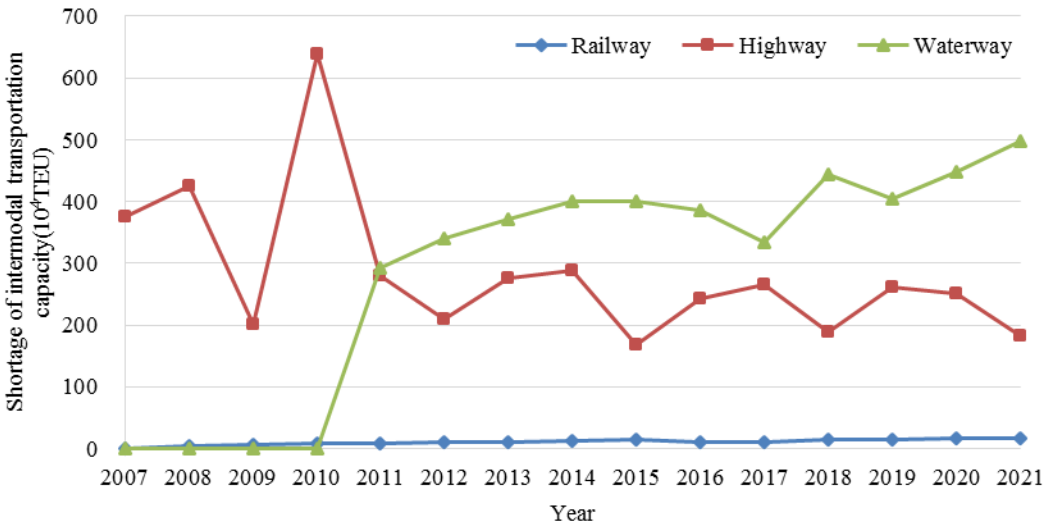


Figure 8: Simulation results of the shortage of intermodal transportation capacity in Shenzhen Port

(1) Shortage of waterway intermodal transportation capacity in Guangzhou Port is the largest with the fastest growth rate.
As shown in Figure 7, during 2017-2021, except for railway intermodal transportation, the shortage of highway and waterway intermodal capacity in Guangzhou Port will continue to exist and keep going on. Especially, the shortage of waterway intermodal capacity is the largest, and the growth rate of which is the fastest. In 2017-2021, the average growth rate of shortage of highway and waterway is 1.90% and 8.10% respectively, and growth rate of the waterway is 6.20% higher than that of the highway. It is predicted that the shortage of waterway, highway intermodal transportation capacity in Guangzhou Port will reach 676.51×10^4 TEU and 578.17×10^4 TEU in 2021, and the shortage of waterway intermodal transportation capacity will be 98.34×10^4 TEU larger than that of the highway.

(2) Shortage of waterway intermodal transportation capacity in Shenzhen Port will show an overall upward trend.
As shown in Figure 8, in 2017-2021, the shortage of railway and waterway intermodal transportation capacity in Shenzhen Port will show an overall upward trend, and the shortage of highway will continue to exist with the decline. Especially, the shortage of waterway intermodal transportation capacity is the largest, and growth rate of the shortage of railway is the fastest. According to the model prediction results, the average growth rate of shortage of railway, highway and waterway intermodal transportation capacity in 2017-2021 is 11.02%, 5.32% and -5.48% respectively, and the shortage of railway, highway and waterway will reach 17.21×10^4TEU, 182.88×10^4TEU and 498.48×10^4TEU in 2021.

(3) Focus of the Shortage Problem of Intermodal Capacity in both Guangzhou Port and Shenzhen Port is on Waterway.
Judging from the two dimensions mentioned above, waterway intermodal transportation is the focus of future development. With the continuous growth of containers needed for waterway transportation, the shortage of waterway intermodal transportation capacity is increasing, which is not conducive to the sustainable development of the port. Therefore, investment in waterway infrastructure construction needs to be the top priority of the future transportation investment of the governments

6. Conclusion

In this study, a system dynamic simulation model is developed for supporting future development of the intermodal transportation system in the Greater Bay Area in China. The model was utilized to analyse and forecast the demand for three intermodal transportation modes, as well as the capacity shortage of which in major container ports. The simulation results show that: (1) Demand for highway intermodal transportation was generally greater than that of the waterway in Guangzhou Port, but the gap between the demand for highway and waterway transportation has gradually narrowed since 2011 and the latter begin to exceed the former since 2019; (2) Demand for highway intermodal transportation had always been dominating in Shenzhen Port, while the demand for railway and waterway intermodal transportation will maintain steady and rapid growth except for the slow decline in the demand for highway in the future; (3) The rapid growth of demand for three intermodal transportation modes mainly due to the vigorous development of intermodal transportation system in container ports; (4)The shortage problem of intermodal transportation capacity in both Guangzhou Port and Shenzhen Port lies on the waterway, which should be the focus of future development and the investment in waterway infrastructure construction needs to be the priority. However, due to limited data, the model only considers the main three container ports, which has limitations to a certain extent. Further consideration will be taken to include all ports in the Greater Bay Area with a more improved model.

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Landing Charges with Ramsey Pricing Mechanism: An Application at TPE

Jin-Ru Yen[,1] (corresponding), Chia-Yi Shih[1], Chia-Ping Tsou[1], Man-Hsuan Chen[1]*

[1]Dept. of Shipping and Trans. Mgmt., National Taiwan Ocean University, Keelung, Taiwan 202.
Email: [1]jinruyen@gmail.com

*Corresponding Author

Abstract

Landing fees are the main sources of aeronautical revenue to airport operators, and are also important to airlines. Therefore, it is essential to formulate a suitable charging mechanism for landing fees in order to increase the revenue of airport operators and still maintain the airport's competition. Traditionally, pricing methods for airport landing fees are based on the maximum takeoff weight or maximum landing weight, which have little theoretical rationale. Now airport landing fees charged in Taiwan are also based on the aircraft weight for historical reasons.

There are various pricing methods in academia such as average-cost pricing, marginal-cost pricing and Ramsey pricing. In general, Ramsey pricing is suitable for uncongested airports or any airports in its off-peak periods, while marginal-cost pricing is appropriate for congested periods. Due to the increase in traffic volume and its hub operation, peak and off-peak hours become more obvious in Taiwan Taoyuan International Airport (TPE). Thus, TPE is thinking to differentiate its landing fees in different periods.

This research aims at developing a charging mechanism that applies the Ramsey pricing model. The proposed pricing mechanism is then validated at TPE. Although price elasticity is essential to Ramsey pricing, it is difficult to directly calculate this elasticity of airline demand in landings. The ordinal probit model is used to estimate the price elasticity from different passenger groups, and then the estimation results are applied in the Ramsey pricing model in order to calculate the price elasticity of airline's landings.

Empirical results indicate that landing fees are higher as the aircraft is larger and the distance is longer, based on the proposed Ramsey pricing model. Additionally, calculation results reveal that the current charges at TPE are less than the calculated landing fees. It is consistent with the fact that TPE has deficits on its financial performances at airside. The proposed pricing mechanism is applicable to other uncongested airports or the off-peak periods of any airports in the world.

Keywords: Landing fee, Ramsey pricing, Airport pricing, Ordinal probit model.

1. Introduction

Traditionally, pricing methods for airport landing fees are usually adopted by the maximum takeoff weight (MTOW) or maximum landing weight. However, these pricing standards have little theoretical rationale. The airport landing fees charged in Taiwan are also based on the MTOW and thus are not determined by the supply and demand of the market. There are various pricing methods in the academic field such as average-cost pricing, marginal-cost pricing and Ramsey pricing, etc. The Ramsey pricing is more appropriate when airports are in off-peak periods. Due to the increase in traffic volume and its hub operations, peak and off-peak hours become more obvious in Taiwan Taoyuan International Airport (TPE). Thus, TPE is thinking to differentiate its landing fees in different periods, which is believed to make airport operations more efficient.

This study aims to calculate the landing fee of TPE during off-peak hours with the Ramsey pricing model. TPE is located in about 40 kilometers from the center of Taipei. It is the busiest international air entry point in Taiwan and is also an important East Asia transit hub, with a lot of routes serving Asia, North America, Europe, and

Oceania. Aircraft types adopted in this research are Boeing 747-400 and Airbus 330-300, which are in the top two places in terms of landing frequency at TPE.

The developed Ramsey pricing model has 4 variables, the marginal cost of landing incurred to the airport operator, the price elasticity of the airline's demand in landing of different aircraft types, the operating costs of different aircraft types, and the multiplied Lagrange. Due to the difficulty of calculating the price elasticity of the airline's demand in landing, it is dealt with as a function of the price elasticity of passenger demand, under the theory of output effect. The price elasticities of passenger demand with respect to different aircraft types and distances are calculated with the ordinal probit choice model and the aggregate passenger air travel demand function. The distance is divided into short-haul, regional, and continental. Short-hauls are the flights between Taiwan and China. Regional flights are from Taiwan to Japan or Korea. Continental flights are to America, Europe and Australia. Specifically, flights from TPE to Shanghai Pudong (PVG), Tokyo Narita (NRT), San Francisco (SFO) and Brisbane (BNE) are investigated.

2. Research Related to Landing Charges

2.1. Average-Cost Pricing

Average-cost pricing is a regulatory policy used for public utilities (especially those that are natural monopolies) in which the price received by a firm is set equal to the average total cost of production. The advantage of average-cost pricing is that the firm is guaranteed a normal profit. Yen et al. (2016) develop a mechanism based on the costs incurred from airside services. Costs considered in the research include the value of land, the depreciation and operations costs of related equipment and the compensation of staff involved in providing the services.

2.2. Marginal-Cost Pricing

Marginal-cost pricing is one of the pricing methods that the price received by a firm is set equal to the marginal cost of production. When the price is set equal to the marginal cost of production, the sum of consumer surplus and producer surplus would be the maximum. Therefore, marginal-cost pricing is also called "first best pricing." Morison (1979) presents the theoretical model of optimal runway pricing to solve the problem of congested airports. The model is assumed to determine landing fees that maximize a weighted sum of airline consumers' surpluses subject to a revenue requirement. Thus, optimal landing fees with a revenue constraint are made up of a component based on total flight costs (including congestion cost and the value of passengers' time) and external congestion costs (marginal runway maintenance cost). The model is applied to San Francisco international Airport. Carlin and Park (1970) develop marginal delay or congestion costs for New York LaGuardia Airport, and explore the possible use of congestion tolls as a solution to the short-term congestion problem.

2.3. Ramsey Pricing

While economics suggests setting monopoly prices according to marginal costs in order to maximize social welfare (optimal solution), marginal-cost pricing will result in deficits if average total costs are above marginal costs (Mankiw, 2008). As the airport is uncongested, Ramsey pricing is suitable for charging the landing fees. Morrison (1982) developed the landing fees of Ramsey pricing model. The model is derived by maximizing the difference between social benefits and costs, given a constraint on profit. Ramsey pricing is considered to be quasi-optimum pricing (second best pricing) scheme designed for a natural monopolist. Unlike current weight-based fees, the landing fees of Ramsey pricing model vary with aircraft type and distance. According to Morison (1982) and Martín-Cejas (1997; 2010), Ramsey pricing would result in increased landing fees for larger planes or longer flights. Ramsey prices are optimal for airports with cost recovery problems, but are inefficient for busy airports (Hakimov and Muelle, 2014a; 2014b)

3. Methodology

3.1. Ramsey Pricing Model

Ramsey pricing provides a solution when landing fees based on marginal costs do not generate enough income to cover costs, a common situation for an uncongested airport. Ramsey pricing is derived by maximizing the difference between social benefits and costs, given a constraint on profit (Morrison, 1982), as illustrated in equations 1 and 2.

The objective function and constraint are

$$\max_{Q_1,\dots,Q_n} \mathrm{NSB} = \mathrm{SB} - \mathrm{SC} \tag{1}$$

$$\mathrm{s.t.} \quad TR - \mathrm{TC} = 0 \tag{2}$$

where $Q_1,\dots,Q_n$ = numbers of landing by category 1 to category n,

NSB = net social benefits, the difference between social benefits and costs,

SB = social benefit of the demand functions for the different aircraft types of the landings,

SC = social cost of the landings,

TR = total revenue to the airport authority of the landings, and

TC = total cost to the airport authority (including total variable cost and total fixed cost).

Social benefit (SB) is calculated from the demand functions for the different aircraft types of the landings, as expressed in equation 3.

$$SB = \int_0^{Q1} \mathrm{P}_1(\mathrm{Q}_1)\mathrm{dQ}_1 + \cdots + \int_0^{Qn} \mathrm{P}_n(\mathrm{Q}_n)\mathrm{dQ}_n \tag{3}$$

where P_i = the landing fee charged to aircraft in category *i* (a category is given by an aircraft type and length of flight), and

Q_i = the number of landings of category *i*.

Social cost (SC) is total variable cost to serve aircraft from category 1 to category n landing at the airport.

$$\mathrm{SC} = \mathrm{C}(\mathrm{Q}_1, \dots, \mathrm{Q}_n) \tag{4}$$

Total revenue (TR) is landing charges collected from landing aircraft of category 1 to category n.

$$\mathrm{TR} = \sum_{i=1}^{n} P_i Q_i \tag{5}$$

Total cost (TC) includes total variable cost and total fixed cost incurred by the airport authority to serve all types of aircraft.

$$\mathrm{TC} = \mathrm{C}(\mathrm{Q}_1, \dots, \mathrm{Q}_n) + \mathrm{F} \tag{6}$$

where F is equal to the fixed costs which must be covered.

The above objective function and constraint can be expanded in detail as follows.

$$\max_{Q_1,\dots,Q_n} \int_0^{Q1} P_1(Q_1)dQ_1 + \cdots + \int_0^{Qn} P_n(Q_n)dQ_n - C(Q_1, \dots, Q_n) \tag{7}$$

$$s.t. \qquad \sum_{i=1}^{n} P_i Q_i - [C(Q_1, \dots, Q_n) + F] = 0 \tag{8}$$

Forming the Lagrangean, we have

$$\max_{Q_1,\dots,Q_n,\lambda} \mathcal{L} = \int_0^{Q1} P_1(Q_1)dQ_1 + \cdots + \int_0^{Qn} P_n(Q_n)dQ_n - C(Q_1, \dots, Q_n)$$

$$+\lambda\left[\sum_{i=1}^{n} P_i Q_i - C(Q_1, \dots, Q_n) - F \right] \tag{9}$$

The first-order conditions are

$$\frac{\partial L}{\partial Q_i} = P_i - \frac{\partial C}{\partial Q_i} + \lambda\left(P_i + Q_i \frac{dP_i}{dQ_i} - \frac{\partial C}{\partial Q_i}\right) = 0 \qquad i = 1, \dots, n \tag{10}$$

Solving equation 10 results in

$$\frac{P_i - \frac{\partial C}{\partial Q_i}}{P_i} = \left(\frac{\lambda}{1+\lambda}\right)\frac{1}{\varepsilon_i} \qquad i = 1, \dots, n \tag{11}$$

where $_i$ is the (absolute value of) price elasticity of demand in landings, and $\partial C/\partial Q_i$ is the marginal cost of category i (MC_i). This is the standard Ramsey pricing result, which indicates that the percentage markup of price over marginal cost should be inversely proportional to the price elasticity of the demand (Baumol and Bradford, 1970). In other words, as $_i$ is less, the difference in P_i and MC_i (mark-ups) is greater. That is also called inverse elasticity rule.

As the elasticity of airlines' demand for landings ($_i$) is difficult to obtain, Morrison (1982) reformulated equation 11 to be able to estimate each component. According to output effect in microeconomic theory (Layard and Walters, 1978), when the proportion of production factors is fixed (1 aircraft plus 1 landing equals 1 flight), the airline's demand elasticity for landings is equivalent to the passenger's price elasticity of demand in air travel multiplied by the fraction of landing fees to total flight costs. The detailed description of output effect is in equations 12 to 19.

Output effect is the change which would occur if factor proportions were held constant, but output changed in response to changes in its price (Layard and Walters, 1978). Now we will illustrate why the elasticity of (airline) demand in landings can be replaced by a function of the elasticity of passenger demand. The explicit explanation can be seen in the following.

Suppose 1 unit of x requires a units of K (fixed factor) and b units of L (variable factor). Then, under perfect competition the price of x is

$$P_x = a \cdot w_K + b \cdot w_L \tag{12}$$

We suppose production function in short-run (within a certain period of time, at least one factor is fixed while others are variable) and let w_L rise but assume that the price of the other factor (w_K) is constant. The proportional increase in price of x is

$$\frac{\mathrm{d}P_x}{P_x} = \frac{\mathrm{d}(b \cdot w_L)}{P_x} = \frac{b \cdot w_L}{P_x} \cdot \frac{\mathrm{d}w_L}{w_L} = \upsilon_\mathrm{L} \cdot \frac{\mathrm{d}w_L}{w_L} \qquad (13)$$

$$\mathrm{d}\log P_x = \upsilon_\mathrm{L} \cdot \mathrm{d}\log w_L \qquad (14)$$

where υ_L is the share of L in costs.

The demand elasticity of consumer (η^D) is

$$\eta^\mathrm{D} = \frac{\mathrm{d}Q_x/Q_x}{\mathrm{d}P_x/P_x} = \frac{\mathrm{d}\log Q_x}{\mathrm{d}\log P_x} \qquad (15)$$

$$\mathrm{d}\log Q_x = \eta^\mathrm{D}\,\mathrm{d}\log P_x = \eta^\mathrm{D} \cdot \upsilon_\mathrm{L} \cdot \mathrm{d}\log w_L \qquad (16)$$

Since production is by fixed proportions, the proportional fall in each factor is the same as the proportional fall in output.

$$\mathrm{d}\log L = \mathrm{d}\log Q_x \qquad (17)$$

$$\mathrm{d}\log L = \eta^\mathrm{D} \cdot \upsilon_\mathrm{L} \cdot \mathrm{d}\log w_L \qquad (18)$$

Hence, the firm's demand elasticity of L (variable factor) is share of L in costs multiplied by demand elasticity of consumer.

$$\frac{\mathrm{d}\log L}{\mathrm{d}\log w_L} = \varepsilon_{LL} = \eta^\mathrm{D} \cdot \upsilon_\mathrm{L} \qquad (19)$$

In summary, we assume each flight requires one landing (variable factor) and aircraft operation for a flight (fixed cost) in this study. In the short-run, the aircraft operating cost is constant. υ_L is the share of landing in aircraft operating costs. Since airline's short-run production is by fixed proportions, the proportional fall in the number of landings is the same as the proportional fall in output (flights). Therefore, the elasticity of demand for landing is equal to the share of landing in total flight cost multiplied by the elasticity of demand for passengers. Thus, equation 19 results in

$$\varepsilon_i = \eta_i \left(\frac{P_i}{P_i + TC_i}\right) \qquad i = 1, \dots, n \qquad (20)$$

where η_i = the (absolute value) price elasticity of demand for passenger trips of the i category, and

TC_i = the cost of the flight for the i^{th} category exclusive of landing fee.

Finally, combing equations 11 and 20, the result of landing fee of Ramsey pricing for category i is

$$P_i = \frac{MC_i + \frac{\mathrm{k}}{\eta_i} TC_i}{1 - \frac{\mathrm{k}}{\eta_i}} \qquad i = 1, \dots, n \qquad (21)$$

where k = λ/1+λ, and

MC_i = the marginal cost of the landing incurred to the airport operator.

Equation (21) shows that the landing fees charged to aircraft in category *i* are related to the marginal cost of a landing to the airport operator, the elasticity of passenger, and the cost of the flight. Since this model is concerned with uncongested airports, the marginal costs are borne only by the airport operator; that is, there are no congestion externalities.

3.2. Aggregate demand function and elasticity

In order to use the elasticity of passenger demand to calculate the elasticity of airlines' demand in landing as illustrated in equations 11, 20 and 21, a discrete choice modeling approach with disaggregate passenger data is employed in this research. According to Daganzo (1979), the estimated discrete choice model is a choice probability function (CPF) of a vector of specified attributes **a** and a parameter vector θ. The CPF of alternative j can be stated as $P_j(\theta, \mathbf{a})$, j= 1, 2, …, J, with J as the number of alternatives. For a given vector of model parameters θ, the aggregate demand function of alternative j can be expressed as:

$$D_j = N \int_{a_1} \int_{a_2} \cdots \int_{a_K} P_j(\theta, \mathbf{a})\, f_A(\mathbf{a})\, d\mathbf{a} \tag{22}$$

Where N is the population size, K is the number of attributes specified in the choice function, and $f_A(\mathbf{a})$ is the probability density of the attribute vector **a** across the population. By definition, $P_j(\theta, \mathbf{a})\, f_A(\mathbf{a})\, N$ represents the density of decision makers with an attributes vector **a** who choose alternative j. Therefore, the integral in equation (22) is the expected value of $P_j(\theta, \mathbf{A})\, f_A(\mathbf{A})\, N$ with respect to **A**, and aggregate demand function D_j can be written as $E_A[N\, P_j(\theta, \mathbf{A})]$ or $N\, E_A[P_j(\theta, \mathbf{A})]$, with E_A as the expectation function with respect to the vector of random variables **A**.

Theoretically the elasticity of the aggregate demand for choice alternative j with respect to attribute **a** can be derived as equation 23 by definition.

$$\varepsilon_a^{D_j} = \frac{\partial D_j}{\partial a}\frac{a}{D_j} = \frac{\partial\, \{E_A[P_j(\theta,\mathbf{A})]\}}{\partial a}\frac{a}{E_A[P_j(\theta,\mathbf{A})]} \tag{23}$$

The standard approach to obtain the aggregate demand for a specific choice alternative is either taking the integral in equation 22 or weighting the individual probability across the population. The multiple integral is generally difficult to solve in practice. In some case when the choice probability is not a closed function such as the probit model, the weighting process is computationally intensive. Specifically, if the population is homogeneous, the expected aggregate probability for the population can be approximately by the probability of a representative individual whose values of the explanatory variables are respective mean values of the population. Consequently, equation 23 can be simplified as equation 24 (Yen, 2000).

$$\varepsilon_a^{D_j} = \frac{\partial\, P_j(\theta,\bar{\mathbf{A}})}{\partial a}\frac{a}{P_j(\theta,\bar{\mathbf{A}})} \tag{24}$$

where さ is the vector of the population mean values of the explanatory variables. Empirically, the partial derivative in equation 24 can be approximated by a differentiation in equation 25.

$$\varepsilon_{a_K}^{D_j} = \frac{P_j(\theta,\bar{\mathbf{B}}) - \partial\, P_j(\theta,\bar{\mathbf{A}})}{\Delta a_K}\frac{a_K}{P_j(\theta,\bar{\mathbf{A}})} \tag{25}$$

where the elements of vector だ are the same as in vector さ except that attribute a_K in the former is replaced by $a_K + \Delta a_K$. Equations 24 and 25 define the point elasticity of the demand for choice alternative j with respect to attribute a_K. If Δa_K is substantial, equation 25 is referred as an arc elasticity, with P_j(θ, さ) in the denominator being replaced by the average of P_j(θ, さ) and P_j(θ, だ).

4. Empirical Study

4.1. Price Elasticity of Passenger Demand (η_i)

Survey and Questionnaire

The derivation presented in section 3.1 shows that the airline's demand elasticity in landing ($_i$) is proportional to the price elasticity of passengers (η_i as in equation 20. To calculate η_i, it is essential to develop the aggregate demand function as in equation 22. Additionally, the CPF $P_j($, $\mathbf{a})$ is important to obtain the aggregate demand function and the demand elasticity of passenger for various aircraft types. The CPF, based on the ordinal probit model, was estimated by Yen et al. (2015). The data of this study and Yen et al. (2015) were collected from a passenger survey conducted in May 1-24, 2015, in the departure lounges at TPE. Various flights departing from TPE were pre-chosen to cover different aircraft types and flight distances. Passengers in each sampled flight were chosen by purposive sampling. A valid sample of 444 passengers departing from TPE was collected.

Details of the questionnaire can be referred to Yen et al. (2015). To summarize, the questionnaire contains 6 versions, combing 2 aircraft types and 3 destinations. Aircraft types adopted in the survey include Airbus 330-300 and Boeing 747-400. Three destinations from TPE, short-haul, regional, and continental, are further chosen for each aircraft type. The destination of short-haul flight is PVG for both types of aircraft. The destination of regional-flights is NRT for both aircraft. Finally, the destinations of continental-flights are BNE for A330-300 and SFO for B747-400. All versions of questionnaires contain 6 questions on travel experiences, 5 questions on individual demographic characteristics and 3 different scenarios. All questions related to travel experiences and demographic characteristics are the same for each of the 6 version. Only the content of the scenarios are different in each version because of the difference in flight distances and thus the ticket prices in each version. In each questionnaire, the respondent was asked of their willingness of choosing this route for how many times in three different rating scenarios. Therefore, the CPF of passengers associated with different aircraft and flight distances can be estimated (Yen et al., 2015).

Sample Statistics

Key characteristics of sampled passengers are listed in Table 1, with relative frequency calculated by aircraft and by flight distances. Thus, there are 6 sub-sample sets in Table 1. The number of respondents in each sub-sample is from 60 to 95. In general, gender is evenly distributed in each subsample, which is consistent with the air travel population. In terms of trip purposes, business travelers dominate short-haul flights with both types of aircraft, 57% for B747-400 and 60% for A330-300. Travelers for leisure account for the major part of regional flights, 73% for B747-400, and 62% for A330-300.

Firstly, this research examines the passenger information of Boeing 747-400. There are 65 respondents in the short-haul with B747-400, 58% of which are male, 68% of the respondents traveled by air more than 2 times per year. Approximately 57% of the respondents travel with business purpose. There are 74 respondents in regional-flights with B747-400, and 46% of them are male. More than 73% of the respondents travel for leisure. Lastly, there are 74 respondents continental-flights with B747-400, and among those 49% are male. More than 60% of the respondents travel for leisure or to visit friends and relatives (VFR), and a relatively small portion of sample (25%) travel for business.

With respect to A330-300, there are 76 respondents in short-haul flights, and 51% of which are male. Approximately 39% of the respondents travel by air within 2 times per year and 32% travel by air within 3-5 times per year. Approximately 60% of the respondents travel with business purpose. In regional-flights, there are 63 respondents, with 52% of them being male. Approximately 62% of the respondents travel for leisure. As for continental-flights, there are 92 respondents and 38% of which are male. More than 66% of the respondents travel less than or equal to 2 times per year by air.

To sum up, for short-haul from TPE, most passengers' purpose of traveling is for business. Passengers traveling for leisure mostly exist in regional-flights. For continental-flights, passenger's travel purposes are mainly for leisure, VFR, or business.

Table 1: Summaries of Sample Characteristics

Characteristics		Boeing 747-400			Airbus 330-300		
		S	R	C	S	R	C
Gender	Male Female	38(58) 27(42)	34(46) 40(54)	36(49) 38(51)	39(51) 37(49)	33(52) 30(48)	35(38) 57(62)
	Total	65	74	74	76	63	92
Air trips per year	< = 2 3-5 > = 6	21(32) 22(34) 22(34)	48(65) 18(24) 8(11)	41(55) 25(34) 8(11)	30(39) 24(32) 22(29)	31(49) 22(35) 10(16)	61(66) 26(29) 5(5)
	Total	65	74	74	76	63	92
Purpose	Leisure Business VFR Others	19(29) 37(57) 5(7) 4(7)	54(73) 17(24) 1(1) 2(2)	24(32) 18(25) 24(32) 8(11)	16(21) 46(60) 5(7) 9(12)	39(62) 12(19) 4(6) 8(13)	45(49) 4(4) 21(23) 22(24)
	Total	65	74	74	76	63	92

Note: Numbers in the parentheses are percentage. S stands for short-haul, R is regional-flight, and C is continental-flight.

Price Elasticity

According to equations 24 and 25, choice probabilities are necessary to calculate the elasticity of passenger air travel demand. This section used the estimated results of the ordinal probit model for TPE by Yen et al. (2015) to frame the aggregate passenger air travel demand function. To the extent that the aggregate demand elasticity is of interest, the aggregate probabilities are predicted with respect to each alternative. The approach labeled as classification is adopted in this paper to predict the aggregate choice probability and thus to calculate the various price elasticities of aggregate passenger air travel demand.

The population of each aircraft type for different distance is divided into several groups according to the dummy variables of those estimated results from the ordinal probit models. Each group is assumed to homogeneous with respect to the explanatory variables and the "average individual" approach is adopted for aggregate forecasting within each groups. That is, the aggregate probability for each group is approximated by the probability of an average individual in the group.

The price elasticity of passenger demand is the percentage change of the number of expected choice due to one percent change in the price of ticket, all else being equal. If the differences between ticket prices that passengers pay in various scenarios are viewed as the changes in the prices of various flights, the predicted probabilities under different scenarios can be used to calculate the price elasticity of passenger demand. Table 2 lists the calculated results. The negative values for each group reflect that decreasing prices of ticket will increase passenger air travel demand.

Table 2: Price Elasticity of Passenger Demand

Aircraft type / Distance	B747-400	A330-300
Short-haul	-1.24	-1.58
Regional-flights	-0.86	-1.27
Continental-flights	-1.56	-1.35

4.2. Cost of Flight (TC_i)

As we concentrate on the cost for the landing of each flight the following calculation is used. The cost of flight during landing (TC_i) is equal to the operation cost per block hour for each aircraft type times the number of block hours per flight and times 2. Operating costs per block hour in 2014 were taken from the Bureau of Transportation Statistics (BTS, 2014). The aircraft characteristics are summarized in Table 3.

Table 3: Aircraft Characteristics at TPE

Aircraft Characteristics	Boeing 747-400	Airbus 330-300
USD per block hour	15,629	10,484
Seats(2-class)	524	335
MTOW(ton)	397	230

4.3. Parameter (k)

The value of k depends on the extent to which the revenue constraint is binding. If the constraint is not binding, then k=0 and Ramsey pricing reduces to marginal cost pricing, i.e., $P=MC$. At the other extreme, when revenue requirement is at the maximum attainable level, the value of λ tends to infinity and we get k=1 that reduces the Ramsey pricing formula to P=MR. Therefore, the value of k will be between 0 and 1.

The unknown parameter k has to be estimated in order to calculate Ramsey pricing. According to the assumption of most of the authors in previous related studies, the landing fees of Ramsey pricing generated with that value for k are of the same order of magnitude as current fees. Therefore, in this research, we choose a level of weight-based fees as basis for estimation, which are the current rates of the smallest aircraft type in the short-haul at TPE. We assume the current rates of the smallest aircraft type in the short-haul as the landing fee (P_i), and then all of the estimated variables (including η_i, TC_i, and MC_i) are put in the Ramsey pricing model. Finally, the research gets the estimated values of k. At TPE, the estimated value of k is 0.0093.

4.4 Marginal Cost Incurred to Airport Authority (MC_i)

This paper assumes that TPE is natural monopolists. A natural monopoly has economies of scale that the average cost is decreasing. Because it has a high fixed cost for a product, marginal cost of producing one more good is roughly constant and approximate to average cost. We use the estimation of Yen et at. (2016) as the indicator of the average cost for landing at TPE. Table 4 shows the average costs of different aircraft types at TPE, which are used as marginal costs (MC_i) in equation 21.

Table 4: Average Costs of Different Aircraft Types in 2012 (In US$)

Aircraft Type	B747-400	A330-300
Average Cost	810	1,370

4.5. Estimation Results of Ramsey Pricing

By applying equation 21 and other parameters calculated in the previous sections, the landing fees based on the Ramsey pricing mechanism with respect to two selected aircraft types are calculated and shown in Table 5. The structure of the Ramsey pricing for landing fees is related to distances and aircraft types. As the aircraft is larger and the distance is longer, the landing fees are higher, which is similar to the results presented by Morrison (1982) and Martín-Cejas (1997; 2010). For example, the calculated landing fees for B747-400 at TPE are US$ 1832, 2692, and 3174 with respect to flight distances from short-haul, regional, and continental, respectively. This phenomenon applies to the other aircraft at TPE. At TPE, for each distance category the calculated landing fees of B747-400 is greater than the one of A330-300.

Table 5 also lists the current landing fee for each aircraft type at TPE. Since TPE does not charge landing fees according to flight distances, there is only one current charge for each aircraft type. The comparison between the calculation results and the current charge reveals that in almost all cases the current charge is less than the land fees based on the Ramsey pricing mechanism. The only exception is the Ramsey pricing of B747-400 for short-haul (cross-strait) flights (TPE-PVG), but the difference is only 8.0%. The ratio of current charge to Ramsey ranges from 0.48 to 0.75, without counting the short-haul flights with B747-400 and A330-300, the base case for estimating parameter k. That is, in most cases less than 75% of landing fees under Ramsey pricing are charged in the current weight-based mechanism. This finding is consistent with the fact that TPE has deficits on its financial performances at airside.

Table 5: Calculation Results of Landing Fees with Ramsey Pricing (In US$)

Distance \ Aircraft type	B747-400	A330-300
Short-haul	1,832 (1.08)	1,053 (-)
Regional-flights	2,692 (0.73)	1,408 (0.75)
Continental-flights	3,174 (0.62)	2,207 (0.48)
Current charge	1,970	1,053

Note 1: Due to the procedure that we used to estimate parameter k, the Ramsey pricing of the smallest aircraft with the short-haul flights is the same as the current charge.

Note 2: Numbers in the parentheses are the ratio of current charge to the landing fees based on Ramsey pricing.

5. Conclusion

In order to use Ramsey pricing mechanism to calculate landing fees, the price elasticity of passenger air travel demand for different aircraft types at TPE are estimated. The results indicate that the price elasticity of passenger demand is associated with flight distances and aircraft types. This elasticity for smaller aircraft is greater than the one for larger aircraft for both short-haul and regional flights. In addition, this elasticity for regional-flights is less than the one for short-haul and continental flights.

The calculation results of the landing fees at TPE demonstrate that the structure of the Ramsey pricing for landing is related to distances and aircraft types. The landing fees are higher for larger aircraft in any distance. Additionally, for each aircraft the landing fees increase as flight distances increase.

The comparison between the calculation results and the current charge reveals that in almost all cases the current charge is less than the land fees based on the Ramsey pricing mechanism. Only the Ramsey price of B747-400 for short-haul routes is less than but close to the current charge. This finding might give the reason that TPE has deficits on their financial performances at airside for years. Although the empirical study was conducted using data from TPE in Taiwan, the mechanism can be applied to airports world-wide.

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Economic Analysis of Liner Company's Collection of Fuel Surcharge

JinYang[1]

[1] School of Navigation, Jimei University, Xiamen, Fujian Province

Abstract

The purpose of this paper is to study the economic principles of fuel surcharges for container liner companies with static and dynamic research methods. The static research method is to compare the fuel cost of container liner transportation with the fuel cost of other types of shipping transportation under the premise of a certain international crude oil price. As a result, the fuel cost of container liner transportation is the lowest among all the shipping companies, even it exceeds 25%; The dynamic research method is to conduct an econometric analysis of fluctuations in international crude oil prices and fluctuations in fuel costs for container liner transportation on the China-Australia route. The results show that there is a dynamic geometric relationship between the international crude oil price and the fuel cost of the container liner company. That is, the increase of the international crude oil price per dollar will cause the fuel cost of container liner transportation to increase by 1.8%. This paper concludes that there is indeed a theoretical basis for economics in the collection of fuel surcharges by container liner shipping companies.

Keywords: Shipping, Fuel Surcharge, Crude Oil Price

1. Introduction

With the rise in international crude oil prices, in June 2018, the global container liner companies Maersk, Hapag-Lloyd and Mediterranean Shipping Company announced their notice of fuel surcharges[S]. The fuel surcharge, after three years' silence, once again evokes the thinking of shippers and shipping operators about the surcharge imposed on the shipper by the container liner shipping company. From July to August 2015, a debate was held between the container liner shipping company and the shipper on whether a surcharge should be imposed. Finally, under the investigation and supervision of the National Development and Reform Commission and the Ministry of Transport of China. On September 15, 2015, after the Japanese mail ship took the lead in adjusting the container liner surcharge items and standards, Taiwan Evergreen Shipping, Wanhai Shipping, Yangming Shipping Kawasaki, Japan; South Korea's Hanjin Shipping, Hyundai Merchant Marine and other shipping companies sent letters to the China National Development and Reform Commission, and proposed to cancel some of the surcharges, simplified and merged the four aspects of the combined charging project, and then argued to regulate the surcharge charges for container liner transportation. Hence, the dispute between the container liner company and the shipper was end[A].

This paper aims to analyze the rationality of the fuel surcharge for shippers from the three largest container liner companies in the world. This paper will analyze the historical origin of fuel surcharge, the static impact of fuel surcharge on the cost of container liner company, and then the dynamic impact.

2. The Historical Origin of Fuel Surcharges

Fuel surcharges have some differences in English names in countries around the world. For example, in the United Kingdom and the United States, the English for fuel surcharges is the bunker adjustment factor (BAF for short). In the Nordic countries, such as Maersk in Denmark, it is called as Emergency Bunker Surcharge (EBS). In the south-central countries of Europe, such as the Mediterranean in Switzerland, it is called as Fuel Adjustment Contribution (FAD). Despite the differences in English, the reason for fuel surcharges is same. The derivation of fuel surcharge is from that the sudden rise in international crude oil prices, an increase in the cost of container liner shipping companies, thus, in order to compensate for the losses caused by rising costs, besides a normal freight rate, container liner companies are paying shippers an additional fee, called a fuel surcharge.

The fuel surcharge collection system first began in the 1970s. By 2008, the international crude oil has risen to $147 a barrel, the fuel surcharge collection system was widely promoted in the international shipping market[I] and the fuel surcharge system has been widely promoted. However, in the early days of the promotion of the fuel surcharge system, there was a sharp confrontation between the shipper and the carrier in the Western countries, and the shipper widely questioned the rationality of the fuel surcharge system[T]. The surcharge system is based on the need for international trade to stabilize the freight rate of container liner shipping. The principal structure is the basic rate plus surcharge system.

In international merchandise trade, buyers and sellers generally adopt the CIF price system, namely the commodity price, transportation insurance and transportation rate system. Although the proportion of maritime transportation costs to CIF prices is only about 10%, the stable transportation rate can also promote the stability of international commodity trade prices. The liner transportation acknowledgment has designed a basic rate plus surcharge rate system, which is a price system that keeps the basic rate stable and the additional rate fluctuates with market factors. The essence is that through the cost pricing, the basic rate will remain stable for a long time to meet the requirements of the international trade market for the liner shipping market rate.

The impact of market factors can only affect the surcharge rate. By levying and canceling the surcharge rate, the additional rate will fluctuate according to the factors affecting the transportation rate, thus achieving the relative stability of the liner shipping rate.

The method of calculating fuel surcharge is first calculated the total fuel cost of a voyage before the fuel rises and then calculate the total fuel cost after the price increase. The difference between the two is divided by the total tonnage of the cargo loaded by the ship to calculate the difference that each deadweight should bear. Some liner companies simply calculate the fuel price increase, multiplying the magnitude by the base rate, which is the fuel surcharge that should be imposed.

3. The Static Impact of Fuel Costs on the Cost of Container Liner Transportation

In the early 1970s, due to the low international crude oil prices, shipping operators were less concerned about the proportion of container liner shipping costs for fuel costs per voyage. Many large ships are equipped with turbines, while they can generate high power and have low maintenance costs. However, in the late 1970s, international crude oil prices rose sharply, the price of crude oil per barrel rose from 8 dollars in the early 1970s to 36 dollars in the late 1970s. The international crude oil price has quadrupled only during a short period of time. In the late 1970s, fuel costs accounted for 13% of total shipping costs, then, in the 1980s, this proportion rose to 34%. In the 1990s, shipping companies introduced a large number of fuel-efficient diesel engines, and the efficiency of fuel utilization was greatly improved. In addition, the price of international crude oil has declined, stabilizing at around 25 dollars per barrel, which has caused the proportion of fuel costs to total shipping costs to decrease, and is finally stable at around 25%. But by the beginning of the 21st century, the price of international crude oil began to rise slowly, more than 50 US dollars per barrel. By 2008, the fuel per barrel reached a record of 147 US dollars. Along with the rise in international crude oil prices, the proportion of fuel costs in the total cost of shipping has increased significantly, making many shipping companies, especially international container liner companies, struggling.

Table 1: The proportion of fuel costs of China's container liner companies in total shipping costs in 2014/100 million yuan

	China Cosco	China Cosco Shipping Lines	China Shipping Container Lines	China Shipping Develop	China Merchant Ship	Bohai Ferry Group
Fuel cost (10,000 Renminbi)	66.7	10.5	35	23	3.1	1.7
Shipping cost (10,000 Renminbi)	280.8	30.9	155	54.7	9.7	3.8
Proportion (%)	24	34	23	42	32	45

Source: According to the editor of the China Times listed company in 2014

Table 1 shows the distribution of fuel costs of various types of shipping companies in China in the total cost of shipping in 2014 when international crude oil prices were basically around 100 dollars per barrel.

It can be seen from Table 1 that shipping companies can be basically fallen into four categories. The first one is ferry shipping enterprises — Bohai Ferry Group; the second category is tanker transport companies — China Merchant Ship; The third type is dry bulk shipping company — China Cosco Shipping Lines and China Shipping Develop, and the fourth category is container liner transportation company — China Cosco and China Shipping Container Lines.

Then, here is the analysis on the proportion of fuel charges to the cost of shipping enterprises for the above four types of shipping enterprises: ferry shipping enterprises accounted for the largest proportion of shipping costs, reaching 45%; followed by dry bulk shipping companies, which reached 34% and 42%; next was merchants ships, fuel costs accounted for 32% of total shipping costs; finally was container liner shipping companies, whose fuel costs accounted for the smallest proportion of total shipping costs, reaching about 25%.

It can be seen from all types of ships, the proportion of the cost of container liner transportation is relatively small, but it also reaches more than 25%. This may be related to the total cost of container liner transport being the highest among the various types of ships.

Therefore, it is necessary to analyze the dynamic impact of fuel costs on the cost of container liner companies, that is, the impact of time series.

4. The Dynamic Impact of Fuel Costs on the Cost of Container Liner Companies

4.1 Measurement Model

In order to study the dynamic impact of crude oil price fluctuations on the shipping costs of container liner shipping companies, the paper establishes a time series between the changes in international crude oil and the fuel costs of container liner companies, which facilitates the study of international crude oil price fluctuations between container surcharges and fuel surcharges. The theoretical measurement model of the relationship is as follows:

$$FC = \beta_0 + \beta_1 p + \mu \quad (1)$$

Among them,

FC represents fuel cost, in unit of 10,000 yuan;

P represents International crude oil price, in unit of dollars per barrel;

β_0 is a constant term;

β_1 is a coefficient;

μ is a random error term.

In the measurement model, since the data is from the China-Australia route in 2017, the unit of fuel surcharge is "10,000 yuan"; since the international crude oil price is from the New York International Crude Oil Futures, the unit of international crude oil is "dollar per barrel".

4.2 Data Analysis

The paper selected China-Australia route as the research object, but did not choose China-Europe, or China-North America route as the research object, mainly because the China-Australia route was not affected by the low crude oil price, hence, enhanced data reliability. In addition, due to the use of "month" for fuel consumption data, the consumption of one month of fuel costs in China Cosco Shipping Lines to Australian container liner routes is used as a cost, corresponding to the average price of New York International crude oil for the "month". So the data used in this paper has spanned three years, from November in 2015 to May 2017, a total of 19 months.

4.3 Model conclusion

The above international crude oil price sample and fuel cost sample are fed into the social science statistics software (Statistical Product and Service Solutions, referred to as SPSS), and the equation (2) is obtained.

$$Log(FC)= 5.571 + 0.018\, P \quad (2)$$

$$(34.192) \quad (5.018)$$

$$R^2 = 0.597 \qquad N = 19$$

From the results of SPSS, the variance test and the t-test are significantly passed and both meet the standard, and are shown in the above econometric equation (2). In Equation 2, the t-statistics in parentheses is significantly passed, and the p values of constants and exogenous variables are significantly passed.

4.4 The economic significance of the model

Further decomposition of equation 2, the equation can be expressed as$FC = e^{5.571+0.018p}$, that is, fuel costs and international crude oil prices are exponential geometric series relationship[J]. For every one dollar increase in international crude oil prices, Container liner shipping company's fuel cost on the Australian route will increase by 1.8%. For container liner companies, due to the large base of fuel costs, every dollar increase in international crude oil prices will increase their fuel costs by tens of thousands or even millions of dollars. Therefore, container liner shipping companies impose fuel surcharges on their shippers or shippers to share the additional cost, which, from the perspective of economic theory, is a theoretical basis.

5. Conclusions

In June 2018, Maersk, Mediterranean Shipping Company and Hapag-Lloyd's, these three container liner companies began to analyze the economic principles of shippers' fuel surcharges. The purpose is to study the international container liner company's fuel surcharge from an academic perspective and to find the rationality of the economics principle. This paper analyzes from both static and dynamic perspectives. From a static perspective, it is believed that shipping companies are indeed a high-fuel-consuming industry. In the four types of operation modes of ferry vessels, dry bulk carriers, oil tankers and container ships, the fuel cost of container transportation accounts for the lowest proportion of total shipping costs, but it also exceeds the proportion of 25%. From the dynamic point of view, the China-Australia route of China Shipping Container Lines is the object of study. Using the econometric analysis method, the result is that every one dollar increase of international crude oil price will increase the fuel cost of container liner companies by 1.8%, that is a large increase. Therefore, in order to maintain the stability of the benchmark transportation rate for international trade, the container liner company should adopt a surcharge to deal with the fluctuation of international crude oil prices, which is a reasonable economic measure.

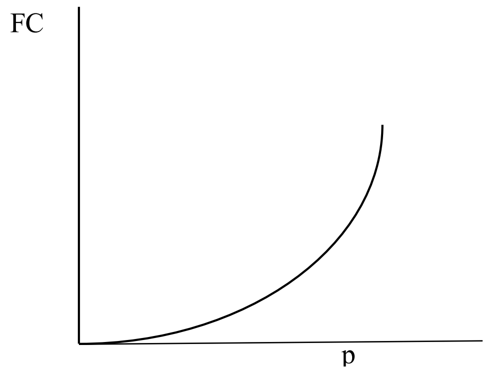

Figure 1: Geometric relationship between international crude oil price and fuel cost

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Structural Breaks and Fuel Surcharge Policy: Evidence from the U.S. Less-than-Truckload Motor Carrier Industry

Angela Yan Du[1] *and Chi Keung Marco Lau*[2]

[1] Department of Economics, Finance and Accounting, Fort Hays State University, Hays, KS, 67601, USA
[2] Department of Accountancy, Finance and Economics, University of Huddersfield, Queensgate, UK
Email: [1]y_du10@fhsu.edu

Abstract

The U.S. LTL (less-than-truckload) industry, in which goods of unrelated business customers are shipped together, has received less attention than its significance deserves. An important feature of trucking since the 1980 deregulation has been multi-part pricing. In the LTL sector for instance, freight bills typically include three components: (a) a base charge for essential capital and labor inputs, (b) a premium for accessory services, and (c) a surcharge for fuel-related costs.

Earlier LTL studies have focused either on the cost side or the determinants of LTL market rates. Few have addressed multi-part price formation. Yet this formation is crucial because, in both competitive and monopolistically competitive environments, one firm's surcharge policy affects another. A well-designed surcharge policy can, if applied properly, be an important source of carrier revenue, and in fact has become a significant profit center at many firms. To complement the current institutional and econometric literature, we focus on the structure of LTL fuel surcharge policies, drawing on panel data of major U.S. LTL carriers between 2015 and 2018. The very recent character of this dataset permits a highly contemporaneous view of how surcharge rates are formed and what its inter-firm dynamics look like.

The objective of our work is to determine how LTL carriers develop and utilize fuel surcharge policies to recover fuel expenses. We use the monthly observations from July 2015 to January 2018 of five major LTL firms: FedEx Freight, Yellow Roadway Corporation Worldwide, Old Dominion Freight Lines (ODFL), UPS Freight, and ArcBest Freight, accounting for just over 50% of LTL industry revenue. Along with standard linear and nonlinear unit-root test methodologies, we construct a spillover index of inter-firm linkages among fuel surcharge practices.

Preliminary results, using the five-firm average as benchmark, indicate ABF consistently sets its surcharges above industry average. A structural break at every firm is observed in 4th quarter 2015, after which the inter-firm surcharge gap has been narrowing and converging toward the sectoral average. For example, ODFL required about a year after the end of 2015 to catch up with its competitors' surcharges. Our hypothesis that major LTL fuel surcharges have been converging toward the industry average since 2015 is confirmed, suggesting competition has intensified in recent years.

JEL Classification: C22 R41

Keywords: Freight Transportation, Less-than-Truckload, Fuel Surcharge, Trucking

1. Introduction

The rising demand for ground transportation, influenced not only by GDP growth but the globalization of manufacturing and retail supply chains, has affected every sub-sector of the industry: truckload (TL, above-10,000-lb shipments), less-than truckload (LTL), and small packages (under 100 lbs). LTL carriers collect freight from various shipper docks and consolidate it into enclosed trailers for line-haul to a consolidation or hub terminal, where it is further sorted and consolidated for additional line haul. After inspection on these inbound shipments, the freight is loaded onto an outbound trailer, which forwards the freight to a breakbulk, connection, or delivering terminal and then to the consignee. Because this consolidation requires a network of freight terminals, it is more capital-intensive than TL freight is. It also, for the same reason, requires more labor which, along with more unionized wages, consume up to half of an LTL carrier's revenue.

LTL Industry and Multi-Part Pricing Strategies

Trucking deregulation in the *Motor Carrier Act of 1980* dramatically boosted the number of U.S trucking companies of all types. Carrier operating systems have adapted to this new environment. In the process, mid-sized firms have become vulnerable to competition from national companies, capable of providing efficient service through their established networks, so that a new wave of post-1980 carrier mergers is occurring. The aftermath of these mergers and acquisitions is an industry structure consisting of a few large, full-service logistics companies and many small niche LTL providers. The most recent three largest mergers and acquisitions in LTL history took place in 2015: FedEx acquired TNT express at $4.8 billion, becoming the largest LTL carrier in the US; UPS Freight bought Coyote Logistics at $1.8 billion; and XPO Logistics bought Norbert Dentressangle at $3.8 billion and Con-Way at $3 billion. (Table 1 provides a detailed history of merger and acquisitions in the LTL industry in the past two decades.[98]) The aftermath of these acquisitions is that, of the sixty leading name-brand North American LTL carriers in 1983, only seven exist today. As of 2017, the top ten LTL carriers (FedEx Freight, YRC Worldwide, XPO Logistics, Old Dominion Freight Line, UPS Freight, Estes Express Lines, ArcBest Freight, R+L Carrier, Saia Inc. and Southeastern Freight Lines) accounted for 79% of market revenue.[99]

Another consequence of the 1980 deregulation has been the introduction of multi-part pricing schemes, permitting shipper-customers to observe how certain aspects of the carrier's costs are structured. Freight bills now typically include three components: (1) the net charge for moving freight from one point to another along the carrier's routes; (2) charges for any accessory services; and (3) a fuel surcharge to cover fuel-related costs. Separating the base from the fuel surcharge distinguishes the LTL carrier's charges for its (relatively permanent) capital-labor complement from its (more volatile) fuel costs, allowing customers to compare these components with other transportation options at their disposal.

More generally, the presence of a separate charge for a base service and a fuel-related service implies there are two distinct – and thus at least potentially observable – aspects or sub-services. For example, fuel sub-charges are more volatile than non-fuel sub-charges and, as they change, customers generally will wish to substitute shorter- for longer-haul strategies. Charging fuel-related costs to non-fuel inputs such as truck and warehouse capital would effectively subsidize customers who do not adapt to fuel sub-charge variations.

The objective of the present study is to examine how LTL carriers develop and utilize fuel surcharge policies to recover fuel expenses. Using monthly observations from 2015 to 2018, we will compare the leading LTL carrier fuel surcharge policies to whether the operations and cost structures of carriers that determine their own fuel surcharge policies differ from those who imitate competitors in this regard. If they do, some shippers may be over- or under-compensating carriers for diesel fuel.

Earlier Work

Early work on the LTL industry focused mainly on the supply side, especially on the 1980 deregulation's effects on cost, production, and market structure. Mixed empirical results have been encountered. Daughety (1985), McMullen and Stanley (1988), Daughety and Nelson (1988), Winston *et al.* (1990), Grimm *et al.* (1989), Harmatuck (1991, 1992) and McMullen and Tanaka (1995) report no evidence of increasing returns to scale; Keeler (1989) finds significant scale economies among smaller firms and mild evidence of economies among larger, while Ying (1990) finds economies at all firm sizes. However, Allen and Liu (1995) suggest LTL scale

[98] Acquisition and merger data are from online news reports.

[99] Data are from *Transport Topics Top100 For-Hire Carriers, 2018*.

economies are being substantially underestimated in absence of data on service quality. By contrast, Friedlaender and Spady (1981), Chiang and Friedlaender (1984), and Keaton (1993) find economies in LTL operations, both before or after deregulation, to be substantially due to traffic density rather than total firm size: unit cost falls sharply as ton-mile traffic volume rises in a constant-size network, so that net service improves as well. Generally speaking, trucking deregulation has improved consumer welfare and economic efficiency, yet at the same time intensifying market concentration as the more efficient hauling firms acquired or replace the less efficient ones (Liu, 1993 and 1994; McMullen and Tanaka, 1995).

Recent studies have brought important institutional insight into LTL pricing determinants and performance. Kay and Warsing (2009) find LTL rates to be inversely proportional to weight, distance, and shipping density. Smith, Campbell, and Munday (2007) find the determinants of freight charges to be shipping volume, weight, distance, and interaction between weight and distance. Smith *et al* (2007) point out that LTL competitive environments also affect pricing: net rates tend to be higher in small and northeastern-corridor cities than in larger centers, and lower where more competitors are active. Özkaya *et al* (2010) offer a scorecard to quantify intangible factors in LTL pricing. They find the most significant ones to be negotiating power; the freight's economic value; and the final determination of the freight's class as opposed to that originally contracted with the shipper. Using data from Taiwan in contrast, Lin, Lin, and Young (2009), show that the common practice of distance/weight-based pricing tends to underestimate operating costs, corrected only by considering network capacity in pricing decisions.

Going beyond these studies of the tangible and intangible drivers of LTL rates, Du and Buccola (2018a) investigate an LTL sub-charge's uniquely multi-part character, and in so doing, providing a more explicit picture of LTL technology. They find a clear though incomplete jointness between base transportation functions (which involve relatively more capital and labor) and fueling functions (which involve relatively more fuel), justifying separate fuel surcharges that nonetheless depend on base-service charges. Rather than cover fuel expenses only, fuel surcharges in their work include elements of capital and labor costs, reflecting the joint character of LTL labor, capital, and fuel productivity. Du and Buccola (2018b) further apply a revenue function approach to LTL sub-charge analysis to identify the opportunity costs of the fuel services forgone, which vary with sub-charges and input levels.

Scholarly Significance

To complement the above institutional and econometric literature, the present paper focuses on the uses and industrial organization of an LTL firm's fuel surcharge policy, drawing on panel data of several major U.S. LTL carriers from 2015 to 2018. Consider first the user side. Fuel surcharges help protect the carrier from unexpected fuel sub-charge spikes, allowing them to respond more flexibly to market conditions and in that way significantly reducing total carrier cost. A well-designed surcharge policy can also, if applied properly, be an important source of carrier revenue, and in fact has become a significant carrier profit center at many firms. A deeper examination of fuel surcharge policies thus will require an analysis of how the usefulness of a carrier's fuel-surcharge policies can be optimized. Many of the lessons learned here will be of value outside the LTL industry, applicable also to airline, air cargo, and small-package delivery industries.

Second, as detailed above, earlier LTL studies have focused either on the cost side or the determinants of LTL market rates and their principal multi-part structures. But few have addressed the industrial organization of LTL sub-charge formation. Given the competitive or monopolistically competitive environment in which they find themselves, firms' surcharge policies generally affect one another. In their explication of how LTL carriers develop and utilize fuel surcharge policies to recover fuel expenses, Kent, Smith, and Grant (2008) have been the greatest exception to ignoring this issue. They note that fuel surcharge policies involve three key components: a fuel surcharge base rate; a trigger; and the sensitivity to the trigger. They find carriers either establish their own surcharge policies or, more frequently, imitate those of their better-established peers. Kent *et al* adopt a part-to-whole qualitative approach to examining how firms determine these components, enumerated by way of a standardized interview protocol of LTL carriers. As an extension and supplement to their study, we here conduct a time series analysis of monthly observations, July 2015 to January 2018, of several major U.S. LTL carriers' pricing structures. The very recent character of this dataset permits a highly contemporaneous view of how fuel surcharge rates are being formed in the industry, of particular value in view of the frequency of mergers and acquisitions in this industry during the past few years.

Finally, as fuel surcharges have become a significant part of transportation invoice expenses, an increasing number of shippers are expressing interest in and concern over surcharge policies. An understanding of fuel surcharge rate formation, structure, and inter-firm dynamics thus will provide customers the transparency they need to negotiate effectively for shipping rates.

Data and Methods

The data set consist of monthly fuel surcharges over the period July 2015 to January 2018. Fuel surcharge data for five major LTL firms, including FedEx Freight (FXF), Yellow Roadway Corporation Worldwide (YRC), Old Dominion Freight Lines (ODFL), UPS Freight and ArcBest Freight (ABF), accounting for more than 50% total revenue share in this industry, are available in the fuel surcharge archive of the carriers' websites. Table 1 gives the summary statistics.

Table 1. Summary Statistics
Fuel Surcharges at Selected U.S. LTL Motor Carriers, By Carrier

	ArcBest	FedEx	Yellow Roadway	UPS	Old Dominion
Mean	0.214725191	0.210732824	0.210828244	0.202175573	0.201464122
Std. Dev.	0.013256089	0.011409729	0.011478705	0.021927321	0.023162065
Max	0.245	0.237	0.2375	0.237	0.2407
Min	0.186	0.185	0.185	0.142	0.145

We express each firm's monthly fuel surcharges relative to the contemporaneous monthly five-firm average, so that the series of interest for firm *i* at time *t* is:

$$y_{i,t} = ln\left(\frac{g_{i,t}}{\bar{g}_t}\right) \qquad t = 1 \ldots\ldots T \tag{1}$$

where y_{it} is the relative surcharge, g_{it} the surcharge at firm i, and $\bar{g}_t$ the average surcharge at all firms. Under the null hypothesis of stationarity, the model yields:

$$y_{i,t} = r_{i,t} + Z_{i,t}\beta + \varepsilon_{i,t} \tag{2}$$

$$r_{i,t} = r_{i,t-1} + \mu_{i,t} \tag{3}$$

where Z_{it} is a deterministic component, ε_{it} are stationary errors, and μ_{it} are independent identically distributed errors. r_{it} is a random walk process with initial values $r_{i0} = 0\forall i$. Z_{it} controls the dynamics of the above data generating process (DGP). Setting $Z_{it} = [1]$ gives a level stationary process lacking any trend or breaks. Following Hadri and Rao (2008) and the notation in Ranjbar et al. (2015), five models are considered, varying according to the form the Z_{it} vector takes:

$$Model\ 0:\ Z_{i,t} = [1, t]' \tag{4}$$

$$Model\ 1:\ Z_{i,t} = \left[1, D_{i,t}\right]' \tag{5}$$

$$Model\ 2:\ Z_{i,t} = \left[1, t, D_{i,t}\right]' \tag{6}$$

$$Model\ 3:\ Z_{i,t} = \left[1, t, DT_{i,t}\right]' \tag{7}$$

$$Model\ 4:\ Z_{i,t} = \left[1, t, D_{i,t}, DT_{i,t}\right]' \tag{8}$$

The dummy variables D_{it} and DT_{it} are respectively defined as:

$$D_{i,t} = \begin{cases} 1, & if\ t > T_{B,i}, \\ 0, & otherwise \end{cases} \tag{9}$$

$$DT_{i,t} = \begin{cases} t - T_{B,i}, & if\ t > T_{B,i}, \\ 0, & otherwise \end{cases} \tag{10}$$

where $T_{B,i}$ is the break date in the intercept or time-trend function of firm i's relative surcharge. Model 0 is a trend-stationary process without breaks. Model 1 specifies a possible break in level but no trend. Models 2 through 4 are trend-stationary processes. Model 2 allows for a break in the level only and model 3 only in the slope. Model 4 admits a break in both level and slope.

Based on the Hadri and Rao (2008) estimation strategy, models 0 to 3 can be estimated by the following 3-step procedure:

1) Break-point estimation: The appropriate break points are selected by minimizing the sum of squared residuals (SSR) of form:

$$\left(\hat{T}_{B,i}\right) = \underset{\hat{T}_{B,i}}{\arg\min}\, SSR\left(T_{B,i}\right) \tag{11}$$

Model selection: The appropriate model is selected by minimizing the Schwarz Bayesian Information Criterion (BIC):

$$BIC_{ik} = \ln\left(\frac{SSR_{ik}}{T}\right) + q_{i,k}\frac{lnT}{T} \tag{12}$$

where SSR_{ik} is the sum of squared residuals of the i'th firm and k'th model; $q_{i,k}$ is the number of regressors; and T is sample size.

2) Computation of test statistics with unknown break: The univariate test statistic is calculated as:

$$LM(\lambda_i, k, T) = \widehat{\omega}_i T^{-2} \sum_{t=1}^{T} \hat{S}_{i,t}^2 \tag{13}$$

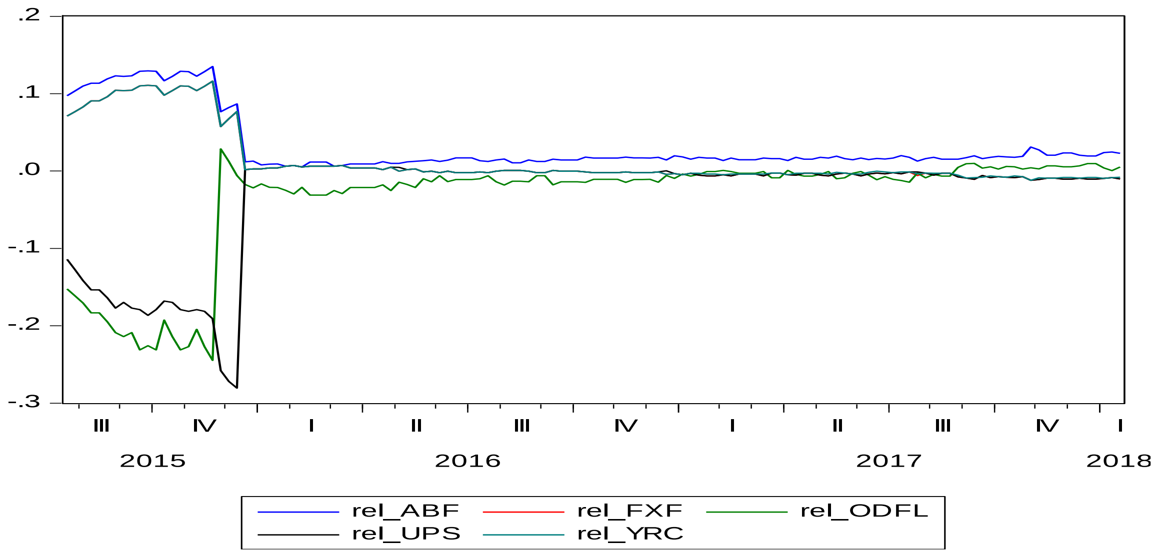
where $\hat{S}_{i,t}^2$ is the partial sum of the estimated ordinary least squares obtained from equation (2). The break is detected at location λ_i, namely the fraction of this partial sum relative to entire sample period T. Finally, the heteroskedasticity- and autocorrelation-consistent estimates of the long-run variance of $\varepsilon_{i,t}$ are represented by $\widehat{\omega}_i$. The finite-sample critical values of the individual univariate test statistic are calcuated by a Monte Carlo simulation based on 20,000 replications.

Preliminary Results and Discussions

Figure 1 shows the relative fuel surcharge at each firm, in which the base surcharge is the average surcharge of the five firms at time t. Results show ArcBest Freight (ABF) always sets its fuel surcharge above the average.

More interestingly, on the basis of a unit root test with structural breaks, we observe that a structural break in every firm's fuel surcharge policy occurred in the 4th quarter of 2015. Since then the cross-firm

Figure 1: Relative Fuel Surcharges, Selected U.S. LTL Motor Carriers



surcharge gap has been narrowing and converging toward the sectoral average, again with the five-firm average as benchmark. In particular, it took Old Dominion Freight about one year after the end of 2015 to catch up with the other firms' surcharges. In conclusion, our findings confirm the prediction that major LTL carriers' fuel surcharge policies have been converging toward the industry average since November 2015. These results also suggest the market has become more competitive during this same period. See regression results in Tables 2 and 3.

Results of Hadri and Rao's (2008) test for stationarity in our firms' relative fuel surcharges are reported in Table 3. The univariate test statistics ($LM(\lambda_i, k, T)$) obtained are shown in the sixth column of the Table. Model 1 (i.e., level shift but no trend permitted) is found to be valid for ArcBest, FedEx, and Yellow Roadway, and Model 3 (slope break permitted) is instead valid for UPS and Old Dominion. The finite sample critical values for these test statistics are calculated by way of Monte Carlo simulation with 20,000 replications. Results at the 5% significance level, using the BIC criterion, are presented in the third and fourth columns of Table 3. The null hypothesis of stationarity is accepted at every firm, suggesting that fuel surcharges at all five firms are converging toward the long-run industry average. Finally, the estimated break dates of the selected models are shown in the last column of Table 3. At ArcBest, FedEx, Yellow Roadway, and UPS, the break date was 2015/12/14, while at Old Dominion it was only three weeks prior, on 2015/11/23.

We plan next to examine alternative hypotheses for the sudden change in 2015 IV that initiated the gradual reintegration of these firms' fuel-surcharge policies. The Figure 1 surcharge plot suggests a significant occurred that year, either a government policy change or a correction in expected market fuel prices. One way to test for this would be a cointegration analysis, including possible explanatory factors such as expectations of tax, regulatory, or wholesale fuel-price shifts or changes in surcharge strategy.

Table 2. Stationarity Test with Structural Breaks

Univariate Unit Root Test/Stationarity Test			
LTL Carriers	**ADF**	**PP**	**KPSS**
ArcBest	-2.751*	-1.941	0.593**
FedEx	-2.589*	-1.699	0.8045***
Yellow Roadway	-2.589*	-1.712	0.792***
UPS	-2.304	-2.133	0.635**
Old Dominion	-2.107	-2.258	0.763***

Note: To compare HR (Hadri and Rao, 2008) stationarity test results, we performed three univariate unit root tests: the Augmented Dickey–Fuller test (Dickey and Fuller, 1979), the PP test (Phillips and Perron, 1988) and the KPSS test (Kwiatkowski et al., 1992).

Table 3. Hadri and Rao (2008) Stationarity Test Results

Individual Test Statistics For Model Allows for Serial Correlation					
Firm	**Test Statistics**	**P-value (5%)**	**Optimum Lags**	**Selected Model**	**Break Date**
ArcBest	0.026	0.109	1	1	2015/12/14
FedEx	0.026	0.108	1	1	2015/12/14
Yellow-Roadway	0.028	0.11	1	1	2015/12/14
UPS	0.02	0.108	2	3	2015/12/14
Old Dominion	0.041	0.113	1	3	2015/11/23

Notes: Models 1 and 3 examine, respectively: a trend-stationary process in absence of breaks; a level shift but no trend process; and a trend function with shift in both intercept and slope process. We use the Schwarz Bayesian Information Criterion (BIC) to find the appropriate break-type model for the series. The optimum lag(s) are used in the Sul et al. (2005) procedure to estimate the consistent long-run variance.

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Liability Implications of the Rotterdam Rules for Indian Dry Ports

Girish Gujar[1]*, Sik Kwan Tai*[1]*, and Adolf K.Y. Ng*[2,3]

[1] Division of Business and Management, BNU-HKBU, United International College, Zhuhai, China
[2] Department of Supply Chain Management, Asper School of Business, University of Manitoba, Winnipeg, MB, Canada
[3] St. John's College, University of Manitoba, Winnipeg, MB, Canada
Email: [1]sktai@uic.edu.hk

Abstract

The carrier's liability during the sea leg of transportation is fairly unambiguous. However, the shipper's concerns during the land leg remain to be adequately addressed. In India, the land leg of container transportation between gateway ports and dry ports is conducted by the dry port operators. The inland transportation of containers, however, is governed by different legal instruments, the provisions of which are not congruent; especially with regard to the liabilities and responsibilities of the dry port operator vis-à-vis the carrier. Understanding such deficiency, this paper attempts to ascertain the implications of ratifying the Rotterdam Rules for India's existing maritime law regime, especially those applicable to dry ports. We examine the maritime law regimes of different countries which are already signatories to the Rotterdam Rules and apply a similar reasoning in the Indian context. We conclude that one of the effects of ratification by India would be the reduction of ambiguities concerning the liabilities of dry port operators, being now considered a maritime performing party. As a consequence, dry port operators would now be held responsible for container security and thus would be perforce to exercise due diligence in discharging its duties as a custodian of the cargoes in its charge. In addition to the efficiency gains that such development would bring about, it would be beneficial for the evolution of an appropriate container security policy for the Indian dry ports sector as a whole.

Keywords: Rotterdam Rules, Dry Ports, Container Security Policy, and India.

1. Introduction

The establishment of an efficient and integrated door-to-door transportation system plays key roles in eliminating interruptions and bottlenecks in the seamless movement of cargoes. In India, inland transportation is part of the door-to-door supply chains, and the handling of containers is mostly carried out by the various dry port operators which do so by using one or more mode(s) of transportation. Broadly speaking, dry ports act as critical nodes along global supply chains, where their primary purpose is to consolidate and distribute cargoes while simultaneously acting as intermodal transportation exchanges. Dry port operations can be broadly divided under three categories: (1) container yard operations, for the storage of empty and laden containers; (2) freight station operations regarding storage, stuffing and stripping of containers; and (3) transportation of empty and laden containers by rail, road or both between dry and gateway ports.

Hitherto, in India, inland transportation and the handling of containers are covered by different legal regimes depending on the transportation mode. The provisions of these regimes are not entirely congruent, resulting in the creation of ambiguities as regards to the contractual relationship between dry port operator and carrier who issues the bill of lading for the entire door-to-door transportation service. In this case, imagine a chemical shipment from a factory in New Delhi to a warehouse in Munich (both located far away from gateway ports) covered by a *through bill of lading* issued by the carrier (e.g., shipping line). According to the Indian Carriage of Goods by Sea Act of 1925 (COGSA) and its subsequent amendments, the carrier is expected to exercise *due diligence* in protecting the cargoes and its prompt dispatch until the final destination. However, according to Section 46A of India's Railway Act (1989), under which the cargoes are stuffed and moved during the inland leg of the journey by the dry port operator, the latter cannot be held responsible for not exercising *due diligence*, nor it is responsible for any delays in delivering the cargoes (Mukherjee. et al., 2009). In this case, the limitation of liability, amounts between 50 and 200 Indian Rupees per kg stated under the different Acts, varies sharply.

In addition to COGSA, India enacted the Multimodal Transportation of Goods (MMTG) Act in 1993. This was loosely based on several international maritime conventions, such as the Contract for Carriage of Goods by Road of 1956 (C.M.R. Convention), and the International Carriage of Goods by Rail - 1980 (C.O.T.I.F). However, in practice, the MMTG Act is not widely used as it does not cover the activities of sub-contractors who are the actual performing parties. For instance, at present, the shipper has a contractual relationship with the carrier (bill of lading), governed by COGSA. The latter subsequently enters into a separate contractual relationship with the dry port operator through an Inland Way Bill (IWB) governed by the Railways Act. Subsequently, the dry port operator enters into another contractual agreement with a road/rail transport operator covered by the Railways Act. However, the Act itself is silent on the responsibilities and liabilities of the dry port operator vis-à-vis the carrier.

Thus, the simultaneous application of different legal regimes to different contractual relationships between the various parties involved in the inland transportation of cargoes leads to the creation of ambiguities as regards to the responsibilities and liabilities especially of the dry port operator. Furthermore, internationally-recognized transportation documents, such as the FIATA Bill of Lading and COMBICON, are not recognized by the Indian government. In addition, the Multi-modal Transport Document (MTD) issued under the MMTG Act is often not accepted by foreign banks, causing inconvenience for shippers, carriers, multimodal transportation operators, and consignees.

To address such issues, the Rotterdam Rules were drafted by the United Nations Commission on International Trade Law (UNCITRAL), adopted by the UN and opened for signature in 2008 and 2009, respectively. At the time of writing this paper, 21 countries have signed but none, including India, have ratified them. A salient new feature of the Rotterdam Rules is the introduction of the *performing party* concept. Article 1(6) defines performing party as an entity that performs, or undertakes to perform, any of the carrier's responsibilities under a contract of carriage, and acts (directly or indirectly) at the carrier's request or under the carrier's supervision or control. Based on this, a dry port can be considered as a *performing party* under a contract of carriage, such as a bill of lading.

This definition is broader than the *performing carrier* used in previous international conventions, such as the TCM Draft, MT Convention, and the ICC Uniform Rules. Moreover, the Rotterdam Rules provide for liability, specifically for a *maritime performing party* and not for all performing parties. Article 1(7) defines a maritime performing party as one that offers services related to sea carriage. By nature of its functions, we argue that a dry port operator is a maritime performing party and is thus liable to the carrier for any loss/damage of cargoes while in its custody. The ratification of the Rotterdam Rules by India would not only facilitate the establishment of appropriate contractual relationships between the carrier and other performing parties, such as dry ports, but also promote the establishment of a proper regulatory framework governing dry ports throughout the country.

In fact, the entire transportation process is governed by multiple laws, some of which are civil in nature while some of them are administrative. The objectives and purposes of every such law are different. As such, it is impossible for a single research paper to cover the entire gamut of laws governing the entire transportation process, nor is this paper attempting to do so. In this regard, the paper focuses on the simple counterfactual, i.e., ratification of the Rotterdam Rules and its probable impacts on container security. We purposely ignore other probable impacts of ratification of the Rotterdam Rules as they are beyond the purview of this study.

2. Contextual Setting of Dry Ports and their Responsibilities and Liabilities

An Inter-Ministerial Committee (IMC), acting under the control of the Ministry of Commerce of the Indian government, was established in 1992 with the primary aim of facilitating exports by way of encouraging the establishment of dry ports. IMC is thus the competent authority licensing the setting up of dry ports. However, the IMC guidelines that specify the establishment and functions of dry ports are silent when it comes to the law that should apply to dry port operations. In fact, the guidelines do state that dry ports should broadly fall under the overall control of the local Customs Commissioner, although they fail to give the details its powers and duties (http://www.customsindiaonline.com/content.php?id=manual23). Thus, the mechanism for reviewing the dry port's (who is considered as a *custodian* of the cargoes in its charge) conduct and performance is delegated to the local custom commissioner. As such, IMC, which initially licensed the applicant for setting up a dry port, does not play any further roles in dry port operations.

According to the Customs Act of 1962, the jurisdictional Commissioner of Customs is the competent authority for the approval of a physical place as *customs area*, and for the approval/appointment of a *custodian* (in this case, a dry port operator) under Sections 8 and 45, respectively. Section 16 of the General Clauses Act of 1897 (http://lawcommissionofindia.nic.in/51-100/Report60.pdf) stipulates that powers vested with an authority, for any appointment, include the power to suspend or dismiss the person so appointed. Hence, the Commissioner of Customs has also the authority to de-notify or take away a custodianship in the case of non-compliance to the principles of natural justice (Customs Circular F.No.450/105/2008-Cus.IV, dated 25th July 2008). Nowadays, dry port operations, including container transportation, involve numerous key federal and regional stakeholders, such as customs, railways, police, and similar enforcement and inspection agencies. The onus of conducting the day-to-day operations of dry ports lies with the *custodian* (Annexure-II: Setting up of ICDs/CFSs, Customs Manual, 2006-07). As the *custodian*, the dry port operator is responsible for the safety and security of the cargoes stored in its arena. Also, the Commissioner of Customs is empowered to review the approval granted before the expiry of the initial period and may order a review before the completion of the approval period.

Also, in discharging its duties and responsibilities towards the Customs Commissioner, the dry port operator needs to exercise *due diligence* so as to ensure the safety and security of cargoes while in its custody. To properly do so, it needs to undertake the precautionary steps to ensure the safety and integrity of cargoes in the port, equipment, and personnel need to be allotted (or at least prescribed), and cargoes handling procedures be stipulated. Nevertheless, more often than not, this is not the case. There are no prescribed yardsticks or benchmarks for dry ports to observe, or for the customs to request. There have been attempts to fill such a gap through assigning the supervision of dry ports to the Commissioner of Customs.

The first dry port in India was established by the Container Corporation of India Ltd. (CONCOR), a state-owned enterprise under India's Ministry of Railways. The Indian government authorized CONCOR as a dry port operator so as to issue the CONCOR IWB, *in lieu* of a Railway Receipt (RR), and to quote and collect all charges directly from the customer (Indian Railway Commercial Manual, Volume 2, Para 1476, ISO Containers services). In 2007, container rail transportation was opened to the private sector. Nowadays, there are 16 Container Train Operators (CTOs), including the state-owned CONCOR that also issue IWBs.

The IWB constitutes *prima facie* evidence of receipt of cargoes by the dry port operator from the carrier, in apparent good order and condition, except as otherwise noted with respect to damage sustained by the cargo before arriving at the dry port. The IWB is issued by the dry port operators for the containers to be carried by it, and it must be given up at destination, by the consignee, at the time of taking delivery. It is issued subject to the conditions and liabilities as specified in the Railways Act. According to the terms stated in the Railways Act, the carrier must accept responsibility for all *particulars* furnished in respect of cargoes tendered by it for stuffing containers and carriage to the gateway port by the dry port operator. It goes on to state that the carrier is deemed to have indemnified the dry port operator against any damage or loss suffered by it by reason of incorrect *particulars* provided by him in regard to the cargoes.

Hence, it can be summarized that the dry port treats the carrier as a consignor and enters into a contractual relationship with it to handle and transport containerized cargoes to and from gateway ports. Dry port does not recognize the shipper with whom the carrier has its own contractual relationship. Because of this, the shipper cannot move against the dry port operator for any loss/damage to its goods while they are in the custody of the dry port. Furthermore, according to the IWB issued by the dry port operator to the carrier, the contractual relationship between them is governed by the Railways Act. Accordingly, the dry port operator does not automatically indemnify the carrier in regard to any liabilities and responsibilities the latter may have accepted vis-à-vis the shipper. Hopefully, such circumstance is going to change, once the dry port operator is considered a *maritime performance party*.

Regarding the liability of the shipper/carrier for erroneous declaration of containerized goods, it is critical to understand the *mens rea* of the stakeholder and the liability due to its act of erroneous declaration. Perhaps considering the potential of damages caused by the liability in question, the time has arrived to look beyond the co-relationship coefficients between the freight earned and the compensation payable. This argument indicates a necessity for re-visiting the limitation clauses in the various sea transportation legislations. Eventually, it may force the carrier to discharge/exercise its due diligence responsibilities more effectively.

3. The Rotterdam Rules and the concept of *Performing Party*

The current legal regime governing the transportation of cargoes by sea is burdened by the co-existence of three different maritime conventions: The Hague Rules; the Hague-Visby Rules; and the Hamburg Rules. In addition, several hybrid versions of these are in existence. This state of affairs has often led to numerous legal ambiguities. Under the current regime of the carriage of goods by sea, shippers and carriers do not have the benefit of a binding and balanced universal instrument in support of contracts of carriage involving various modes of transportation. To rectify this situation, the Comité Maritime International (CMI) and the UNCITRAL have formulated a unified set of rules (Myburgh, Paul, 2000). The final product has resulted in a Convention, known as the *United Nations Convention on Contracts for International Carriage of Goods Wholly or Partly by Sea*, commonly referred as the *Rotterdam Rules*.

The main purpose of the Rotterdam Rules is to rectify the contractual imbalance with regard to the responsibilities and liabilities of the shipper on the one hand, and of the carrier on the other. To understand the complexity, we need to appreciate that, due to intense cross holdings of different interests across international borders, it often becomes onerous to segregate the interests of the shipper, the carrier, banks, and consignees. For instance, due to the proliferation of open registries, the ship-owner is seldom the citizen of the (trading) flag state. The same can be said of cargo interests. In practice, open registries have made irrelevant the original characteristics of the nations who were signatories to the Hague-Visby or Hamburg Rules (Sturley, 1995). In this case, the Rotterdam Rules address topics not covered by other international instruments on the carriage of goods, including matters pertaining to the rights of controlling party, transfer of rights, jurisdiction, and arbitration. Also, it spells out the parties liable and responsible for the transportation of cargoes. The comprehensive coverage of the Rotterdam Rules provides a transparent and detailed account of maritime trade information. This is bound to boost the confidence of trading parties and hence spur more trade (Goddard, Kathleen, S., 2010). Furthermore, it offers a higher weight-based limitation of liability of three Special Drawing Rights (SDRs) per kg of cargoes, representing a substantial increase over the current $500 per package limitation provided for under COGSA. Finally, it imposes liability on carriers for delay in delivery, provided the time of delivery has been agreed upon in the contract of carriage.

Also, the Rotterdam Rules recognize that shippers, rather than carriers, are better-suited to identify certain types of serious risk, such as shipments that involve hazardous cargoes. In such cases, the Rotterdam Rules require shippers to share information regarding the hazardous nature of cargoes and impose liability on shippers that contravene this requirement. More importantly, it provides the employees of the carrier, agents, and independent contractors with the same rights and obligations as those enjoyed by the carrier, as long as they are deemed as *maritime performing parties* (Nikaki, T., 2009). In this case, the rapid rise of container shipping and the appearance of Non-Vessel-Operating Common Carriers (NVOCCs) serve as the major reasons behind the concept of *performing party*. Unlike the present definition of a performing party in the Rotterdam Rules, the draft provision on the performing party made expressed reference only to ‘handling, custody, or storage of the goods’, without reference to ‘carriage’. The modified texts of the Rotterdam Rules suggest that the concept of a performing party has a much wider scope than what was initially conceived.

The concept of performing party is mainly defined in Article 1 of the Rotterdam Rules as follows:

1) “Performing party” means a person *other than the carrier* that *performs* or undertakes to perform any of the *carrier’s obligations* under a contract of carriage with respect to the receipt, loading, handling, stowage, carriage, care, unloading or delivery of the goods, to the extent that such a person *acts, either directly or indirectly*, at the carrier’s request or under the carrier’s supervision or control.

2) A "performing party" *does not* include any person that is *retained*, directly or indirectly, by a *shipper*, by a documentary shipper, by the controlling party, or by the consignee instead of by the carrier.

Accordingly, a performing party can be understood from different perspectives, as follows:

1) It *must not be a carrier* which, as defined in Article 1, means *a person who enters into a contract of carriage with the shipper*. This definition must be read in the light of Article 1, which also defines the contract of carriage as *a contract in which a carrier, against the payment of freight, undertakes to carry goods from one place to another. The contract shall provide for carriage by sea and may provide for carriage by other modes of transport in addition to the sea carriage*. From these provisions, and for the purpose of determining a *performing party*, a carrier may be under a carriage contract, wholly or partly by sea. An international carriage contract involving no sea leg is thus excluded from the ambit of the Rotterdam Rules.
2) The performing party must carry out some of the carrier's responsibilities under the contract of carriage. This means that there is a need to establish the expectation that the party is actually performing what the *carrier is obliged* to do under the contract of carriage.
3) The performing party must act or perform *either directly or indirectly, at the carrier's request or under the carrier's supervision or control*. This implies that a connection must exist between the two so as to establish whether a party is, in reality, the performing party for the purposes of the Rotterdam Rules. If it can be argued that a party engages in acts which are not requested, supervised or controlled by the carrier, the party is not a performing party for the purposes of the Rules.
4) The connection between the performing party and the ocean carrier is both essential and exclusive, in terms of establishing the party's position under the Rotterdam Rules.

As per point (4), the following entities *cannot* be perceived as a *performing party* in the spirit of the Rotterdam Rules, even though they may perform some acts similar to what the performing party would normally undertake:

1) A party retained by the shipper (defined in Article 1 paragraph 8 as a person that enters into a contract of carriage with a carrier).
2) The documentary shipper (defined in Article 1 paragraph 9 as a person, other than the shipper, that accepts to be named as *shipper* in the transport document or electronic transport record).
3) The consignee, who directly appoints a party to undertake to perform a part of the contract (defined in Article 1 paragraph 13 as the person that -pursuant to Article 51- is entitled to exercise the right of control).

Thus, the *performing party* is a carefully-defined concept with a specific role in a carriage contract covered by the Rotterdam Rules. This includes the obligation to receive goods at a point convenient to the shipper, carry the goods to the port of departure, or from the port of destination, by appropriate means, load them onto a vessel, properly handle, store, and care for them during carriage (whether the goods are on board or in a warehouse), carry them safely in compliance with the carriage contract, unload them at the port of destination, and deliver them safely at the point agreed in the carriage contract. While the legal liability of container carriers, or NVOCCs, often extends beyond the port-to-port segment of a carriage contract, they are not fully protected against loss or damage to cargoes while at the custody of the dry port. This is also problematic for the shipper who often faces unexpected legal difficulties, concerning whom to sue and how, in case of loss or damage to cargoes. A benefit of the concept of performing party is in its attempt to address such difficulties, arising from current shipping practices.

A *maritime performing party* is an entity that *performs, or undertakes to perform, any of a carrier's obligations, from the arrival of the goods at the port of loading to their departure from the port of discharge*. This means that a *maritime performing party* must *first* be a performing party and one which performs or undertakes to perform the carrier's obligations only in the port-to-port segment of a carriage. Due to the contractual relationship between the performing party and the maritime performing party, the liability of both must be jointly read and assessed. This means that a reference to the performing party, undertaking carrier obligations in the port-to-port leg, must also be read in reference to the maritime performing party, carrying out similar tasks. For instance, a port authority which loads/unloads cargoes, or a rail/road transportation company that transports the cargoes between the gateway ports and dry ports, or a dry port which offers temporary storage to the cargo before being transported to the final destination.

However, in the Rotterdam Rules, a *performing party*, or a *maritime performing party*, is frequently and interchangeably mentioned in concurrence with the carrier, in the provisions concerning receipt, handling, carrying, loading or unloading and delivery of cargo. As such, either party could assume the same liability to the cargo interests, such as the shipper. In brief, the carrier is liable for the breach of its obligations caused by the acts or omissions of any *performing party* under the contract of carriage, to the extent that the person acts either directly or indirectly at the carrier's request or under the carrier's *supervision or control*. This arrangement is logical in the sense that the carrier is the one who enters into the carriage contract with the shipper or other cargo interests.

4. Implications of Dry Port as a *Performing Party*

As mentioned, the dry port operator issues an IWB to the carrier as evidence of a contract of inland carriage. This IWB goes on to state that the inland contract of carriage is subject to the Railways Act. However, the Act is silent about dry port operations and its contractual relationships with the carrier. This aspect creates uncertainties and ambiguities especially in the absence of adequate case laws, legal judgments, and precedents. In this case, the IWB further goes on to state that the carrier is deemed to have indemnified the dry port operator with regard to liabilities arising from mis-declaration of cargoes. *Prima facie*, this clause appears to be incomplete, especially as it does not define 'mis-declaration of cargoes' and 'limitation of liability'. Thus, the legality of the contractual relationship between the carrier and the dry port operator appears to be vague and improperly defined. Therefore, one of the key implications of India's ratification of the Rotterdam Rules would be the possibility of a dry port operator to being considered a *maritime performing party*. This could probably result in the elimination of ambiguities with regard to the contractual relationship between the carrier and the dry port operator. Also, as a *maritime performing party*, the dry port operator would be considered responsible and liable, to the same extent as the carrier, for the goods in his custody, in spite of the fact that it has no direct relationship with the shipper. By issuing the IWB, the dry port operator would be deemed to have indemnified the carrier for claims brought against him by the shipper in respect of loss or damage suffered by the goods while in the custody of the dry port operator. Nowadays, dry ports assume a pivotal position in global supply chains. A significant amount of cargoes is stuffed/de-stuffed at dry ports rather than at the gateway seaports. Thus, the importance of container security at dry ports needs to be looked at carefully. For several reasons, this issue, does not get the attention it deserves and, as a result, over a period of time, it has evolved into the weak link of the supply chain.

Security at dry ports has been entrusted by the customs to the Customs Cargo Service Providers (CCSPs), or dry ports which act as custodians of cargoes. The customs have prescribed in great detail the infrastructure the *custodian* is required to provide at the dry port (Handling of Cargo in Customs Areas Regulations, 2009. No. 26/2009 - Customs (N.T.), dated 17 March 2009) (e.g., adequate parking space for vehicles, boundary walls, internal roads for service and circulating areas, electronic weighbridge, gate complex). The violation of the guidelines may attract severe penalties and the Commissioner of Customs can even revoke the custodian's license in case of persistent violations. In this case, it is pertinent to note that the customs guidelines do not mention *electronic surveillance*, such as installation of Close Circuit Television Systems (CCTV), for recording the activities at the dry port gate complex or inside the warehouse/yards. Moreover, according to the Rotterdam Rules, the examination of exported goods is supposed to be done by the customs and not by the *custodian*. However, cargo inspections do not contribute to increase security, as their primary aim is, apparently, to prevent revenue leakage rather than to ensure container security. Indeed, the Customs Act also states without ambiguity that the examination of goods is a customs function. However, the responsibility of cargo security in a dry port is with the custodian which does not have a suitable container security policy in place. As a result, inadequate personnel, together with increasing throughputs, serves to widen the crucial *container security* gap.

5. Discussions, Analysis and Inferences

Cargo safety and security in the inland container transportation is a complex issue that involves numerous key stakeholders, such as customs, railways, and police, in addition to other enforcement and inspection agencies.

The onus of providing security in the dry ports has been placed on the *custodian*. However, the custodian is not saddled with the responsibility of exercising *due diligence* in its operations so as to eliminate the possibility of contraband in containers. *Due diligence* in this context would mean the steps, equipment, personnel, and the procedures that ought to have been allotted or prescribed for cargo-handling, or the precautionary steps taken by the custodian to ensure security and integrity of cargo in the dry port.

The Railways Act which presently governs dry port operations in India was drafted in an era when Indian Railways (IR) were not transporting containers. It has yet to develop a system of container cargo inspections and still continues to rely on the expressly stated threat in the Railways Act that makes the consignor (carrier) liable for any damage or loss suffered by it - blaming incorrect particulars, furnished by the consignor in regard to the cargo, in the forwarding note submitted by it to the dry port operator. It is interesting to note that, hitherto, all the agencies involved in stuffing, loading, and transportation of containers hold the consignor liable for the particulars and do not consider checking the correctness as part of their responsibilities, even when they are expected to carry out due diligence in such matters.

Currently, dry port operators issue their own IWBs for the goods received by them for transportation. However, there is no standardized format for the IWBs. The IWBs implicitly state that *"This Inland Way Bill is issued subject to the conditions and liabilities as specified in the Railways Act 1989.*" Also, it is mentioned in the IWB that the claims for loss suffered while transporting containers by road are actually settled as per Carriage by Road Act 2007. Thus, the provisions of the Railways Act are invoked only for the railway portion of the transportation which further complicates the issue of responsibility from the perspective of the shipper. It is obvious that there is an inherent contradiction between the stated legal status on the IWB and the legal obligations arising out of the Railways Act under which road transportation is undertaken. In addition, there is the issue of implementation that invariably demands larger allocation of resources.

In addition to the stated arguments, there are a few more listed here under, which will further enhance the general standards of container security if the Rotterdam Rules are ratified. First, it would help in the identification of precise risks carried by the specific stakeholders at the time where failure of container security is breached. Second, it would increase the transparency of the entire transportation process. Third, it would assist in the enforcement of due diligence responsibility of the carrier strictly. Fourth, it would help in the reduction of ambiguity in identification of risk holder jurisdiction. Fifth, it would assist in apportioning of the blame for the container security risk failure and share of compensation payable. Sixth, it would clarify as to who should prosecute the shipper for misinformation provided if any. Finally, it would help in resolving the legal implications for resolving the legal implications.

As regards to compromising of the ISPS code, it is obvious that the breach of container security results in the vessel becoming unseaworthy. However, the consignee becomes aware of this factor only after the container reaches its destination and is de-stuffed, i.e., after the voyage is complete. As such, it is rather fruitless to terminate the contract of carriage. However, in several cases, the consignees have refused to accept the consignment due to the contents not matching with the description in the manifest and thus terminating the contract of carriage. Apart from the above, there are some additional advantages such as it has the potential to reduce misuse of the unknown clause by carrier as provided for by the Hague-Visby Rules. It is widely known fact that in several cases the shippers are essentially subsidizing the empty container repositioning costs of carrier hence carriers are not too keen in prosecuting them for erroneous information provided by them. In the absence of the Rotterdam Rules, different modes of inland transporters are governed by different laws and different procedures too. This might help in standardization of such issues. Such a state of affairs creates confusion, delay, and the culprit escapes responsibility and somebody suffers injustice without redress. Finally, the Hague-Visby Rules are silent about third party liability and associated risks are inadequately covered.

6. Conclusions

Although India enacted the MMTG Act in 1993 to provide a seamless legal environment for the entire inland transportation of international containerized cargo, it failed to achieve the stated objective for several reasons. One of the most important reasons was the non-recognition of the MMTG Act by foreign nations. Another reason for the failure to gain wider acceptability was its inability to appropriately integrate the different legal provisions mentioned in the different Acts which governed the inland transportation process, especially in regard to the liabilities and responsibilities of the various performing parties, including dry ports. Hence, we argue that the ratification of the Rotterdam Rules by India could bring much needed clarity regarding responsibilities and liabilities of the dry port operator, especially in exercising *due diligence* while conducting stuffing operations at the dry port.

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Analysis of the Matching Relationship between Airport Passenger Transport Scale and Home City Scale in China Based on Relative Concentration Index

Zhongzhen Yang[2,], Dan Wang[1], Rui Ding[2], and Chao Wang[2]*

[1] College of Transportation Engineering, Dalian Maritime University, Dalian, 116026, China
[2] Faculty of Maritime and Transportation, Ningbo University, Ningbo, 315211, China

[*] *Corresponding Author*

Abstract

In order to analyze the scale matching relationship between airport passenger transport and the home city spatially and temporally, and further to clarify the passenger transport function orientation of airports at different levels in the air transport system, this paper uses the Relative Concentration Index (*RCI*) to analyze the matching relationship between airport passenger transportation scale and home city scale. Specifically, 125 airports in 123 cities of China are selected as our research objects, and the time span is from 2006 to 2017. First, the concentration ratio of airport (*CRa*) is calculated based on air passenger throughput. And then, the concentration ratio of city (*CRc*) is calculated based on population and *GDP*. Last, we synthesize *CRa* and *CRc* to get the Relative Concentration Index (*RCI*), which is used to analyze the matching relationship between airport passenger transport scale and home city scale in China.

The analysis results show that for a single airport and a single city, the relationship between airport passenger transportation scale and airport home city scale does not match in most cases, but for the major multi-airport systems in China, its air passenger transport scale matches the corresponding city agglomeration scale; the large-scale hub airports and airports in some tourist cities siphon the passenger flow of surrounding airports, limiting the development of passenger transport in surrounding airports; the matching relationship between the airport passenger transport scale and home city scale is constantly changing, and the changing trend can be divided into three types: rising, falling and fluctuating; the evolution of the relationship between airport passenger transport scale and airport home city scale is a gradual process, that is, the changes of *RCI* of all airports are continuously evolving towards adjacent stages, and will not directly evolve towards another stage across the adjacent stages.

Keywords: Airport-City relationship; Passenger transport; Scale; Evolution

1. Introduction

In the past 40 years, China's airport passenger transport has developed rapidly. By the end of December 2018, there were 235 civilian airports in China, and the volume of air passengers reached 610 million persons. Compared with the beginning of the reform and opening up in 1978, the number of airports had increased nearly three times, and the air passenger traffic volume had increased nearly 265 times. With the rapid development of the airport industry, how to determine the relationship between the scale of airport passenger transport and the scale of the airport home city has been a huge problem for decision makers. From the function of the airport to serve the city's external transportation, the phenomena of big airport vs small city or small airport vs big city can be seen commonly in China. As far as a single airport serves a single city, the airport is too large, which may lead to the waste of aviation resources. As an external window of the city, the airport can't play its own advantages. The airport is too small, which may lead to the excessive strain of passenger transport resources at the airport, and the ultimate result is a large loss of passenger resources. Therefore, the matching of airport passenger transport scale and airport home city scale is pretty important.

At present, along with the increase of airports and the rapid expansion of air transport networks, the hierarchical air passenger transport network structure has basically formed (Wang, 2003). The airports of Beijing, Shanghai and Guangzhou have become the hub airports of the whole country, and their service scope has already exceeded the area of the home city where the airport is located. Most airports, such as Nanjing and Ningbo, are increasingly becoming the hinterland airports serving the home city. A small number of airports, such as Sansha and Haixi, are increasingly becoming a pure feed airport. As far as hub airports are concerned, they occupy most of the market share. According to the statistics bulletin of Civil Aviation Airport production published by civil aviation department, the annual passenger throughput of Beijing, Shanghai and Guangzhou in 2018 accounted for about 23.3% of the total domestic airport passenger throughput. For the hinterland airport, Ningbo and Nanjing are taken as examples. Located in the Yangtze River Delta, Ningbo is surrounded by large airports in Shanghai and Hangzhou. Because of the serious overlap of its routes with Shanghai and Hangzhou, plenty of passenger resources are lost. On the contrary, Nanjing has obvious airport spillovers due to its well-established route network and complete hardware facilities. As far as pure feed airports are concerned, most of them are located in the northwest region. Due to backward economy and inconvenient transportation, congenital passenger resources are scarce. However, some small and medium-sized airports have been super-scaled construction in the initial stage of construction, and the operation process has blindly opened the "thin and long" routes to mega-cities, which results in serious economic losses (Zhang, 2018).

Through the above analysis, it is found that no matter whether big airport vs small city or small airport vs big city, and the space is different, the results of each development are different. Therefore, at this stage, whether the scale of airport passenger transportation in China matches the scale of the airport home city is a problem worthy of further exploration. However, little research has been done on this issue at home and abroad, the existing researches related to airports and airport home cities mainly focus on the impact of airport on city economic development, the interaction between airport and city development, and the coordinated development of regional airports. Tveter (2017) used the airport in Norway as an example to explore the effect of airports on regional development, Bruce et al. (2015) explored the relationship between air service and city growth from a policy perspective, Sheard and Nicholas (2019) studied the intrinsic relationship between the airport and the economic growth of the US metropolitan area and found that airport size has a positive impact on local employment. In China, Song and Yang (2006) studied the impact of civil aviation airports on city and regional economic development, Zhang et al. (2010) used Nanjing Lukou International Airport as an example to study the relationship between airport operations and regional economic growth, Hao and Quan (2016) studied the development strategy of Beijing-Tianjin-Hebei Airport Cluster under the goal of world-class city agglomeration. However, they do not involve the discussion of the matching relationship between the airport passenger transport scale and the airport home city scale. Based on this situation, this paper attempts to start from a macro perspective, using the Relative Concentration Index (*RCI*) proposed by Vallega (1979) to quantitatively analyze the relationship between them. Then summarize the general law of their development, thus providing a theoretical support for the rational positioning of the airport, to avoid problems such as wasteful resources and unbalanced development caused by blind expansion of the airport and vicious competition.

The structure of the article is as follows: The second section of the literature review mainly introduces the concept of Relative Concentration Index (*RCI*) and the application of predecessors. The third section mainly introduces the traditional *RCI* calculation method and the improved algorithm based on this research, and introduces the data sources of the sample used in the article. In the fourth section, by observing the calculation results, we analyze the matching relationship between the airport passenger transport scale and the airport home city scale, and the general law of their development is summarized, and the adjustment suggestions for the unmatched airports and cities are proposed. The fifth section is the conclusion of the article.

2. Literature Review

The Relative Concentration Index (*RCI*) was first proposed by Vallega (1979) to express the concept of the relationship between the scale of the port economy and the economic activity of the port city. It first calculates the proportion of the port's throughput in the region, and then calculates the proportion of the port city population to the total number of people in the region, and finally judges the two as the basis. Prior to Vallega, Kenyon (1974) used a similar index to try to use the average cargo tonnage per resident to measure the relative importance of *US* port city transport functions and city scale. Vigarie (1981) uses a similar index to explore the state's dependence on ports. Ducruet and Jeong (2005) made the relationship matrix between port and city function to quantitatively analyze the relationship between port function and city function.

In China, Cheng et al. (2009) applied the *RCI* to comprehensively evaluate the quantitative relationship between port functions and city functions of 25 major port cities in China. Gao and Mao (2010) improved the traditional *RCI* algorithm and found that both ports and port cities have different development factors, and port cities present different development patterns, thus further enriching the connotation of *RCI* analysis method. Li (2011) applied the *RCI* calculation method to analyze the synergy between Haixi port and industrial cluster. Jiang et al. (2011) took six port cities in Liaoning Province as examples to study the relationship between port and city scale. Luo and Song (2013) used *RCI* to analyze and compare the port-city relationship between Qingdao Port and Shanghai Port. Wang et al. (2014) used *RCI* to analyze the development status of 15 port cities in the northeast China for 10 years. Lin (2017) also used *RCI* to evaluate the development level of "bus city" .

The essence of the Relative Concentration Index (*RCI*) is a centralized determination of a certain characteristic (relative city size) of a certain type of city (Luo and Song, 2013), although it is widely used between ports and port cities at this stage, its practical application is wide. Therefore, this paper further expands its application scope, and uses it to explore the matching problem between the airport passenger transportation scale and the airport home city scale.

3. Method and Data Sources

Based on the related researches of Vallega, Vigarie, Kenyon, Cheng, Gao and Lin et al, this paper combines the development status of airports and cities to make appropriate improvements to the *RCI* calculation method. The improved algorithm is as follows:

$$CRai = ti / T \tag{1}$$

$$CRci = 0.5(pi / P + gi / G) \tag{2}$$

$$RCIi = CRai / CPci \tag{3}$$

Where ti is the passenger throughput of airport *i*, and *T* is the sum of the passenger throughput of all selected airports. $CRai$ is the ratio of the passenger throughput of airport *i* to the total passenger throughput of all airports, used to indicate the regional aggregation of airport *i*. gi is the *GDP* of city *i*, and G is the sum of *GDP* of all cities. pi is the population of city i, and P is the sum of the population of all cities. $CRci$ is the aggregation degree of the city *i*, which is used to represent the proportion of the scale of the city *i*. Because *GDP* and population are both important indicators to measure city function, the weights of both are 0.5.

The Relative Concentration Index is used as an indicator to judge the matching relationship between the airport passenger transport scale and the airport home city scale, the determination of the judgment criteria is crucial. Based on the research of domestic and foreign scholars, this paper uses the classification criteria of predecessors: *RCI* is close to 1 (between 0.75-1.25) and believes that the scale of airport passenger transport and the scale of airport mother city are in a matching state. *RCI* > 1.25, considered that the airport passenger transport scale is stronger; *RCI* < 0.75, considered that the scale of the home city is stronger (Ducruet and Jeong，2005；Cheng, 2009)， at this time, the airport passenger transport scale and the scale of the home city do not match. The *RCI* value is more than 3 or less than 0.33, and it is considered that the passenger transport scale of the airport is seriously mismatched with the scale of the airport home city.

In this paper, 128 airports in 125 cities (including multiple airports in Beijing, Shanghai, and Aksu for combined computing) of China are selected as our research objects, and the time span is from 2006 to 2017. First, the concentration ratio of airport (*CRa*) is calculated based on air passenger throughput. And then, the concentration ratio of city (*CRc*) is calculated based on population and *GDP*. Last, we synthesize *CRa* and *CRc* to get the

Relative Concentration Index (*RCI*), which is used to analyze the matching relationship between airport passenger transport scale and home city scale in China.

The data of airport passenger throughput from 2006 to 2017 are from the Civil Aviation Administration of China (CAAC). The population and *GDP* data of cities from 2006 to 2017 are derived from the National Bureau of Statistics, the China Urban Statistical Yearbook and data published by some local government agencies. Among them, the population is the number of population of residence Booklet.

4. Quantitative Analysis of Matching Relation between Airport Passenger Transport Scale and Home City Scale in China

4.1. Analysis of Current Situation and Characteristics

Figure 1 below is a statistical diagram showing the changes in the number of different combinations of 125 airports in China from 2006 to 2017. As far as the overall trend is concerned, the number of airports with *RCI*<=0.33 and *RCI*>3 shows a slow downward trend. The number of airports with 1.25<*RCI*<=3 and 0.33<*RCI*<=0.75 shows a slow upward trend, while the number of airports with 0.75<*RCI*<=1.25 maintains a dynamic balance.

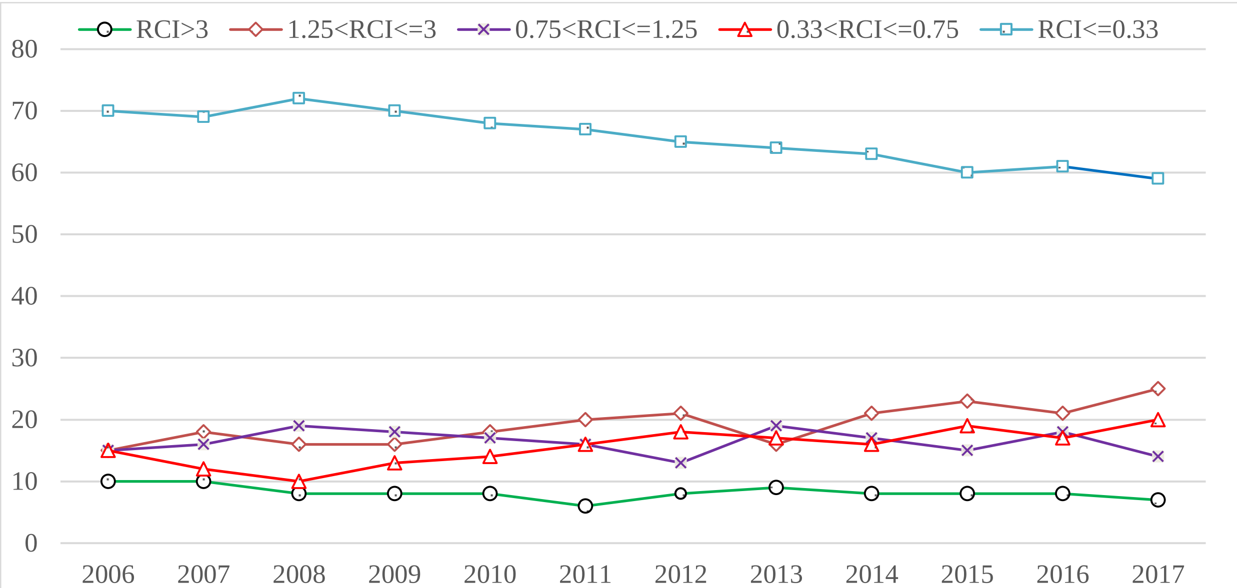

Figure 1: Quantitative Change of Different Combinations of 125 Airports in 2006-2017

Further analysis of the data from 2006 and 2017 shows that the matching relationship between the passenger transport scale of most airports and the scale of the home city presents a dumbbell-like distribution pattern (Fig. 2), that is, "big at both ends and small in the middle": the number of airports with *RCI* > 1.25 and *RCI* < 0.75 is much larger than the number of airports with 0.75<*RCI*<1.25. Further observation shows that although the number of airports with *RCI* < 0.33 and 1.25 < *RCI* < 3 has changed significantly in the past 12 years, the basic pattern of "dumbbell" has not changed substantially, and the phenomena of big airport vs small city or small airport vs big city is still widespread.

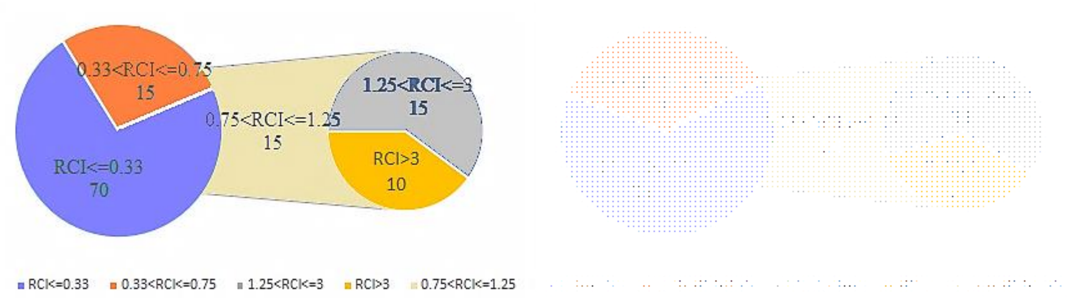

Figure 2: Quantitative Statistics of Different Stages of *RCI* at 125 Airports in 2006 (Left) and 2017 (Right)

4.2. The Evolution of the Relationship between the Passenger Transport Scale of the Airport and the Scale of the Home City Since 2006

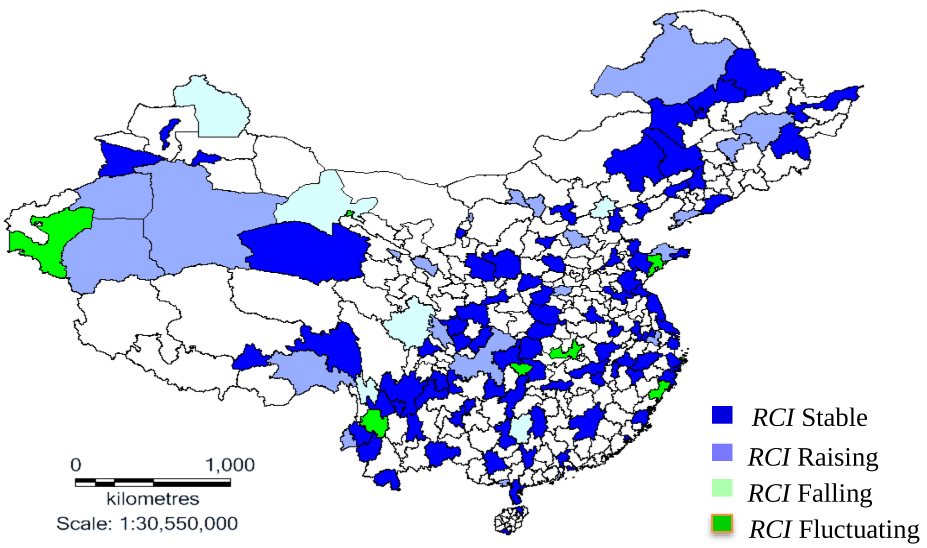

Figure 3: The trend distribution of *RCI* in China's airports from 2006 to 2017

The above figure shows the trend distribution of *RCI* in China's airports from 2006 to 2017. It can be clearly reflected that the number of airports with *RCI* in the stable stage is the highest in these 12 years. The calculations show that among the 125 airports, the number of stable types accounted for 71.2% of the total. Stable airports are widely distributed, covering basically the major provinces, but mainly in the East and South. These regions have developed economies, abundant airport passenger resources and stable market, so the *RCI* has not changed much. Since these 89 airports have not crossed the development stage, they are in a stable stage in the figure above, so it is no longer necessary to distinguish whether *RCI* rises or falls. The remaining 36 airports have distinguished from the rising, falling and fluctuating airports in the figure above because they have crossed the development stage. The following is an analysis of airports that have not crossed the development stage and spanned the development stage.

4.2.1. Airport *that Has Not Crossed the Development Stage*

Table 1: Airport Statistics Table without Spanning the Development Stage in 2006-2017

Range	Airport	Total
***RCI*>3**	Sanya, Haikou, Kunming, Xishuangbanna, Lhasa, Xiamen、Wulumuqi、Lijiang	8
1.25<*RCI*<3	Taiyuan, Shanghai, Nanjing, Hangzhou, Chengdu, Guiyang, Guangzhou, Shenzhen, Changsha, Xi'an, Dunhuang, Yinchuan, Yining	13

0.75<*RCI*<1.25	Shenyang, Jinan, Nanchang, Fuzhou, Nanning	5
0.33<*RCI*<0.75	Tianjin, Ningbo, Hefei, Huangshan	4
***RCI*<0.33**	Qinhuangdao, Yuncheng, Datong, Changzhi, Chifeng, Tongliao, Wulanhaote, Dandong, Jinzhou, Mudanjiang, Qiqihar, etc.	59

The table shows that:

- The *RCI* of the eight airports in Sanya, Haikou, Kunming, Xishuangbanna, Lhasa, Xiamen、Wulumuqi、Lijiang are all higher than 3 in 12 years, and the *RCI* of Sanya Airport is as high as 18.49 in 2014. This shows that the airport passenger transport scale is seriously mismatched with that of the home city, and the airport passenger transport scale is much larger than the home city scale. Further analysis found that the cities where these airports are located are all famous tourist cities in China, and the rich tourism resources attract many domestic and foreign tourists every year. Taking Sanya as an example, in 2017, the number of tourists in Sanya was about 18.31 million, while the passenger throughput of Sanya Airport reached 19.39 million. The airport not only serves city residents, but also serves a large number of domestic and foreign tourists. Therefore, it is reasonable to have a high *RCI*.
- For the airport with *RCI* < 0.33, the passenger transport scale of airport is much smaller than that of home city. At this time, the airport as a service facility of the city is mainly used for the travel of city residents, it is difficult to spread to areas outside the airport home city. Because of its own fewer routes and imperfect infrastructure, its development relies mainly on government finance support, so its development is slow.

4.2.2. Airport That Has Crossed the Development Stage

Among the 36 airports, 28 airports have crossed a development stage in 2006-2017. Seven airports span two development stages, and one airport spans three development stages. The specific crossing stages are shown in Table 2 below.

Table 2: Airport Statistics Table Spanning the Development Stage in 2006-2017

Type	Airport	Initial Stage	Crossing Stage	Terminal
Rising	Shijiazhuang	*RCI*<0.33	*RCI*=0.33	0.33<*RCI*<0.75
	Huhehaote	0.75<*RCI*<1.25	*RCI*=1.25	1.25<*RCI*<3
	Baotou	*RCI*<0.33	*RCI*=0.33	0.33<*RCI*<0.75
	Hulunbeier	*RCI*<0.33	*RCI*=0.33	0.33<*RCI*<0.75
	Wuhai	*RCI*<0.33	*RCI*=0.33	0.33<*RCI*<0.75
	Dalian	0.75<*RCI*<1.25	*RCI*=1.25	1.25<*RCI*<3
	Changchun	0.33<*RCI*<0.75	*RCI*=0.75	0.75<*RCI*<1.25
	Haerbin	0.33<*RCI*<0.75	*RCI*=0.75	0.75<*RCI*<1.25
	Wuxi	*RCI*<0.33	*RCI*=0.33	0.33<*RCI*<0.75
	Yantai	*RCI*<0.33	*RCI*=0.33	0.33<*RCI*<0.75
	Beihai	*RCI*<0.33	*RCI*=0.33	0.33<*RCI*<0.75
	Zhengzhou	0.75<*RCI*<1.25	*RCI*=1.25	1.25<*RCI*<3

(Continued) Table 2: Airport Statistics Table Spanning the Development Stage in 2006-2017

Type	Airport	Initial Stage	Crossing Stage	Terminal
	Chongqing	0.33<*RCI*<0.75	*RCI*=0.75	0.33<*RCI*<0.75
	Mianyang	*RCI*<0.33	*RCI*=0.33	0.33<*RCI*<0.75
	Jiayuguan	*RCI*<0.33	*RCI*=0.33\0.75	0.75<*RCI*<1.25
	Xining	0.75<*RCI*<1.25	*RCI*=1.25	1.25<*RCI*<3
	Linzhi	*RCI*<0.33	*RCI*=0.33、0.75、	1.25<*RCI*<3
	Lanzhou	0.75<*RCI*<1.25	*RCI*=1.25	1.25<*RCI*<3

	Akesu	*RCI*<0.33	*RCI*=0.33	0.33<*RCI*<0.75
	Zhuhai	0.33<*RCI*<0.75	*RCI*=0.75\1.25	1.25<*RCI*<3
	Kuerle	*RCI*<0.33	*RCI*=0.33\0.75	0.75<*RCI*<1.25
	Hetian	0.33<*RCI*<0.75	*RCI*=0.75\1.25	1.25<*RCI*<3
Falling	Beijing	*RCI*>3	*RCI*=3	1.25<*RCI*<3
	Guilin	1.25<*RCI*<3	*RCI*=1.25	0.75<*RCI*<1.25
	Abazhou	*RCI*>3	*RCI*=3	1.25<*RCI*<3
	Qingdao	1.25<*RCI*<3	*RCI*=1.25	0.75<*RCI*<1.25
	Diqing	1.25<*RCI*<3	*RCI*=1.25	0.75<*RCI*<1.25
	Aletai	0.75<*RCI*<1.25	*RCI*=0.33\0.75	*RCI*<0.33
Fluctuating	Wenzhou	0.33<*RCI*<0.75	*RCI*=0.75	0.33<*RCI*<0.75
	Zhoushan	0.33<*RCI*<0.75	*RCI*=0.33	0.33<*RCI*<0.75
	Xichang	0.75<*RCI*<1.25	*RCI*=0.75	0.75<*RCI*<1.25
	Wuhan	0.75<*RCI*<1.25	*RCI*=1.25	0.75<*RCI*<1.25
	Zhangiajie	0.75<*RCI*<1.25	*RCI*=0.75\0.33	0.75<*RCI*<1.25
	Dali	0.75<*RCI*<1.25	*RCI*=0.75\1.25	1.25<*RCI*<3
	Dehong	0.75<*RCI*<1.25	*RCI*=0.75	0.75<*RCI*<1.25
	Kashik	0.33<*RCI*<0.75	*RCI*=0.33	0.33<*RCI*<0.75

- *RCI* shows a marked rise trend: 18 of the 22 *RCI*-rising airports cross a development stage, while Zhuhai, Kuerle and Hetian cross two development stages, mainly due to local financial support and the continuous improvement of the airport's own system. The last one is Linzhi, which has spanned three stages of development. From 2006, the passenger transport scale of the airport was much smaller than that of the home city, and the passenger transport scale of the airport in 2017 was larger than that of the home city. Linzhi is known as "Jiangnan in Tibet" and is a treasure trove of tourism development. In 2003, the local government invested 780 million yuan in the construction of Linzhi Millin Airport, striving to build the second golden line of tourism in Tibet, in order to promote the rapid development of the economy in Linzhi. With the strong support of local government and the attraction of abundant tourism resources, the passenger throughput of Linzhi Airport has increased from 7620 in 2006 to 468,000 in 2017, and the advantages of airport passenger transportation have become increasingly prominent.
- *RCI* shows a significant fall trend: Taking Beijing as an example, the *RCI* of Beijing in 2006 was 3.71, and its RCI value was 2.35 by 2017. Further research found that in 2006, the total passenger throughput of the two airports in Beijing was 49.049 million, and the urban *GDP* was 811.778 billion yuan. By the end of 2017, the passenger throughput reached 101.74 million and the *GDP* reached 2800 billion yuan. It is obvious that the annual growth rate of *GDP* is much larger than that of airport passengers. This shows that Beijing has been mainly committed to the continuous development of the city scale in the past 12 years. Airports such as Guilin, Abazhou, Qingdao, etc., due to the limited advantages of the city itself, cannot blindly expand the passenger transport scale of the airport. Therefore, the *RCI* values are appropriately adjusted to achieve a more matching state. As far as Ataile is concerned, the passenger throughput of its airport is declining, resulting in the final airport passenger transport scale not matching the scale of the home city.
- *RCI* shows a significant fluctuate trend: As shown in the table above, the *RCI* of Wenzhou shows a trend of increasing first and then decreasing, and the same trend is found in Wuhan as well. During the 12 years of development, the passenger throughput of these airports has increased year by year, so the passenger transport scale of these airports has gradually increased. However, the growth rate of *GDP* is faster in a certain period of time, which leads to the fluctuation of *RCI*. The *RCI* values of Zhoushan, Zhangjiajie, Dali and Kashi show a trend of decreasing first and then increasing, just the opposite of Wenzhou. The more special one is Dehong Airport, whose *RCI* value increases first and then decreases, and then shows an increasing trend. Further analysis of the data found that the passenger throughput of Dehong Airport declined in 2008 and 2009 compared with 2007, and it did not start to increase steadily until 2010, after

which the average annual growth rate was approximately 17.9%. The population and *GDP* of the city have been growing steadily, especially *GDP*. In 2006, its *GDP* was 7.04 billion yuan, reaching 35.697 billion yuan in 2017, with an average annual growth rate of about 14.5%, so its *RCI* fluctuations are special. Among the eight airports, Wenzhou, Zhoushan, Xichang, Wuhan, Kashi and Dehong airports have crossed one development stage, while Zhangjiajie and Dali airports have crossed two development stages.

4.3. RCI Analysis of Multi-Airport Systems

The previous paper analyzes the matching relationship between a single airport and its home city. It is found that for a single airport, the passenger transport scale of most airports does not match the scale of the home city. In terms of Multi-Airport Systems (according to the official classification criteria, the Multi-Airport Systems refers to: the North Airport Group, the East China Airport Group, the Zhongnan Airport Group, the Southwest Airport Group, the Northwest Airport Group), whether they do not match the corresponding urban agglomerations (the provinces where airports are located) needs further study and analysis. According to the statistics, the calculation results are as follows:

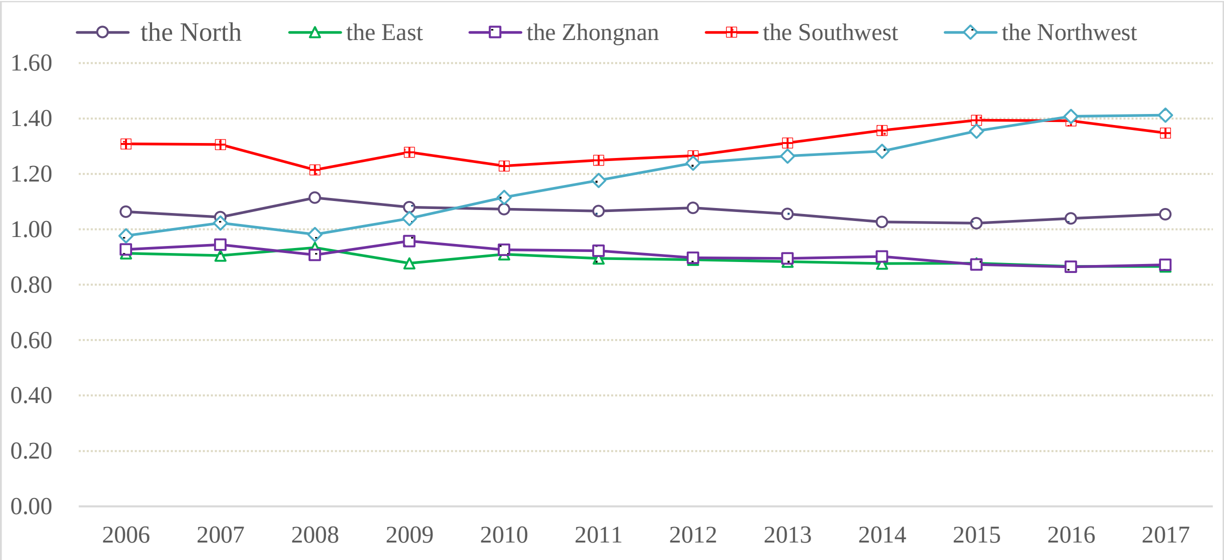

Figure 4: *RCI* statistics for the five major multi-airport systems in 2006-2017

It can be seen from Figure 4 that although there is a serious mismatch between the passenger transport scale of each airport and the scale of the home city, the passenger transport scale of each airport group is in a matching state with the scale of its urban agglomeration.

It is worth noting that compared with other airport groups, the Northwestern Airport Group has increased its *RCI* value year by year since 2006, from 0.98 in 2006 to 1.41 in 2017. On the one hand, since the implementation of the western development strategy, a large amount of capital and manpower have been injected to continuously develop the northwest China, the economic development has improved the people's living standards, and aviation travel is no longer out of reach. On the other hand, since 2006, new airports have been continuously developed and constructed in northwest China. Buerjinkanasi Airport was completed in 2007, Hami Airport was suspended in 1981 and resumed in 2007, Zhongwei and Tianshui Airports were opened in 2008, and Tulufan Airport was relocated in 2008, Jinchang Airport and Bole Airport started construction in 2009, Guyuan Airport opened in 2010, Zhangye Airport opened in 2011, and Gannan Airport and Delingha Airport were successfully opened in 2013 and 2014 respectively. In 2006, the passenger transport of the entire Northwest Airport Group was 19.99 million, reaching 103.41 million by 2017. The total passenger transport of these new or relocated airports reached 1.75 million. Therefore, under the combined effect of the two, the *RCI* of the Northwest Airport Group is rising.

Through the analysis of **4.1, 4.2**, and **4.3** above, we can conclude the general rules that the airport passenger transport scale and the home city scale follow in their development process:

- For a single airport, most of the airport passenger transport scale does not match the scale of the airport home city. The data shows that 35.2% of the airport passenger transport scale is larger than the airport home city scale, 62.4% of the airport passenger transport scale is smaller than the airport home city scale, only 11.2% of the airport passenger transport scale and the airport home city scale relationship are relatively matched.
- The matching relationship between the airport passenger transport scale with home city scale is constantly changing, and the changing trend can be divided into three types: rising, falling and fluctuating.
- The evolution of the relationship between airport passenger transport scale and airport home city scale is a gradual process, that is, the changes of *RCI* of all airports are continuously evolving towards adjacent stages, and will not directly evolve towards another stage across the adjacent stages.
- At present, the total passenger transport in each region can generally meet the development needs of various airports in the region. However, the reality is that large and medium-scaled airports in the region occupy a monopoly position, and small airports are struggling. Since large hub airports and airports in some tourist cities generally serve the entire region, they have a great advantage over small airports in terms of network routes, infrastructure construction, and interval transfers. Therefore, under the siphon effect, the passenger transport development of other airports in the region is severely limited.

4.4. Analysis of the Matching Degree between Airport Passenger Transport Scale and Home City Scale

The traditional *RCI* theory believes that the *RCI* value is between 0.75-1.25, indicating that the airport passenger transport scale matches the scale of the home city. Therefore, measures should be taken to adjust the type of mismatch in order to achieve a matching state. According to the traditional classification criteria, most of the airports in China are in a state in which the passenger scale does not match the scale of the home city. Therefore, the scale of the two should be adjusted in time to achieve a matching status. However, further analysis found that this is not completely consistent with the actual development of the airport in China.

For airports with *RCI* <0.75, the scale of airport passenger transport does not match the scale of the home city. Among these mismatched types, airports with *RCI* <0.33 account for the vast majority. They are mainly distributed in Fujian, Zhejiang, Jiangsu, and parts of the northwest. Although they have great potential for development, the loss of passengers is serious due to the single route network and imperfect infrastructure. Therefore, for an airport with *RCI* <0.75, it should be adjusted according to the traditional adjustment strategy. Its development should be carried out in two steps, first making the *RCI* between 0.33-0.75 and further reaching the matching state.

For airports with *RCI* > 1.25, the situation is different. The table 3 below shows the airport statistics of 125 airports in China with *RCI*>1.25 in 2006, 2012 and 2017. As far as the airports in the table are concerned, although the scale of airport passenger transportation does not match its home city, careful analysis shows that these cities have unique advantages, which can be divided into tourism cities, economic centers, political centers, culture and developed areas of science and education. The airports of these cities have already served not only the airport home city, but also expanding further outward to serve larger areas. This shows that the mismatch at this time is reasonable because they jump out of the traditional "one-to-one" service model and provide services to larger areas. Therefore, the traditional equilibrium point is not fully adapted here, and the airport should adopt a differentiated development strategy. For airports that strive for regional hubs, *RCI* should always be controlled in a range of more than 3, so as to better play the role of hub airports. Therefore, airports in Beijing, Shanghai and Guangzhou need to further enhance their passenger transport capacity and expand the scale of passenger transport. For airports with *RCI* between 1.25 and 3, there are three options for its development: maintaining the status quo, moving forward to make *RCI*>3, and backward development makes *RCI* mind between 0.75 and 1.25. From the data in the table, it is obvious that most airports choose to maintain the status quo, because the three existing hubs, Beijing, Shanghai and Guangzhou, have been basically formed, and it is difficult for these airports to compete with them in a short time. However, it is worth noting that if the airport resources are used effectively, it is undoubtedly the best choice to maintain the status quo. If not, the adjustment strategy should be adopted in time to make the *RCI* between 0.75 and 1.25, avoiding blindness vicious competition.

Table 3: Partial Stage Statistics for 125 Airports in 2006, 2012 and 2017

Range	Airport
***RCI*>3 (2006)**	Beijing、Xiamen、Haikou、Sanya、Abazhou、Kunming、Lasa、Xishuangbanna、Lijiang、Wulumuqi
1.25<*RCI*<3 (2006)	Taiyuan、Shanghai、Hangzhou、Qingdao、Guangzhou、Shenzhen、Guilin、Changsha、Chengdu、Diqing、Guiyang、Xi'an、Dunhuang、Yinchuan、Yining
***RCI*>3 (2012)**	Beijing、Xiamen、Haikou、Sanya、Kunming、Lijiang、Lasa、Wulumuqi
1.25<*RCI*<3 (2012)	Taiyuan、Huhehaote、Dalian、Shanghai、Nanjing、Hangzhou、Guangzhou、Shenzhen、Guilin、Changsha、Chengdu、Abazhou、Xishuangbanan、Diqing、Guiyang、Xi'an、Lanzhou、Dunhuang、Xining、Yinchuan、Yining、Hetian
***RCI*>3 (2017)**	Sanya、Haikou、Kunming、Lasa、Xiamen、Wulumuqi、Lijiang、Xishuangbanna
1.25<*RCI*<3 (2017)	Xi'an、Shanghai、Guiyang、Zhuhai、Beijing、Lanzhou、Yinchuan、Guangzhou、Huhehaote、Chengdu、Dunhuang、Taiyaun、Hangzhou、Xining、Shenzhen、Dali、Hetian、Yining、Abazhou、Zhengzhou、Nanjing、Changsha、Shenyang、Linzhi、Dalian

5. Conclusion

In order to explore the relationship between the airport passenger transport scale and the airport home city scale, the paper introduces Relative Concentration Index (*RCI*) to quantitatively analyse the relationship between them. Through empirical analysis, it is found that the matching relationship between the passenger transport scale and the scale of the home city in most airports in China shows a distribution pattern similar to “dumbbell”: "big at both ends, small in the middle". Therefore, in response to this phenomenon, the paper conducts an in-depth analysis of the relationship between the two, explores the general laws of the development of their development, and analyses the rationality of this mismatch. Finally, it is found that for airports with *RCI* < 0.75, the mismatch is unreasonable and should be adjusted in time. The target of adjustment is the traditional equilibrium point. For airports with *RCI*>1.25, the mismatch is reasonable because these airports no longer meet the “one-to-one” traditional service mode, so the adjustment strategy should not be fully adjusted in accordance with the traditional matching state, and a differentiated development strategy should be adopted.

Although the article uses the improved *RCI* index to analyse the development trend of airport passenger transport scale and home city scale at specific time periods, it is only a general improvement. In the analysis, it is found that different types of city have a great impact on *RCI* results, and the selection of different indicators has a great impact on the results too. Therefore, how to more accurately select indicators to accurately reflect the matching relationship between airport passenger transport scale and home city scale will be the direction we will continue to explore in the future.

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A Study on the Impact of Cruise Liner Service Quality on Customer Loyalty – Using Trust as a Moderator

Tan-Shou Shee[1], *Shih-Liang Chao*[1,*], *Hsuan-Shih Lee*[1], *and Hsian-Ning Hsu*[1]

[1]Department of Shipping and Transportation Management, National Taiwan Ocean University, Keelung, Taiwan, ROC
Email: [1]alexchao@ntou.edu.tw

[*]*Corresponding Author*

Abstract

As people pay more attention to the content and quality of leisure activities, the competition in the cruise market is also getting more competitive. It's not as smooth as it used to be in developing new customers, the cruise operators have to change their marketing strategies that focusing on the relationship with customers and improving customer loyalty in addition to maintaining their service quality. By maintaining a good relationship with customers, it is usually possible to reduce the uncertainty of customers when purchasing products and increase the sense of security of customers, and the operator can earn more profit by maintaining the relationship. Therefore, how to establish mutual trust with consumers to achieve a win-win result is also an important direction that cruise operators must take effort. This study refers to related literatures, and sorting out the main service quality, customer satisfaction, customer loyalty, trust and other items in the cruise industry, in addition to discussing the relationship with customer loyalty, the moderating effect of trust was also examined.

Keywords: Cruise Operator, Service Quality, Customer Satisfaction, Customer Loyalty, Trust

1. Introduction

The rapid growth of Asian economic development has driven the demand for the cruise tourism market recently. According to Asia Cruise trends 2018 report issued by the Cruise Lines International Association (CLIA) in July 2018, the number of cruise ships in Asia from 43 in 2013 grew up to 78 in 2008, increased by 81%. In 2018, the total number of voyages was 2,041, of which 1,922 were 94.2% in Asian region. Moreover, 38 cruise brands were operated in 2017. In 2018, the number of Asian passengers increased by 20.6%. It shows that more operators invested the cruise tourism market, and more cruise ships have come into the Asian region, making the Asian cruise market increasingly competitive.

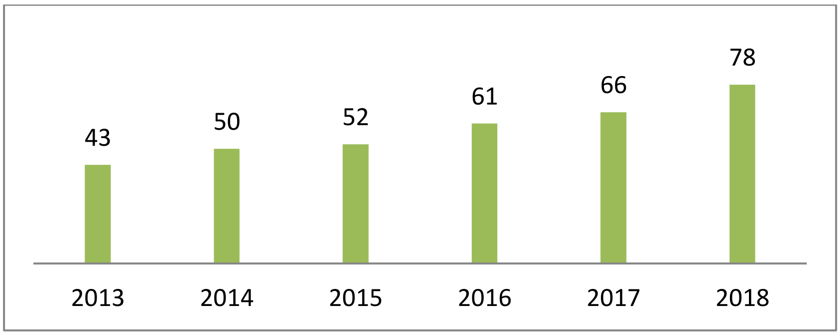

Figure 1: Cruise Ships Deployed by Type, Asian Region
Resource: Asia Cruise Trends 2018 Edition P9

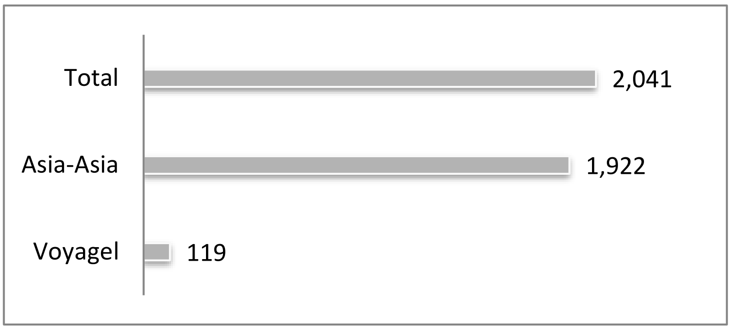

Figure 2: Cruises Offered by Type, 2018
Resource: Asia Cruise Trends 2018 Edition P9

In 2018, 346 cruise ships called at ports of Taiwan, and 247 of which took a Taiwanese port as an origin and destination. According to the statistics of Taiwan International Port Corporation (TIPC), there were more than 1 million passengers in 2018. Most of the passengers were from Taiwan. There are more competitors in the Taiwan cruise market, so that customers have more choices. Reichheld and Sasser (1990) found that profits could be increased by 25% to 85% by maintaining a 5% customer service relation (CSR). Kotler (1999) indicated that 20% of loyal customers will create 80% of the company's turnover. Therefore, continuing to enhance the customer loyalty is one of the important topics for the cruise shipping industry.

This study investigates the impact from the service quality towards loyalty for the customers of cruise carriers. In addition to taking service quality, customer satisfaction and customer loyalty into consideration, the moderating effect of trust on the relationship between service quality and customer loyalty was also tested.

2. Literature review

2.1 Cruise tourism

Teye and Leclerc (1998) pointed out that visitors enjoyed the activities of eating, living, traveling, shopping, and entertainment on board, as well as onshore sightseeing and tourism services. Dowling (2006) indicated that cruises could be considered as floating resorts, which offered transportation, restaurants, bars, sports facilities, shopping centers, entertainment venues. UNWTO (2012) defined that cruises offered transportation and accommodation, as well as provided a variety of activities for customers. A cruise served as a floating resort and offered a short-season journey around a week, where customers could enjoy cruise facilities and entertainment when they were transported between different ports (Rodrigue, 2017).

2.2 Service Quality

Kotler (1999) indicated that services were intangible, and the provision of services is not necessarily related to physical products, so services were not necessarily attached to a product. Services are inherently intangible and typically occur in a single or a series of activities between the customer and the person who provides the service, physical resources, goods or systems (Fitzsimmons and Fitzsimmons, 2004). Therefore, service quality will affect customer satisfaction. (Hurley et al.,1998). Eshghi et al (2008) defined service quality as a general assessment of customer service. In the service industry, service quality has become an indispensable element of organizational competitiveness, especially in improving customer expectations and organizational performance (Evans and Lindsay (2009). This study considers that the quality of cruise service refers to the quality of all intangible and tangible services provided by a cruise from its departure to arrival.

2.3 Customer Loyalty

Dick and Basu (1994) proposed that loyalty was the strength of the relationship between "personal attitude" and "repurchase". Oliver (1997) indicated that customers were willing to purchase the same product or service without paying attention to other possible choices. Singh et al. (2000) found that a customer's willingness to maintain a relationship with service provider is a behavioral intention. Sirdeshmukh et al. (2002) pointed out that customers are willing to maintain relationships with existing companies. Zamora et al. (2005) considered that customer loyalty was the relationship to maintain long-term transactions with specific customers. Yoon and Uysal (2005) emphasized that customers are willing to repurchase and recommend to others. Tuu et al. (2011) suggested that customer loyalty includes the cumulative structure of consumer behavior (action loyalty) and expected consumption (future repurchase). Ishaq (2012) studied the key role of customer buying behavior in the field of service marketing. According to the above discussion, this study defines the customer loyalty of cruise carriers as the willingness of the customer to take the cruise again.

2.4 Customer Satisfaction

Woodside et al. (1989) considered that customer satisfaction is the overall attitude of the customer reflecting the extent to which the customer likes and dislikes after consumption. Teye and Leclerc (1998) defined customer satisfaction as the customers' expectations for the cruise experience were met or exceeded. Szymanski and Henard (2001) indicated that customer satisfaction is a product of service quality, that is, customer satisfaction is related to providing good products or services to customers. Berry et al. (2002) considered that satisfaction is providing customers with an unforgettable satisfaction experience through product value. Ranaweera and Prabhu (2003) indicated that satisfaction is the willingness to maintain relationships between customers and service providers. Dominic and Guzzo (2010) pointed out that companies can maximize customer satisfaction by anticipating and managing customer expectations. It is the feeling of the product or service received by the customer, and this feeling can be an immediate feeling or the feeling after experiencing a series of products or services (Chen et al. 2015). Based on the above literature, this study considers that customer satisfaction refers to the customer's psychological cognition and attitude change after using the service provided by a cruise.

2.5 Trust

Gefen (2000) indicated that based on previous interactions, people feel confident and trustworthy in their positive expectations of what others will do. The customer's services and resources used by a company can meet the customer's own needs and the confidence and attitude of long-term preferences (Shamdasani and Balakrishnan, 2000). Berry (2001) considered that trust is the willingness of a party to trade and have confidence to its partners. Everard and Galletta (2006) pointed out that if customers are convinced of the positive reliability of service providers, they will have a commitment to a positive experience for service providers (Olaru et al., 2008). Kantsperger and Kunz (2010) found that the characteristics of trust is integrity (always telling the truth and making it back according to solid principles) and kindness (focusing on the interests of the customer). In this study, trust was defined as that the cruise carrier pays attention to the interests of customers and provides service commitments, to which the customers generate reliability.

2.6 Research hypothesis

(1) The impact of service quality on customer satisfaction

The relationship between service quality and customer satisfaction has been extensively discussed in the past. Shanka (2012) measured the service quality of Ethiopian private banks and found that there was a positive correlation between service quality and customer satisfaction. Mutaz et al. (2013) also pointed out that the service quality would affect the level of customer satisfaction, and then affected the value-added service of customers' continuous use of mobile communication. That is, providing good service quality had a positive impact on overall customer satisfaction. For cruise operators, if the service personnel have sufficient professional capabilities to accurately grasp the passenger's needs and provide good solutions, the customer satisfaction may be improved. Therefore, this study proposes the following hypothesis：

H_1：The service quality of cruise operators has a significant impact on customer satisfaction.

(2) The impact of customer satisfaction on customer loyalty

Mohsan et al. (2011) investigated the impact of customer satisfaction on customer loyalty through 120 customers who were serviced in Pakistan and had accounts in the bank. The results of the study showed that customer satisfaction and customer loyalty had a positive correlation. Focusing on the mobile instant messaging services, Deng et al. (2010) identified the determinants of customer satisfaction and loyalty. The result confirmed that customer satisfaction was positively related to customer loyalty, and customer satisfaction could directly improve customer loyalty. Jung and Yoon (2012) found a significant positive correlation between customer satisfaction and customer loyalty in a study of family restaurants. In the cruise industry, if the customers are satisfied with the service, they may have a good impression of the carrier, it is easier for them to choose the same carrier again. Therefore, this study proposes the following hypothesis:

H_2：The customer satisfaction of cruise operators has a significant positive impact on customer loyalty

(3) The impact of service quality on customer loyalty
Shiau et al. (2014) found that two constructs "whole environment" and "service personnel" used to measure the quality of casino services had significant positive correlation with customer loyalty. Considering that the Indian banking industry was facing enormous challenges in the market competition, Goyal and Chanda (2017) took the Indian banking industry as an example to investigate the competitive advantage. The results showed that the service quality perceived by customer would directly affect customer loyalty. For cruise carriers, if they can provide customers with good service quality, such as the service personnel with a friendly attitude, highly professional and prompt response to customer needs, customers may feel much better and then increase the willingness to choose the same carrier again. Therefore, this study proposes the following hypothesis:

H_3：The service quality of cruise operators has a significant positive impact on customer loyalty.

(4) Trust moderating effect
Qing (2004) used the Yahoo auction website as an example to show that trust has the moderating effect on the relationship between service quality on customer loyalty. Therefore, this study proposes the following research hypothesis:

H_4：Trust has a moderating effect on the relationship between service quality on customer loyalty.

This study mainly explores the relationship between service quality, customer satisfaction and customer loyalty for cruise carriers. The research model proposed by this study is illustrated in Figure 3.

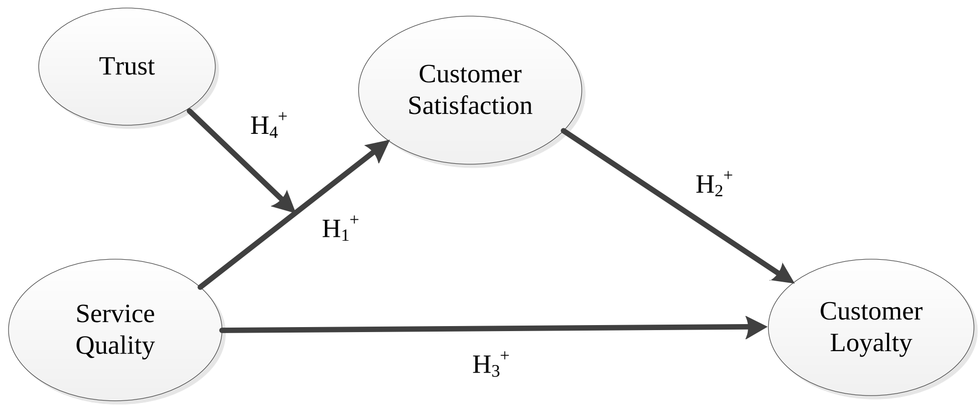

Figure 3: The research model in this study

3. Methodology

3.1 Questionnaire design

A questionnaire was designed to collect samples for carrying out an empirical study. All question items were sourced from relevant studies and measured by a 5-point Likent scale, in which (1) representing "strongly disagree"and (5) indicating "strongly agree". There were two parts in the questionnaire, in which the first part was designed to collect the opinions according to respondents' experience on taking cruises. The second part collected the basic information of the respondents.

As for the construct measures, question items related to service quality were sourced from Garbarino and Johnson (1999) which were developed for measuring the quality of cruise shipping. Satisfaction, which was the second construct in our model, was measured by question items designed in Söderlund(1998) and Casalo et al.(2008). The construct of custom loyalty was measured by question items sourced from Söderlund(1998), Casalo et al.(2008) and Hwang and Han(2013). At last, trust, which is the moderator variable, was measured by items sourced from Garbarino and Johnson (1999). All question items were summarized in the Appendix (see Table A1)

3.2 Sampling and data collection

In this study, the population for sampling was defined as the passengers taking cruises from Keelung Port during July to August in 2018. Altogether 152 passengers were interviewed to answer the questionnaires, in which 8 samples were invalid because they were answered incompletely. As a result, the valid return rate was 95%. The basic information of the respondents is listed in the Appendix (see Table A2), in which 52.1% were male and 47.9% were female. The respondents were mainly distributed from 31 to 60 years old. In terms of education level, 49.3% and 17.4% of the respondents held bachelor's and graduate degrees, respectively. Lastly, more than 95% of the respondents took cruise ships operated by STAR CRUISES and PRINCESS CRUISES.

3.3 SEM analysis

In this study, the two-phased procedure was used to on SEM suggested by Anderson and Gerbing (1988) analysis. The first phase built up a measurement model to examine the reliability and validity by fitting the collected samples to the proposed model. The reliability was tested by examining if the construct reliabilities (CR) of all constructs are larger than 0.7 (Fornell and Larcker, 1981). Meanwhile, the AVE values of all constructs have to be larger than 0.5 (Hair et al., 2013).

In terms of validity, three common validities were tested in this study, in which the first requires all construct measures must be sourced from related studies to ensure content validity. The second validity, called convergence validity, was tested by requiring all factor loadings must larger than 0.5 (Kline, 1998). The third validity, discriminant validity, was tested by estimating the 95% confidence intervals (C.I.) of correlation coefficients between each construct pairs using boostraping method. The discriminant was achieved if all C.I. do not cover one (Torkzahed et al., 2003).

4. Results

(1) The measurement model

As for the measurement model analysis, seven goodness-of-fit measures were examined before discussing the result. As Table 1 reports, all measures achieved their acceptance thresholds, reflecting a good fitness between the collected data and the proposed structural model. The result of measurement model analysis is shown in Table 2. The reliability was tested by examining two indexes, ie. CR and AVE. As Table 2 reports, the CR values of constructs ranged from 0.802 to 0.908, all of which were greater than 0.7 (Fornell and Larcker, 1981, Hair et al., 2014). In addition, the AVE values in Table 2 ranged from 0.511 to 0.712, all of which were larger than 0.5 (Hair et al., 2014). Based on these results, it is obvious that the reliability of our model was achieved. In terms of validity, the content validity was ensured because all question items were sourced from previous related studies. Moreover, a pilot test was conducted in June 2018 by inviting two professors and three practitioners in the cruise shipping industry to answer the draft of questionnaire. The final version of the questionnaire had been revised according to their opinions. The convergence validity was tested by examining the factor loadings of each item. As shown in Table 2, all standard factor loadings were larger than 0.5, indicating that the convergence validity was ensured. The third validity was also tested in this study by examining if the square root of the AVE of each construct is greater than the correlation coefficient between the corresponding construct pairs. As Table 3 demonstrates, all square roots of the AVE are larger than 0.5 (Fornell and Larcker, 1981) and also larger than the correlation coefficients between corresponding construct pairs, indicating that the discriminant validity of the research model was ensured (Shiau and Luo, 2013).

Table 1: Goodness-of-fit measures of the measurement model

Goodness-of-fit measure	Recommended value	Value of this study
^{2}/degree of freedom	3.00	1.888
Goodness-of-fit index (GFI)	0.80	0.869
Adjusted Goodness-of-fit index (AGFI)	0.80	0.813
Normed fit index (NFI)	0.80	0.889
Comparative fit index (CFI)	0.90	0.943
Standardized root mean square residual (SRMR)	0.05	0.028
Root mean square error of approximation (RMSEA)	0.08	0.079

Table 2: The results of the measurement model analysis

Construct	Observation Variable	Standard factor loading	Standard error	Construct reliability (CR)	Average variance extracted (AVE)
Service Quality	SQ2	0.848		0.856	0.549
	SQ3	0.868	0.086		
	SQ5	0.624	0.104		
	SQ6	0.662	0.101		
	SQ8	0.666	0.105		
Customer Satisfaction	SA2	0.747		0.826	0.613
	SA3	0.860	0.121		
	SA4	0.736	0.124		
Customer Loyalty	CL1	0.878	0.094	0.908	0.712
	CL2	0.878	0.102		
	CL3	0.850	0.101		
	CL4	0.763			
Trust	TR1	0.535		0.802	0.511
	TR2	0.825	0.205		
	TR3	0.826	0.196		
	TR4	0.628	0.188		

Table 3: Average variance extracted of each construct and correlation coefficient matrix

	AVE	Service quality	Customer satisfaction	Customer loyalty	Trust
Service quality	0.549	**0.741**			
Customer satisfaction	0.613	0.579	**0.783**		
Customer loyalty	0.712	0.601	0.724	**0.844**	
Trust	0.511	0.675	0.619	0.686	**0.715**

Note: The values on the diagonal represent the root number of the AVE, and the off-diagonal values are the correlation coefficients between the various dimensions.

(2) The structural model

After an appropriate measurement model was ensured, we then built up a structural model to estimate the path coefficients and test our proposed hypotheses. Firstly, seven goodness-of-fit measures were examined. As Table 4 reports, all measures achieved their acceptance thresholds, reflecting a good fitness between the collected data and the proposed structural model. After that, the estimated path coefficients and critical ratios are reported in Table 5. Obviously, the three path coefficients were all significant because their C.R. values were greater than 1.96. Accordingly, the three hypotheses proposed in this study were all supported. That is, the service quality has a significant positive impact on customer satisfaction for the cruise carrier (i.e. H_1). The impact was as high as 0.654. Meanwhile, service quality also has a significant positive impact on customer loyalty for the cruise carrier (i.e. H_3). In addition, the impact from customer satisfaction on customer loyalty was also proven significant (i.e. H_2). However, it was much lower than the other two direct impacts in the model.

Table 4: Goodness-of-fit measures of the structural model

Goodness-of-fit measure	Recommended value	Value of this study
^{2}/degree of freedom	3.00	1.957
Goodness-of-fit index (GFI)	0.80	0.887
Adjusted Goodness-of-fit index (AGFI)	0.80	0.833
Normed fit index (NFI)	0.80	0.915
Comparative fit index (CFI)	0.90	0.956
Standardized root mean square residual (SRMR)	0.05	0.027
Root mean square error of approximation (RMSEA)	0.08	0.076

Table 5: Path coefficients and critical ratios (direct impacts)

Hypotheses	Variables	Estimates	S.E.[a]	C.R.[b]
H_1	Service quality→Customer satisfaction	0.654	0.106	6.173
H_2	Customer satisfaction→ Customer loyalty	0.304	0.108	5.435
H_3	Service quality→Customer loyalty	0.738	0.136	2.810

[a] S.E. stands for standard error [b]; C.R. stands for critical ratio.
[b] CR did not exceed 1.96 at the 0.05 level of significance.

Lastly, the moderating effect of trust on the relationship between service quality and customer satisfaction was tested using model 7 in the PROCESS 2.16 package. The result was summarized in Table 6 and Table 7, which indicated that the moderating effect of trust on the relationship between service quality and customer satisfaction for the cruise carrier was significant because the C.I. did not include zero. The results of the structural model analysis was illustrated with Figure 4.

Table 6: The test results of moderating effect of trust

Hypotheses	LLCI*	ULCI**	Result
H_4：Trust significantly moderates the relationship between service quality and customer satisfaction for the cruise carrier.	0.0526	0.4194	supported

* LLCI: lower level for confidence interval.
** ULCI: upper level for confidence interval.

Table 7: Index of moderated mediation

Mediator	Index	SE(Boot)	BootLLCI	BootULCI
SA234	.1433	.0575	.0303	.2586

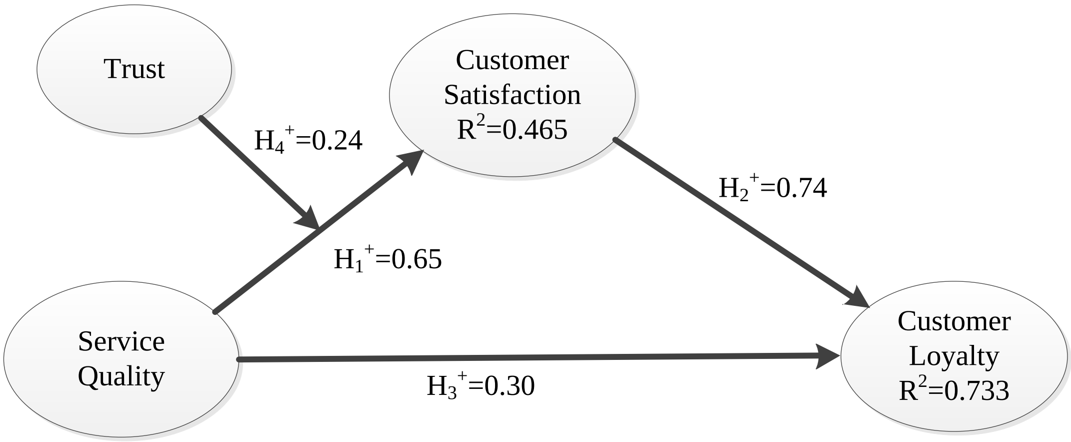

Figure 4: Results of the structural model analysis

5. Conclusions

Taking cruises has become an important way for people to enjoy their vacations. As the cruise shipping market is getting competitive, cruise carriers are concerning issues about measuring and improving their service quality, thereby further strengthen or even increase the loyalty of their customers. In this study, we found that the relationships between service quality, customer satisfaction and customer loyalty for cruise carriers are all positive and significant. At the same time, we also found that customers' trust has a significant moderating effect on the impact from service quality on customer satisfaction. Based on these findings, cruise carriers should continuously pay attention to improve the quality of their services because good service quality will increase the satisfaction and loyalty of their customers, the effect of which may be reflected by repurchasing the service or recommending the service to others. In addition to improving service quality, the moderating effect of trust is also important because it will increase the impact from service quality on satisfaction. That is, cruise carriers may use strategies like reducing the gap between customers' expectation and the actual service, building good reputations and being responsible to deal with customers' problems and complaints to increase the trust of their customers, thereby enhance the impact from service quality to satisfaction. Lastly, due to time constraint, we only investigated the impact from service quality and satisfaction on loyalty. As there are other constructs which may also influence the loyalty of cruise passengers, future studies may include other constructs as antecedents or controlled variables in the model to further.

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Research on the Ship Exhaust Emissions Monitoring Techniques in Port Water

Xin Peng[1], *Yuanqiao Wen*[2,3,4], *Changshi Xiao*[1], *Liang Huang*[2,3,4], *Chunhui Zhou*[1], *Fan Zhang*[1] *,and Haiwen Yuan*[1]

[1] School of Navigation, Wuhan University of Technology, Wuhan 43006, China
[2] Intelligent Transport Systems Center, Wuhan University of Technology, Wuhan 43006, China
[3] National Engineering Research Center for Water Transport Safety, Wuhan University of Technology, Wuhan 430063, China
[4] Hubei Key Laboratory of Inland Shipping Technology, Wuhan 430063, China
Email: [1]7474700791@qq.com

Abstract

Ship emissions is the main contributor of air pollution in coastal ports. Effective regulation and governance of ship emissions is necessary. Realizing remote monitoring of ship's atmospheric pollutant emissions is the basis of screening high-emission and high-sulfur oil ships. This work designs a ship exhaust emission monitoring system based on high-precision sniffing sensors. The methods were selected based on a review of the available literature on ship emission measurements. They were sniffer methods and optical (LIDAR, DOAS, UV camera) methods. The measurements of the sniffer monitoring instruments were performed from station at land and from a helicopter. Designing the land-based sniffing monitoring system based on sniffer sensors and supporting software platform system, integrating ship AIS data, environmental meteorological data, and CO_2, SO_2, and NO_X (NO/NO_2) concentrations to achieve coarse screening of suspected high-emission ships. Information related to ship emissions is visualized on the platform. Comparing the simulated theoretical concentration of gas pollutants obtained from the CALPUFF atmospheric pollutant diffusion model under the same environmental conditions, the monitoring feasibility and accuracy of the sniffer shore-based automatic monitoring system are verified. We designed and installed the UAV-based gas sensors monitoring system and measurement the ship exhaust emissions in Yantian port. Comparing the standard errors of simulated FSC values and laboratory FSC values, the system shows high efficiency and reliability in tracking the FSC of ships.

Keywords: Ship emissions, sensors, monitoring, sniffing

1. Introduction

In the context of global climate change, the issue of ship emissions has always been a highly concerned topic in the shipping industry. Atmospheric pollutants from ships and harbors mainly include oxysulfide, oxynitride, oxycarbide, particulate matters and aerosols(Lloyd's Register of shipping, 1995). In some port cities, atmospheric pollutant from ships have become the main source of pollution, and their contribution rate to air pollution even exceeds that of motor vehicles and power plants(Tobiszewski M et al., 2012).

The MARPOL 73/78 international convention for the prevention of pollution from ships with the Annex VI determines the ship worldwide use fuel sulfur content standards, and in the Baltic sea, the North sea, the North America and the Caribbean range sets up emissions control area of the ship. Air pollution control law of the Peoples Republic of China makes general provisions on the use of Marine fuel and the discharge of air pollutants. In 2015, the ministry of transport issued Implementation Plan of Ship Emission Control Zones in Pearl River Delta, Yangtze River Delta and Bohai Rim (beijing-tianjin-hebei) Waters and Implementation Plan of Special Action for Prevention and Control of Pollution from Ships and Ports (2015-2020)(Qi L et al., 2016). From the perspective of sulfur content of ship fuel, these plans control and reduce the atmospheric environmental pollution caused by a large amount of sulfur oxides.

Effective dynamic monitoring of ship air pollutant discharge is an important basis and urgent problem for further implementation of emission control measures. The special water environment increases the difficulty of installation of ship exhaust monitoring equipment. In addition, the dispersion and flow characteristics of ships make it difficult to collect data of ship parameters and fuel consumption. At present, the core ports in major domestic emission control areas have carried out relevant inspections on preventing and controlling air pollution from ships. However, in maritime supervision, the commonly used method of testing ship exhaust emissions by boarding and extracting fuel has great blindness and hysteresis(Kattner L et al., 2015). According to The United Nations Convention on The Law of The Sea (1982), during the supervision and inspection of port states, officials can only board ships if they have clear and sufficient reasons to suspect that the fuel oil used by the ships is not in conformity with the regulations and collect relevant evidence through reasonable monitoring methods. Therefore, it is of great significance for effective implementation of marine pollutants emission control standards to carry out ship exhaust emissions monitoring.

At present, the research on ship exhaust emission monitoring technology is mostly concentrated in developed countries in Europe and America. The methods mainly include sniffing and optical remote sensing. The sniffing method can realize the high-precision monitoring of the components of CO_2, SO_2 and NO_X. The method requires direct contact with ship exhaust plume. In the field of ship emission monitoring, there are three main sniffing methods: fixed point sniffing, mobile sniffing and portable sniffing. Optical remote sensing methods include laser radar, differential absorption spectrometry and ultraviolet camera. In addition, optical remote sensing method can be divided into active and passive types. The active monitoring system relies on itself as the light source. Passive monitoring systems use sunlight and sky scattering as light sources. The monitoring method of trace gases in the atmosphere has a high sensitivity and identification ability to the monitored gases. The monitoring equipment should be capable of normal monitoring under high temperature, high salt and high humidity monitoring environment and provide real-time and reliable monitoring data (PlattU P D, 2008). Sniffing methods are usually combined with optical remote sensing methods to monitor concentrations of trace gases in the atmosphere.

Finally, the supervision of ship emission should be implemented into the actual gas emission of a single ship. The sniffing monitoring equipment becomes the first choice of ship gas emission monitoring because of its foundation and stability. This work uses shore-based fixed and mobile sniffer monitoring equipment carried by unmanned aerial vehicles to obtain the data of the concentration of atmospheric pollutants from ships. Combined with ship AIS data, Marine meteorological data and other information, through organization and calculation, effective real-time automatic monitoring of ship emissions of atmospheric pollutants is achieved. The real-time data of ship emissions monitoring is dynamically visualized based on the software platform. Accordingly, maritime staff finds and tracks high-emission vessels in time.

The rest of this paper is organized as follows. Section 2 reviews remote sniffing techniques of monitoring ship exhaust emissions. Section 3 introduces the framework and function modules of the land-based sniffing monitoring system and the UAV-based gas sensors monitoring system respectively. Section 4 the purposed monitoring system are applied to measure the ship exhaust emissions in the Yantian port. The analysis and discussion of experimental results are performed. Section 5 provides a conclusion.

2. Related works

2.1 Sniffing Monitoring Systems

The sniffing method can realize high-precision monitoring of the components of CO_2, SO_2, NO_X and other ship exhaust gases, and this method needs to directly contact the ship exhaust plume. Fixed - point sniffing is a relatively mature monitoring method. Mobile sniffing method is carried out by helicopter or unmanned aerial vehicle. The detection cost of mobile sniffer is higher than that of fixed-point sniffer and portable sniffer, but mobile sniffer can detect a wider area, covering an area dozens of nautical miles away from the coastline. Mobile sniffing is required to be measured within a height range of 50-100m from the ships exhaust plume. The height from sea level depends on the marine meteorological conditions and the direction of the ship. When the ship is sailing downwind and the wind speed is low, the ships smoke plume will rise steeply, and the equipment needs to fly to an altitude above 150m for accurate monitoring. When the ship is sailing against the wind and the wind speed is high, the smoke plume emitted by the ship will be within 50m height. Therefore, the sniffer equipment carried by the helicopter can monitor the smoke plume of the ship very well, which is obviously better than the optical remote sensing monitoring method.

Fuel sulphur content (FSC) is normally given in unit of percent sulphur content by mass, in the following written as (%m/m). In 2015, IMO and the EU jointly formulated regulations that the sulphur content of fuel used by ships in the waters of northern Europe and South America shall not exceed 0.1%m/m(IMO, 2009). Researchers in Europe and the United States have carried out some research on the application of sniffer in the field of ship exhaust emission monitoring. The Swedish project Identification of Gross-Polluting Ships (IGPS) and the EU project CompMon implemented the CEF (Connection Europe Facility) scheme for the monitoring of sulphur content in fuel oil and provided funds for the research of various monitoring methods of ship exhaust emission. European countries have made many attempts in the installation site of sniffing monitoring equipment, including land, bridges, aircrafts, ships, and automobiles platforms. Chalmers university of technology has designed a monitoring method that combines DOAS (Differential Optical Absorption Spectroscopy) with sniffer and conducted a series of experimental applications in the European region(Beecken J et al., 2014). The Netherlands and Finland attempted to use DOAS and fixed point sniffing to monitor ship emissions(Beecken J et al., 2015). Belgium and Britain use mobile aerial sniffing to monitor the sulphur content of ships emissions. In 2015, the Danish government installed the fixed-point sniffing atmosphere monitoring system on the great belt bridge, and monitored the concentration of SO_2 and CO_2 emitted by passing ships at fixed points. Meanwhile, the concentration of NO_2 and SO_2 was monitored by the optical remote sensing detector and sniffer onboard the aircraft(Mellqvist, J et al., 2017). Kattner et al. used fixed point sniffing to monitor the concentrations of CO_2 and SO_2 emitted by ships in the waters off the Hamburg port, north of the European SECA (Sulfur Emission Control Areas) for five months(Kattner L,et al., 2015). They relied on monitoring data to determine whether the ships fuel oil is compliant. Sweden had been monitoring the SO_2 and CO_2 emission concentrations of ships in Gothenburg waters for three years by using sniffer fixed point monitoring in Gothenburg waters since 2014. The observation station is set up on a small island in the sea(Mellqvist R J, 2017). Through the data obtained from the observation station, combined with the data information of AIS (Automatic Identification System) and Marine meteorological data, the sulfur content of the fuel oil of the ship was calculated, so as to search out the illegal and ultra-exhaust ship.

Table 1: The characteristics of sniffing monitoring for ship exhaust emissions

Monitoring methods	advantages	Limiting conditions	Fit conditions
Land-based sniffer	low cost, mature technique, high automation level	low automation level, easily affected by detecting location and weather conditions	perennial winds blow from the ocean toward land
Mobil station sniffer	monitoring rapidly, extensive application scope	High cost, use professional, not suitable for rainy days, narrow coverage	simple hydrometeorological environment
Portable sniffer	small volume, easy to carry, monitoring rapidly, high precision	on board use	The ships reserved monitoring entrance

2.2 O*ptical* Monitoring S*ystems*

As an active modern optical remote sensing gas monitoring technology, Light Detection And Ranging(LIDAR) is widely used in environmental monitoring And atmospheric pollutant gas Detection. It mainly uses the ultraviolet to the infrared wave band light wave(Weitkamp C, 2005). As a whole, the lidar system can be divided into three parts: laser emission, echo signal reception, acquisition and control(Luo Q, 2006). The LIDAR monitoring method can realize large-scale, real-time and dynamic three-dimensional measurement of atmospheric pollutants, which has a good reference significance for the monitoring method of ship exhaust emission. Foreign LIDAR monitoring methods have been relatively mature in the application of ship exhaust emission monitoring, but there are few relevant studies in China at present. In 2006, the Netherlands successfully used mobile LIDAR for the first time to monitor the emissions of SO_2 from ocean going vessels at the Scheldt estuary for five days and found 24 vessels with illegal emissions. In the monitoring results, the highest emission reached 37g/s(Berkhout A J C et al., 2012; Brinksma E J et al., 2008; Volten H et al., 2009). Berkhout A J C et al.(Berkhout A J C et al., 2012) took the Netherlands as the research area, compared the costs and benefits of monitoring by combining the use of radar with the acquisition of Marine fuel samples through patrol vessels and by using only patrol vessel sampling to check the quality of Marine fuel. The results showed that in radar monitoring, the total ship monitoring rate increases from 14% to 80%, and the ship monitoring over-discharge rate increases from 3% to 11%, which proved that LIDAR has remarkable effect in monitoring ship exhaust emissions.

Differential Optical Absorption Spectroscopy (DOAS) remote sensing monitoring technology uses ultraviolet - visible light as the light source. Compared with other gas concentration monitoring methods, DOAS has the following advantages: (1) It is possible to simultaneously monitor various types of exhaust emission pollutants in the same spectral band; (2) On the basis of selecting appropriate spectral bands, the monitoring accuracy is high, and pollutants with gas concentration less than 1nmol/m3 can be monitored(PlattU P D, 2008); (3) The monitoring range can be 100m ~ 12km, and the monitoring concentration reflects the average pollution concentration of a region which is more representative than the single-point monitoring method. Therefore, DOAS monitoring technology is one of the mainstream monitoring means of atmospheric environmental pollution. Domestic and foreign researchers have done some applied researches on DOAS monitoring methods in recent years. U. Platt et al. observed the NO_2 emission of ships from Sri Lanka to Indonesia for six years based on the DOAS satellite remote sensing monitoring method, and the observation results showed that the ship emission line was basically consistent with the ship track(Beirle S, 2004). For the first time, Wang et al. carried out a two-day monitoring of SO_2 in the Po River in northern Italy by using the airborne MAX-DOAS (multi-axis differential optical absorption spectrometer), and made a comparative analysis with the ground monitoring results(Wang P, 2006). The monitoring results of the two monitoring methods were well consistent. The advantage of airborne monitoring is that the position and height of the monitor can be moved rapidly according to the wind direction and speed, and the accuracy of monitoring results can be improved effectively. In China, the DOAS monitoring method is still in the experimental stage in the field of ship emission monitoring. Fudan university started DOAS research on urban atmospheric environmental monitoring in 1999. Wang et al. conducted a one-year atmospheric NO_2 monitoring of Shanghai area by using the method of combined active and passive DOAS monitoring(Wang S, 2012). The results showed that the vertical column density of NO_2 in the troposphere can well reflect the NO_2 pollution in the whole atmosphere.

Fourier Transform infrared spectroscopy (FTIR) has significant advantages in the infrared spectral analysis, which can realize a variety of gas detection at the same time(Fuller M P et al., 1978; Selimovic V et al., 2018). There are few studies on the observation and application of gas concentration based on Fourier transform infrared spectroscopy in China. At present, the application of FTIR in ship exhaust emission monitoring is still in the theoretical research stage. FTIR has been able to achieve continuous real-time monitoring of CO_2 concentration, but external factors such as temperature, pressure and humidity will affect the accuracy of monitoring results. In addition, the high price limits the application of FTIR method to some extent.

3. Sniffing Monitoring System

3.1 Land-based Monitoring Station

The land-based monitoring system applies commercial air quality analysers for the high precision and automatic measurement of SO_2, CO_2, NO and NO_2 from the ship emissions. The actual equipment as shown on Figure 1.

Figure 1: Physical Map of Land-based Monitoring System

The land-based sniffing monitoring system designs adopts modularization that are composed of the gas sample quality control module, the air pollutant monitoring module, AIS module, micro weather station module, communication module, zero air calibration module and Uninterruptible Power Supply (UPS) module.

The module of quality control for the gas sample, which is responsible for controlling the flow, the temperature, the humidity and the salinity of gas into sniffer equipment.

The module of air pollutant monitoring module are composed of three commercial air quality analysers by the electrochemical principle, one for the measurement of SO_2, one for the measurement of CO_2, and another one for the measurement of NO, NO_2 and NO_X. The working temperature of the sniffing monitoring system at between -30℃ and 70℃ in normal gaseous, while ambient conditions that include toxic gases, the temperature of -20℃-50℃. The working humidity range between 10%RH and 95%RH generally, The land-based sniffing monitoring system is supposed to be in continuous operation for twelve hours. The measurement of Sulphur dioxide is performed by a Thermo Scientific 43i instrument that use the pulsed ultraviolet fluorescence patented technology with a maximum monitoring concentration of 100ppm SO2. Because of having strong ultraviolet light, the minimum detection limit of SO2 is 0.5ppb. The instrument of monitoring NO, NO_2 and NO_X is based on 42i from Thermo Scientific, that supports monitoring the concentration of NO, NO2 and NO_X synchronously, calibrating gas respectively. The supervision precision is 0.4ppb. Depending on the plume speed, three different continuous monitoring times(40s, 80s and 300s) can be set, the response time is <10s.

AIS module provides the ships' dynamic information and static information, includes velocity, heading, position (longitude and latitude), MMSI, name of ships by AIS receiving Stations.

Micro weather station module basically satisfy demands for the marine meteorological service, automatic collection meteorological data, such as wind speed, wind direction, pressure, temperature and humidity of environment around the monitoring stations in real-time.

The UPS module provides reliable power protection for the monitoring equipment have run normally continuous under the abnormal electrical power supply, such as in the situation of power cut, undervoltage, maritime environmental disturbance.

The function of the communication module is transforming the measure data by the sniffer system to the software platform, act as pass-through and communication for data with ground data center.

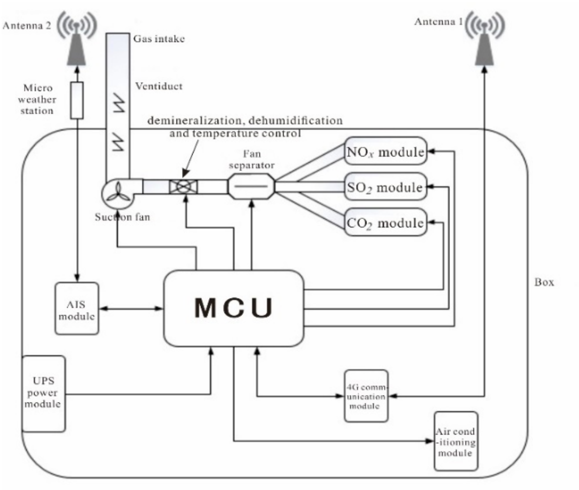


Figure 2: Frame Diagram of The Land-based Monitoring System

3.2 UAV Gas Sensors System

Using a mobile(airborne-based and ship-based) station it is possible to maximize the sampling probability by positioning the instrument downwind of the emission source and by moving closer to it. Installing the sniffing monitoring instrument on the unmanned aerial vehicle (UAV) platform allows targeting particular ships approaching from the downwind direction. The high costs for buy or rental of helicopters/planes, allow for fast checks on target ships also at tens of miles from the coast and considering the large area that can be covered this makes the measurements cost effective, compared to other options. Only the distance is 50m-100m between the UAV and target ships, can the mobile gas sensor effective monitoring the target ships. The ship plume rise to 50m in the condition of the strong wind speed and sailing against the wind, therefor the UAV platform suits to monitoring the ship plume best compared with other monitoring techniques, figure 3 shows working processes of UAV gas sensor system.

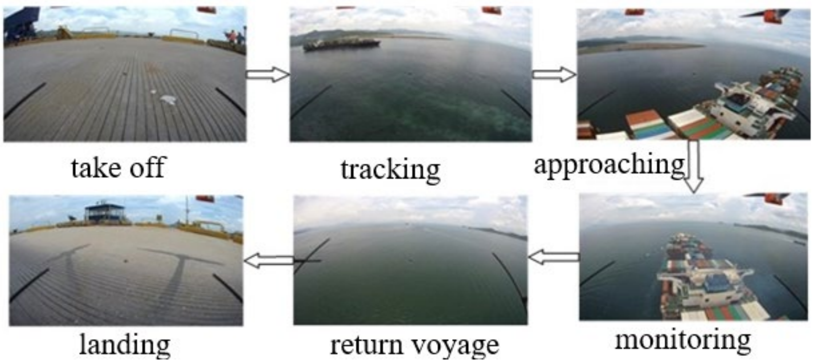


Figure 3: The Workflow of The UAV-based Gas Sensors System

The mobile sniffing monitoring instrument are composed of four gas sensors to automatic measure the concentration of CO_2, SO_2, NO, NO_2 from ship plume independently in real time, the monitoring range of those sensors, respectively is: 0-2000ppm, 0-20ppm, 0-1000ppm and 0-5000ppm, and the sensors distinguishability, respectively is: 1ppm, 0.1ppm, 0.5ppm and 1ppm. Those gas sensors collection some information about the monitoring system, includes the monitoring positions, times and the monitoring height. Those sensors have a lot of functions in data analysis, for example: storing and accessing historical data, shows the dynamic data of measurement gas concentration in curve graph.

In order to monitoring the ship exhaust emissions in the complex marine meteorological environment, choosing KWT-X6L helicopter as the mobile monitoring platform. KWT-X6L as a professional multi-rotor aircraft with better dynamic redundancy and wind resistance, it is suitable for operating in high altitude areas. This helicopter is capable of over an hour continuous flight, keeping track of the ship plume effectively, that provides high-definition aerials of monitoring processes. Auto cruise module of KWT-X6L supports to flight and landing autonomous. KWT-X6L as shown in Figure 4.

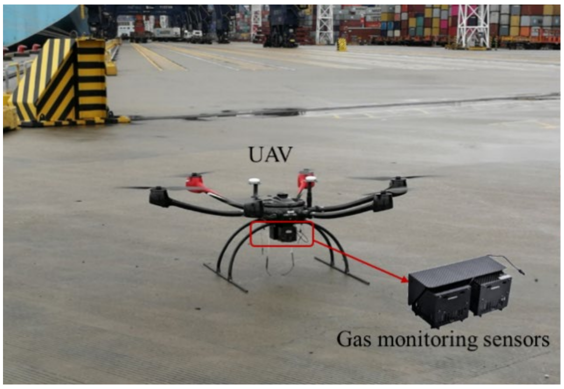


Figure 4: Physical Map of UAV Gas Sensors System

3.3. The Visualization Platform

The visualization platform of monitoring data to analysis data and visual displays of geographic information. According to the different needs of users, with the electronic chart, map and satellite imagery as working map respectively to display the ship emissions-related information. AIS data and meteorological information are displayed in a tabular format, visualization the ship trajectory on the working map, a window pops shows the ship dynamic and static information. The platform interface as shown in Figure 5.

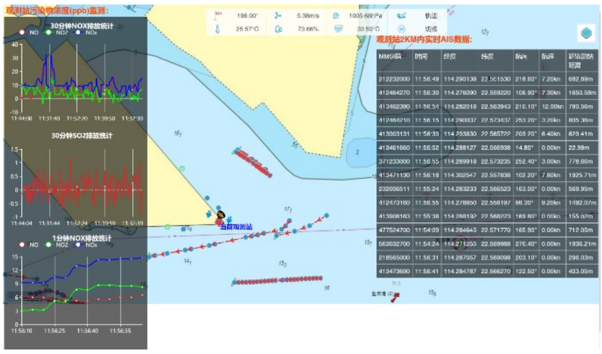
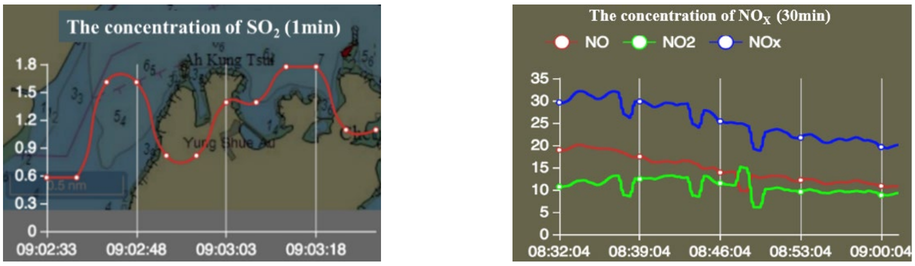


Figure 5: Figure of The Platform Interface

The platform dynamic displays the concentration of the monitoring atmospheric pollutant from ship dynamic monitoring data by using chart. The users are allowed to view information for the variation trend of monitoring air pollutant during 1min and 30min, as shown in Figure 6.



(a)1min (b) 30min

Figure 6: Dynamic Chart of Air Pollutant Concentration

4. Experiment and discussion

4.1 Experiment Introductions

In order to validate the availability of the land-based and UAV-based sniffing monitoring techniques. There are many installation conditions of the land-based sniffing monitoring system, the measurement site is located in open area, another condition is normal power supply. The UAV-based sniffing monitoring instrument should be applied in the condition of clear visual field, slight electromagnetic interference, fine weather and low wind speed (<10m/s).

Yantian port, Shenzhen as the experimental site, based on different monitoring instruments to measure the atmospheric pollutant from the navigating ship emissions from June to August 2018. Shenzhen is in the coastal area of southeast Guangzhou province, that attendance low latitude tropics the reason, belongs to the tropical marine climate. Because of the influence of summer monsoon, prevailing southeast wind in summer, prevailing northeast wind during the rest of the season. The land-based sniffing monitoring system was installed in upwind of the shore or a position near the channel networks to measure the passing ships. The flow of vessel traffic is low in Yantian port that is beneficial to experiments. The land-based monitoring station located in (114.28°E, 22.57°N), the research area scope is(22.53°E, 22.61°N), (114.24°E, 114.33°N) as shown in the Figure 7.

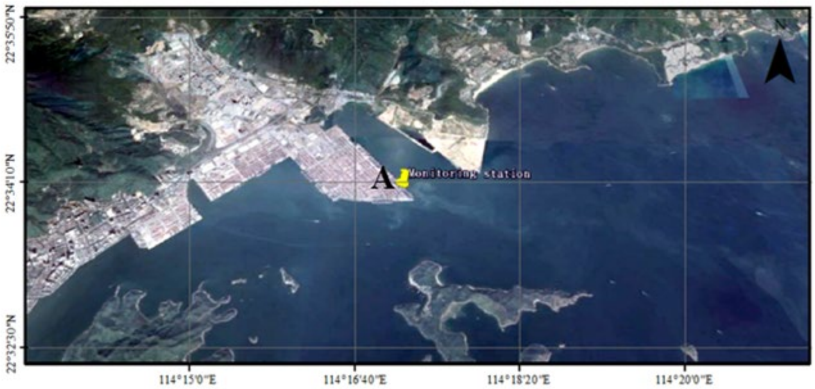


Figure 7: The Research Area

4.2 Analysis of Test Results

The UAV-based sniffing monitoring system measured 42 ships plume, and the land-based sniffing monitoring system measured more than 400 ships. Using CULPUFF that is a simulation model of the atmospheric pollutant diffusion, integrating the air pollutant monitoring data, AIS data, maritime meteorological data to calculate the theory values of pollutant concentration and compare the theory values with monitoring values.. Though choosing two ships that are typical samples to verify the effectiveness of the sniffing monitoring techniques, information of those samples are presented in table 2.

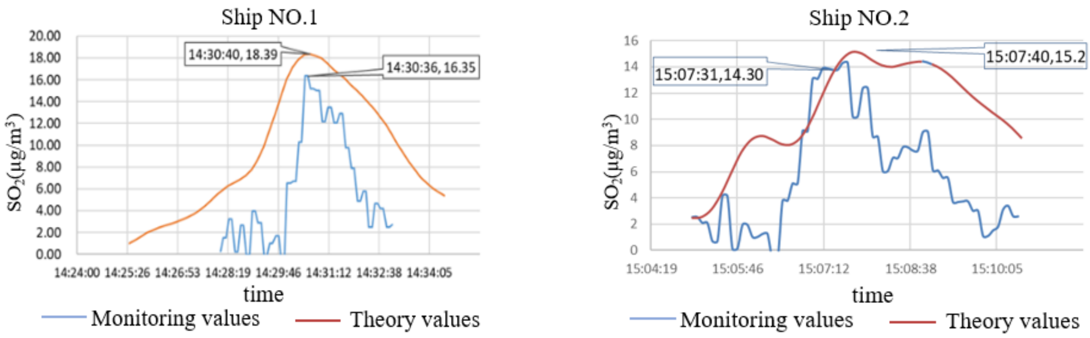
Table 2: Experimental Ships Information

NO.	power of main engine (KW)	power of auxiliary engine (KW)	Max speed (kn)	Wind speed (m/s)
1	45500	12800	24	4.95
2	45716	16000	23.5	4.11

4.2.1 The Land-based Sniffing Monitoring System

Choosing two navigating ships(NO.1 and NO.2) as experimental samples, comparing the theory air pollutant concentration with the monitoring values. The comparison results as shown in the figure 7. The red lines are monitoring values on line, the blue lines are calculated theory values by CALPUFF.

Figure 8(a) shows the comparison results of the ship NO.1. The monitoring concentration of SO_2 gradually increased since 14:30 during the ship NO.1 passing to the monitoring station, reaches the maximum that was 16.35μg/m3 in 14:30:36, after 14:33, the values fell to the values of background concentration. The monitoring concentration comparisons with the simulated concentration of the ship NO.2. Because of the navigating ship passing the monitoring station, the monitoring values started to rise in 15:05, it has grown to the maximum value was 14.30μg/m3 in 15:07:31. The dynamic monitoring values has the similar variation tendency to the simulation theory values. This indicates the monitoring values and theory values have preferable comparability. The land-based sniffing monitoring system could be used to measure the air pollutant plume from ships effectively.



(a)ship NO.1 (b)Ship NO.2

Figure 8: Comparison of Measured and Simulated Concentration of Ships on Shore

4.2.2 The UAV-based Sensor Monitoring System

The purpose of this experiment is to analyze the probability of measurement individual ship exhaust emissions by the UAV-based sensors, and getting instantaneous concentration of atmospheric pollutant from ship. Observing the variation tendency of the monitoring air pollutant concentration during UAV to track individual ship. Figure 9 shows high-resolution image of ship plume was taken by UAV, figure 10 shows navigating image of the target ship.

Figure 9: The Monitoring Image of Target Ship Plume

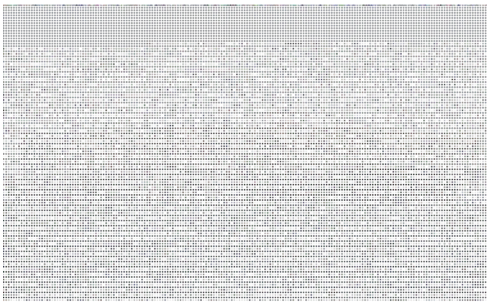
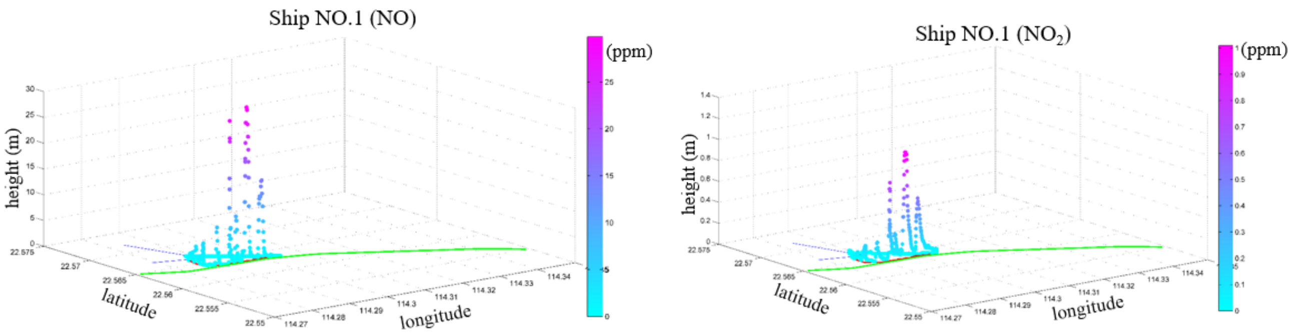


Figure 10: Navigating Image of Target Ship

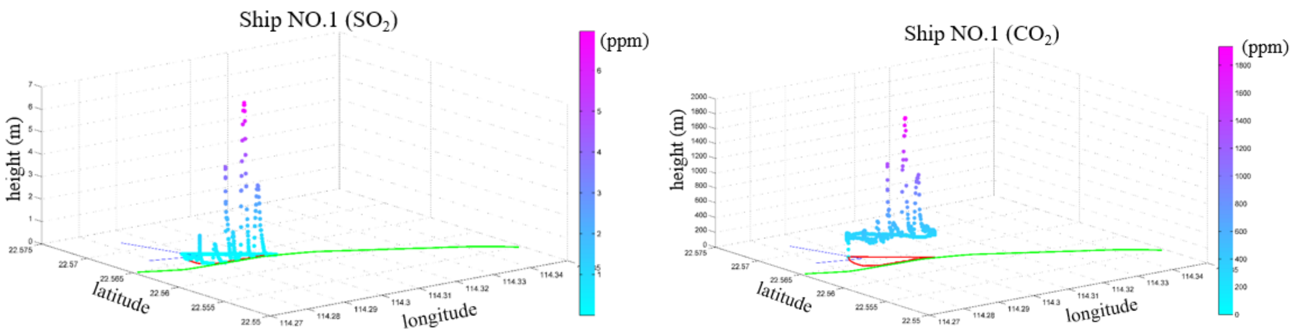
Fuel sulphur content (FSC) is normally given in unit of percent sulphur content by mass, in the following written as %(m/m). Based on the monitoring concentration of SO2 and CO2 to estimate the FSC of ships by calculation equation (1).

$$FSC[\%]=\frac{S[kg]}{fuel[kg]}=\frac{SO_2[ppb]\cdot A(S)}{CO_2[ppm]\cdot A(C)}\cdot 87[\%]=\frac{SO_2[ppb]}{CO_2[ppm]}\cdot 0.232[\%] \tag{1}$$

The target ship is a container ship, The monitoring concentration of ship exhaust emissions(NO, NO_2, SO_2, CO_2) as shown in figure 11. The initial distance between the UAV and target ship is about 1000m in 14:58:38, the minimum distance is about 40m in 15:02:40. The results showed that the monitoring concentration gradually rise with the UAV approaching to target ship. Calculation FSC based on SO_2 and CO_2 monitoring concentration, the range of calculated values is [0, 1.6517%]. The actual FSC is 1.29%(m/m) that provided by testing laboratory. The standard deviation of the calculated FSC and the tested FSC is 28.03%.



(a)NO (b)NO2



(a)SO_2 (b)CO_2

Figure 11: The Graphs of Monitoring Concentration

5. Conclusions

Designing the ship exhaust measurement instruments of land-based and UAV-based，using high-precision sensors to monitoring air pollutant, it realized measure the concentration of SO_2, CO2, NO, NO_2 from ship plume on line. The visualization platform displays information that about ship emissions monitoring by different types of visualization methods. Yantian port was the experimental field. The theory values are the concentration of the target ship emissions diffuse to the position of land-based monitoring station, which are simulated by CUPLUFF. This work compares and analyses the monitoring concentration and theory simulated concentration to demonstrate the reliability and availability of land-based sniffing monitoring system.

Using the UAV-based gas sensors monitoring system to measure the concentration of the ship exhaust emissions is feasible. Experimental results indicated that the variation tendency of different components of ship exhaust emissions is quite similar. Based on the monitoring concentration of CO_2 and SO_2 to calculate the SFC of ships' oil. The maritime staff are liable to detection high-emissions ships by UAV-based gas sensors monitoring system.

Sniffing monitoring techniques belongs passive remote sensing, maritime meteorological conditions are the key influence factor of the accuracy of measurement. Therefor, choosing the position of the monitoring station takes a full consideration for the influence of wind direction and speed. On the other hand, the limits of precision and sensitivity of the monitoring techniques, the accuracy of air pollutant concentration monitoring needs to be verified in the future study.

6. Acknowledgements

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A Study on the Implementation of Ocean Freight Forwarders' Corporate Social Responsibility in Vietnam

Tai-Cherng Lirn[1,2] *,and Doan Thi Ngoc Thao*[1]

[1] Department of Shipping and transportation management, National Taiwan Ocean University, Taiwan
[2] China Maritime Institute
Email: tedlirn@email.ntou.edu.tw

Abstract

Corporare social responsibility (CSR) is becoming a global trend that applied by organizations in the world. CSR practices differ among countries and among industries. The research was conducted by targeting ocean freight forwarders and shippers who have used freight forwarders' services in Vietnam to explore the key practices of CSR in Vietnam ocean freight forwarding industry. The Analytical Hierarchical Process (AHP) methodology is employed to assess and weigh 15 sub-criteria that are covered by three dimensions: environment performance, social rating and corporate governance rating. Using the snowball sampling technique, 32 responds are received from employees of the abovementioned companies.

Consequently, the result indicates that among three evaluation dimensions, environment dimension is perceived to have the highest degree of importance and among 15 sub-criteia, protection of labor,pollution prevention, clean energy and materials are top three criteria that were perceived to have the highest degree of importance when a freight forwarder wants to fulfill its CSR. The study is important for manager in orientating the effective approaches when they deploy CSR implemtation in their company, it also could be a guidance for future reseaches in related industry in Vietnam or in the same industry in other countries.

Key words: Corporare social responsibility (CSR), Viet Nam ocean freight forwarding industry, Analytical Hierarchical Process (AHP) methodology

1. Introduction

Corporate Social Responsibility (CSR) is a concept that had been initially addressed in many researches since 1950s. Interpretation of CSR are differed among countries (Crane et al., 2008) and are also even differed among organizations', companies', and NGOs' perceptions depend on their characteristics, economic context, and economic development level (Nguyen and Luu, 2008). One of difinitions are regularly mentioned in some researches is Carroll (1979)'s: "*The social responsibility of business encompasses the economic, legal, ethical, and discretionary expectations that society has of organizations at a given point in time*". Although all of these four dimentions should be existed in the same time of organization's CSR implementation but we should prioritize emphasising respectively economic, legal and then ethical, discretionary responsibility (Carroll.,1979). In addition, the UN Global Compact established ten generals principles that relating to human rights, labor rights, environment and anti-corruption. These principles are not mandatory, but they are considered as a formal framework in UN platforms because they likely can be applied at a very wide range of businesses and organizations. Dahlsrud (2008) defined CSR by five dimensions: environment, social, economic, stakeholder, and voluntariness. Dahlsrud also revealed that all of dimensions are necessary to clarifiy CSR definition and there's almost at least three of these dimensions are mentioned in other exiting researches, these dimensdions contribute to construct CSR based on specific context. Another fairly popular definition is European Commission's that "A concept whereby companies integrate social and environmental concerns in their business operations and in their interaction with their stakeholders on a voluntary basis" Although there are numberous different concepts and difficult to define briefly but in essence, CSR literally is a initiative that businesses have to meet society's expectations when planning their business strategies (Gössling and Vocht, 2007).

Many corporations in the world confirmed that CSR can ameliorate their brand (He, Li, 2011), motivate their employee (Lee, 2013), create positive perception to customer (Lee, 2012), and improve finance performance (Bowman, Haire, 1973). In developed countries, after a long and wide-ranging growth history, this concept has been considered as a global trend in first decades of 2000s because of those flagrant benifits. Like the other industries, CSR activities in logistics service providers are also increasingly interested to, in particular, ocean freight forwarders served as the whole supply chain coordinators and they have to keep harmonization of stakeholders' interests with social responsibility issues. It is not only a business tendency to expanse company reputation, image, but also a vital issue which can be used to attract potential customers and investors (Mackey at el. 2007) which ensure the corporate survival and sustainability. In this respect, CSR is defined as 'the integration of social and environmental concerns in the business operations of shipping firms and in the interaction with stakeholders on a voluntary basis' (Pawlik et al. 2012). Pawlik and his partners also revealed in their research finding that shipping companies virtually put more concern in environment rather than social issues since improving environment performance positively effect to financial performance. With B2B transaction feature, there are more stakeholders relating to the ocean freight forwarder, such as shippers, employees, shareholders, society, and regulators (Sarkis, 2010), in other words, they will receive more pressures to force them practise CSR activities, so that ocean freight forwarders need to increase thier awareness on CSR to satisfiy stakeholder's expectation as well as to improve their competitiveness.

Vietnam and other countries in ASEAN altogether are considered as developing countries, the international economic integration has required ASEAN country organizations applying CSR as essential issues in their business (ASEAN CSR, 2017). CSR does transform significantly among Asian countries but the transformation depends on factors in the separately national business systems (Chapple, Moon, 2005). Local culture and region's religions are also the factors that have effected the implementation of CSR strategies(Shimoni, 2011; Vivie, 2006), especially, Buddhist traditions in Asia should be also become an issue that make executives consider how and when to plan judicious CSR practices (Nelson, 2004). Like Thailand, a country has an ancient culture inclined Buddhist, it clearly relative to moral, take the situation of the most famous Logistics Company DHL (Thailand) as example, their staffs are willing to donate and help others when they have opportunities, they also pay attention to environmental protection plan through activities such as focus on CO2 reduction, recycling. Improving operating procedures is also their company issue as well as protecting labor right (Ferguson, D., 2011).

In a research of Yuen and Thai (2016a) to measure the customer satisfaction to shipping servive of 126 manufactures and 86 freight forwarder in Singapore. They listed charity, labor right, transparent, company procedures and pollution prevention in CSR activities base on context after evaluate each dimension for clarity, readability, and accuracy by eight senior managers from shipping companies. In another research recently, Yuen and Thai (2016b) anew mentioned transparent, company procedures, eco-friendly activity in shipping firms' CSR construct measurement and specially emphasized education improvement activities among employee as well as social community are important to CSR in the shipping industry. They also revealed that shipping firms should practice CSR when they have enough ability to provide a high quality shipping service. According to Lim and Yuen (2016), low willingness to pay for CSR and high regulatory standards are two key elements that hinder the CSR implementation in the Singapore shipping industry.

Although CSR in Malaysia general company have focused on the environment conservation, education and training, and social welfare (Chapple, Moon, 2005), but most of the logistics service providers(LSPs) do not have a clear sustainable development strategy related to environmental issue as well as society community for long term plan, because these LSPs have only focused on improving their service quality in short term, most of them only indicated that they will consider being environmental friendly in the future (Zailani et al. 2011). The way CSR is perceived and practiced is expanded by culture, religion, political and socioeconomic conditions, thus there are likely great differences in the way CSR is processed across different countries and regions (Bronn, Vrioni, 2001). So that it is necessary to have a research distinctly from each country about CSR in a specific industry, especially there is also a lack of academic research related to Vietnam LSPs even though the country now has acted as an important chain linking global trade(Banomyong et al. 2015). Over the past few years, the international economic integration is an objective development trend for some developing countries like Vietnam. Although some achievements that Vietnamese corporates have achieved due to global ecnonomic integration, Vietnam has not yet effectively dealt with arising socio-economic and environmental problems(Nguyen, 2013). With its open market to foreign investment policy, applying appropriate environmental regulation and encouraging the implementing of CSR issues into business operations to meet stakeholders' demands has been considered as essential activities for all economic entities in Vietnam. Put simply, CSR has become one of the requirements for corporates operate in Vietnam. This reality makes more companies in Vietnam change their working style to meet the international standards, including the sustainability and CSR standard set up by the UN Global Compact and ISO26000(CSR Compass, 2019). This study is to analyze the factors influencing Vietnamese ocean freight forwarders' CSR performances. By using AHP technique, the research findings can be used to help the executives choosing the most effective CSR practices to achieve the corporate aims.

2. Literature review

The multi-dimensionality of the CSR performance construct is the primary difficulty in measuring its performance because of its broad concept (Chen and Delmas, 2011). Although CSR conceptions and models in exiting researches which almost conducted in Western developed countries, these models also can be applied to Asian developing country with the significant differences because of culture disparity (Visser, 2008). The perception on CSR among enterprises in Vietnam might be not exactly the same as the western one. Some enterprises consider CSR as the promotion of charity activities and community volunteering campaigns, while others have defined CSR as how to satisfy customers' requirements on quantity, quality, and delivery time of goods(Do, 2005). Lai et al. (2013a) classified the implementation of green shipping practices into six components： company policies and procedures, shipping documentation, shipping equipment, shipper cooperation, shipping materials, and shipping design and compliance. Therefore, many factors should be considered to improve LSPs' CSR practices. In this research, the researchers have employed Chen, Delmas' (2011) CSR framework which focus on the Kinder, Lydenberg, and Domini Inc. (KLD) database, the construct includes three dimensions: environment performance, social performance and corporate governance that provide a comprehensive information source for CSR performance research (Domini, 2019).

According to IEA report 2016, Transport's share of global energy-related CO_2 emissions is 23% and it has increased by 2.5% annually between 2010 and 2015. In adition, the 2014 Environmental Performance Index ranked Vietnam 170 out of 178 countries for air quality, thus including Vietnam among the 10 worst countries for air pollution (UNDP, 2015). Although environment dimesion is not included in the early CSR definitions, but when making an indepth analysis, environment and social should be considered as the same essential elements to measure the CSR performance(Dahlsrud, 2008). In the Southeast Asian countries, CO2 emission is an important factor for shipper when choosing forwarders/carriers because those shippers are national or government-linked companies and they need to adhere to their government's environmental policies (Chang and Thai, 2017). In addition, they also encounter the pressure from consumers who demonstrate a growing ecological awareness or even environment protection pressure from regulatory authorities (Dominica and Monika, 2014). CSR towards the environment was measured by not only practicing and controlling external demand for protecting environment, but also a very simple and easy internal demand to implement CSR practice to encourage environment-friendly activities inside the offices (Dominica, Monika, 2014). These activities include the reduction of negative environmental impact by adopting green logistics, recycling packing materials (Su and Yong, 2017), using environmental-friendly materials and equipment and using environmental –friendly shipbuilding designs (Yuan et al. 2017).

Su and Yong (2017) revealed that logistics firms should remember that stakeholders are the important targets for the adoption and promotions of CSR practices. Thus, both external stakeholders' and internal employees' rights should be equally respected and treated fairly. Corporate social responsibility has a positive direct effect on customer satisfaction because of the rising demand on a company's fulfillment of its moral and social obligations from customer (Yuen et al., 2016) When the firm's CSR performance is improved, the employees' motivation is also improved at the same time and finally it will positively effect to their work performance (Su and Yong, 2017). Social activities like charity, support education, social contributions, and volunteering have helped the company increase its reputation, competitiveness and positive perception in community (Carroll, 1979; Su and Yong, 2017; Dominica and Monika, 2014; Chen and Delmas, 2011). Those activities are not mandatory requirements, they are optional activities depended on the corporate strategic decisions and are called expectation responsibilities (Carroll, 1979).

The implementation of CSR is not only related to social or environment problem, but also the direct expression of the whole production process and business activities of corporation. CSR in developing countries should consider corporate governance as a priority element because it can control and improve all of criteria in the other two dimensions. Therefore, more transparent and ethical governance implementation should be employed to create the underlying basic of CSR practices in developing countries (Visser, 2008). Managing social responsibility inside a company is fairly difficult. CSR should be comprised in the organizational structure, and it must be practiced, supervised and verified regularly (Dominica and Monika, 2014).

Reviewing CSRliterature, this research has synthesize a table including criteria and dimensions of the freight forwarders' CSR measurements and relevant criteria as below:

Table 1. The freight forwarding industry CSR dimension and respectively items

<table>
<tr><th>Dimension</th><th>Criteria</th><th>Explaination</th><th>References</th></tr>
<tr><td rowspan="5">Environmental performance</td><td>Protect ecological quality</td><td>Projects focused on conserving the natural resources e.g : planting trees</td><td>Dominica, Monika, 2014; Dahlsrud, 2008.</td></tr>
<tr><td>Clean energy and materials</td><td>Using clean and low-sulphur fuels for company equipment, and environmentally friendly material in packaging process (if any)</td><td>Lai et al, 2013a, Yuen et al, 2018</td></tr>
<tr><td>Design compliance</td><td>Keeping optimal office temperature control, and installing corridor and stairway lamps with movement sensors</td><td>Dominica, Monika, 2014; Lai et al, 2013a; Yuen et al. 2018</td></tr>
<tr><td>Recycling</td><td>Waste segregation, and print on both side of a paper sheet.</td><td>Dominica, Monika, 2014</td></tr>
<tr><td>Pollution Prevention</td><td>Minimizing negative impact to environment through greater load capacity, and better route planning or changes in the means of transport to save fuel consumption, and reduce transport emission</td><td>Su, Yong, 2017; Dominica, Monika, 2014,</td></tr>
<tr><td rowspan="5">Social performance</td><td>Protection of labor</td><td>Providing a good and safe working condition, practicing equal employment opportunities, respecting the diversity and human rights of employees</td><td>Carroll,1979; Su, Yong, 2017; Dahlsrud, 2008; Karaman, Akman; 2017</td></tr>
<tr><td>Anti-corruption</td><td>To detect, investigate and prosecute and raise awareness of corruption.</td><td>Carroll, 1979; Joseph et al. 2016</td></tr>
<tr><td>Voluntary group participation & community protection</td><td>Participating in community development, actively conducts philanthropic activities and contribute to local community development.</td><td>Carroll, 1979; Su, Yong, 2017; Dominica, Monika, 2014; Dahlsrud, 2008</td></tr>
<tr><td>Support education</td><td>Improving extra-curricular activities to develop the next generation's skills (including soft-skill and advanced skills), offer free internship and educational scholarship, and spending time to training new staff.</td><td>Dominica, Monika, 2014; Yuen at el. 2018</td></tr>
<tr><td>Charity</td><td>Donating money and supporting resources to charitable organizations</td><td>Su, Yong, 2017; Chen, Delmas, 2011; Yuen at el. 2018</td></tr>
</table>

(Continued) Table 1. The freight forwarding industry CSR dimension and respectively items

Corporate governance	Good corporate governance	Good system of rules, practices and processes which a firm is directed and controlled	Su, Yong, 2017; Visser, 2007
	Morality	Complying with the tax laws and regulations in all operating. Does not use unfair methods when competing with other companies.	Carroll , 1979; Su, Yong, 2017; Visser, 2008
	Stakeholder relationship	Makes the effort to mutually cooperate with partners, responds promptly and fairly to stakeholder's disputes without undue cost or burden.	Su, Yong, 2017; Lai et al, 2013b; Fafaliou et al. 2006
	Customer feedback procedures	Having a system that captures and handles customers' feedback and complaints	Yuen et al. 2018
	Transparency	Providing full transparency of company activities, structure, financial situation, and performance to the public	Su, Yong, 2017; Yuen et al. 2018; Visser, 2008

3. Research methodology

AHP technique is known as the most popular practical and accepted method in multi-criteria decision-making (MCDM) (Mardani et al., 2015), which is initially proposed by Saaty (1977) to pairwisely compare factors in the same level of a hierarchic structure based on ratio scales to select the best alternative among a set of specified criteria (both qualitative and quantitative criteria) (Lirn et al., 2018).

The advantages of AHP to the user includes the easy accessibility to get judgment data and the small number of sample required to carry out the analysis, however it must be conducted by the person who has deep knowledge about the research field (Shin and Pak, 2016). The AHP also has ability to adjust inconsistencies in judgments and perceptions(Mani et al., 2014). The simple step-by step procedure and the supporting of user-friendly commercial software like Expert Choice, Decision Lens, Hipre 3+, Right choice DSS, Criterium, Easymind, Questfox, ChoiceResults, AHPProject, 123AHP, etc. to make the analysis process conduct more effectively and precisely (Tyagi and Kumar, 2015; Mani et al., 2014; Ishizaka and Labib, 2011).

AHP definitely cannot replace the thinking of the decision-maker. However, it can support manager in making decision process by organizing their thoughts and considering all of the factors involved in a complex decision, and helping the manager prioritize alternative choices and evaluating criteria (Handfield et al., 2002). The application of AHP is perceived as a decision making tool that expands a lengthy period (Omkarprasad and Sushil, 2006). Many applications of AHP have been discussed in previous researches related to selecting a best alternative, resource allocations, resolving conflict, optimization etc. (Vaidya and Kumar, 2006). The AHP is also used in many different research fields like economic, education, commerce, manufacturing, finance, engineering, military, environment and agriculture (Zavadskas and Turskis, 2011).

For this CSR research, firstly, relevant literatures in transportation industry analyzed by the AHP technique are reviewed. In a research by Mardani et al. (2015), they ranked AHP as the first method that is most frequently used MCDM technique in transportation management, and 23 academic research papers are found to employ the AHP and Fuzzy, and the AHP technique to evaluate service quality and transportation performance. Sipahi and Timor (2010) presented that AHP is utilized in transport industry in some papers for improving ship registry (Kandakoglu, et al., 2009), passenger security in airport (Yoo and, Choi, 2006), port security (Tsai and Su, 2005), and transportation investment (Tudela et al., 2006). The AHP technique was also adopted by Karaman and Akman (2017) to assess and weigh of criteria and performances of multiple alternatives in the CSR program for the Turkish airline industry, the result has shown that economic factor is ranked as the most important CSR factor and then followed by environment, and social factors respectively. Shin and Pak (2016) identify the key factors influencing a successful purchasing negotiation for Korea freight forwarders by adopting the AHP technique, and they found that AHP is the most useful method to solve those complex problems involving human negotiation.

Second, relevant to CSR issues, the AHP approach is also employed in many previous CSR researches. According to Stankova (2014), the AHP technique could be used in evaluating and measuring the degree of importance for various factors influencing a company's CSR performance. Stankova also has summarized factors in the environmental, economic, and social dimensions in his research as CSR assessment criteria for banking organizations in Czech Republic. Indre(2016) and ISAPH(2018) used AHP to set the weights of each criteria and to form the final CSR complex evaluation system in commercial bank industry.

In the analysis of Xu et al. (2013), the degree of importance of the main criteria and sub-criteria are identified by AHP method in selecting supplier base on the Southern region of India companies' CSR performance, they found that the decreasing degree of importance for the following seven criteria: organizational legal responsibility, pollution, human rights, under age labor, long working hour, safeguarding mechanisms in CSR, and feminist labor issues. Kheiri et al. (2015) have employed the AHP and fuzzy TOPSIS techniques in measuring and ranking the CSR practices which should include economic, social and environmental factors in the five star hotels in Tehran. The result obtained with AHP technque has indicated that economic is ranked as the most important dimension and followed by environment, social dimensions respectively. Lakshmi and Visalakshmi (2015) used SEM model to investigate the major dimensions and factors influencing a company's CSR performance for Indian manufacturers, and the AHP technique is applied to rank degree of importance for each criterion related CSR initiatives. They found that automobile industry perceived customer and environment criteria have high degree of importance whereas the cement industry perceived employee and community criteria have great degree of importance to their CSR performance.

From above-mentioned AHP applications literature reviews, it is obvious that there are many researchers applied AHP in their study as it is an effective method to solve complex problems related to transportation industry and CSR issues. CSR is considered as a complex problem with multiple criteria and the lack of standard indicators in dealing with CSR performance evaluation (Shiau, 2013). In addition, with the limitation about geography and time, AHP technique is perceived to be an ideal method to carry out this research because it requires only a smaller number of participants. Thus, the AHP method was employed in this research. It is not only the most popular MCDM tool but also its applications can meet the research requirements, particularly AHP technique can be employed to identify those critical criteria for freight forwarding companies to focus on when they want to implement CSR activities in their organization. It will not only ameliorate freight forwarders' CSR performance systematically and become a guideline for other related industry to improve their CSR performance effectively.

The research methodology procedure is organized as follow steps:

Step 1: Select the criteria influencing CSR performance reported in previous literatures

Step 2: Pairwise comparing the degree of importance of the reported criteria according to the experts' judgments. Saaty's scale is used to decide this relative degree of importance for various dimensions and criteria.

Step 3: Checking the separate consistency result of each respondent with the supporting of Expert Choice software

If the Consistency Index (CI) <0.1, then the result is acceptable. If not, the respondent would be asked to reconsider and revise their judgment until achieving the final reasonable consistency index.

Step 4: Identifying local weights and global weights for each of the investigated criteria. Base on the result, highlight and put more resources in the top three important criteria influencing freight forwarders' CSR performance .

After a survey period for two months, the questionnaire were sent from the beginning of November to the end of December in 2018. Snowballing sampling technique is used. Thus, the research team members have recruited potential respondents for a study through their personal newtworking. A total of 32 respondents from ocean freight forwarders and manufacturererss who are using forwarder services in Vietnam have responded, and 31 copies of the responses are have completed all the quesitons.

Table 2: Overall weights and ranking of CSR sub-criteria

Criteria	Sub-criteria	Local weight	Local Ranking	Global weight	Global Ranking
Environmental performance (0.383)	Protect ecological quality	0.144	4	0.055	9
	Clean energy and materials	0.243	2	0.093	3
	Design compliance	0.135	5	0.052	10
	Recycling	0.204	3	0.078	4
	Pollution Prevention	0.274	1	0.105	2
Social performance (0.326)	Protecting labor	0.359	1	0.117	1
	Anti-corruption	0.152	3	0.049	11
	Voluntary group participation & community protection	0.146	4	0.048	13
	Supporting education	0.218	2	0.071	6
	Charity	0.124	5	0.040	14
Corporate governance (0.292)	Good corporate governance	0.167	4	0.049	12
	Morality	0.243	2	0.071	7
	Stakeholder relationship	0.104	5	0.030	15
	Customer feedback procedures	0.256	1	0.075	5
	Transparency	0.231	3	0.067	8

Note: Community Protection is a unique service, set up to tackle antisocial behaviour (ASB) and environmental crime in urban areas.

4. Research Finding

The primary research findings are shown as table 2, both Vietnamese forwarder and shipper all aggreed that environment criterion should be more emphasized when company conduct CSR activities, which has the highest degree of weight (0.383), folowed by social criterion(0.326) and then corporate governance are perceived as the least important criterion with a smaller weight (0.292).

All the sub-criteria under the environment criteria are listed from largest to smallest in term of their relative degree of importance: pollution prevention, clean energy and materials, recycling, ecological quality protection, and design compliance. Similarly, the order of five sub-criteria under the social performance criteria are listed as follows: protecting labor, supporting education, anti-corruption, voluntary group participation & community protection, and charity. There are five subcriteria under the corporate gorvernace criteria, customer feedback procedures subcriteria has the greatest weight and followed by morality, transparency, good corporate governance, and stakeholder relationship has the least degree of importance either from local weight's or global weight's perspective.

Ultimately, among all of the 15 CSR evaluation sub-criteria, this result showed that protection of labor is perceived to have the highest degree of importance(0.115), followed by pollution prevention (0.104), and clean energy and materials (0.091). Those three sub-criteria are the top three important issues that the LSPs' managers should input more resources when they intend to implement CSR in their organization effectively.

In the light of shippers' viewpoint, the top three important CSR sub-criteria are the same as the overall surveyees' jugdment with a slight ranking difference. The shipprers perceive that the polution prevention subcriterion should be the most important CSR subcriterion, followed by the protection of labor, and clean energy and material subcrieria. From the forwarders' perceptive, the protection of labor is the most important CSR subcriteria. Secondarily, extended education to teach employees the CSR practices must be supported in the forwarding companies to improve their CSR image. Finally, morality subcriterion is found to have the third highest degree of importance .

5. Conclusion

With the popularity of CSR trend in the modern business environment as well as the LSPs stakeholders' requirement, implementing CSR practices in Vietnamese forwarding industry became a necessity. By considering three criteria and 15 sub-criteria, the research showed that environment criterion is emphasized and has the highest level of importance in light of the polution in Vietnam constanly deteriorated post its launching a series of economic and political reforms since 1986. The research also found out the top three important CSR sub-criteria: protection of labor, pollution prevention, and clean energy and materials as well could all be employed to help small and medium-size Vietnamese freight forwarding companies to effectively improve their CSR practices as these companies have very limited resources (such as capital, labor force, and facility) to implement CSR practices comprehensively. This result also could be an implication for the large-size forwarders to invest more on high important issues or even reduce the amount of resources invested in less important criteria and subcriteria. LSPs managers could also consider the perception differences between forwarders and shippers before they decide their CSR strategy according to their aims and business plans. The research findings are not only useful for forwarders, the gorverment agencies and non-profit oriented organizations can also outlined their strategies to encourage Vietnamese forwarders to carry out their CSR activities in an adequate way by promoting some rewards, cerifications for company that excellently complete indices of each criterion in a period of time. In addition, this research also provides a literature for future research when they intend to study CSR issues in this industry or even other related industries in other countries.

This research actually contains some limitations. First, because CSR is a concept that related to many stakeholders, so that this study only considers forwader employees and its shippers perspective whereas other stakeholder perception like shareholders, society community, regulators, who likely has different judgement in CSR issues, have not included in the survey. Second, because of limited number of researches related to CSR in forwarding industry, so this research hierarchy is built by reviewing previous relevant literatures reported in the other transportation industries (e.g. airlines industry, shipping line industry, port industry, etc.). It certainly influences the respondents' judgment and consequently have great impacts to the final research results. Future researches could include a larger- amount of potential respondents to overcome this limitation and constraints..

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The Effects of the Employee's Perceived Safety Behavior in Ferry Services

Rhaptyalyani Herno Della[1], *Taih-Cherng Lirn*[1], *and Kuo-Chung Shang*[2]

[1] Department of Shipping and Transportation Management, National Taiwan Ocean University, Taiwan
[2] Department of Transportation Science, National Taiwan Ocean University, Taiwan
Email: tedlirn@email.ntou.edu.tw

Abstract

This paper evaluates the effect influence of safety behavior with safety training, safety knowledge, and safety management at ferry services in Indonesia. Data was collected from the questionnaire by workers of ferry services from ten companies in Indonesia, which total of 469 valid questionnaires are used for this analysis. Exploratory factor analysis identified factors of safety management as safety communication, safety leadership, and safety commitment. Further explanation using confirmatory factor analysis and structural equation modeling to examine the effects of safety training, safety knowledge, and safety management on safety behavior. Study finding that safety training has positive effects on employees safety behavior. Yet, no significant effect between safety knowledge and safety management to employees safety behavior.

Keywords: ferry services, safety behavior, safety training, safety knowledge, safety management

1. Introduction

Indonesia as an archipelago consists of thousands of islands with sea area above 96,079.15 km causing Indonesia as the largest archipelagic country in the world. It's having coastline around 81,000 km and sea area around 70% of Indonesia's total area. It put up sea transportation mode become so important for mobility. Transportation is the lifeblood of the economy of the people and the nation of Indonesia. The development activities of transportation in Indonesia will impact economic activity and social-cultural and community activities. Therefore, integration inter-island transportation network to serve the needs of the community in order to improve regional growth and equitable development become the challenge of Indonesia. To accommodate mobility in sea and waterways in Indonesia, one of mode that used is ferry. Based on data of Indonesia Ministry of Transportation 2018, Indonesia has 294 ferry trajectories which divided become two; pioneer 229 trajectories and commercial 65 trajectories.

Ferry as one of the most used transportation in Indonesia influences with safety factors. Likely other modes, ferry safety involve service user and service provider, where is service user as passengers and service provider as ferry company. Ferry companies must organize their safety issues to provide good service quality for passengers. Over 14 year period from 2000 to 2014, Indonesia has the second most with 17% proportion from 43 countries ferry accident (Golden and Weisbrod, 2016) and in mid of 2015, worldwide ferry safety association renewing data become 13% in the same rank after Bangladesh. Mapping of vessel accident characteristic in Indonesia from 2007 to 2014 shows that passengers vessel have the highest rank depend in accidents than others vessel, about 43.90% accident happen to ferry as passengers vessel (Hasugian et al., 2017). As mention of Indonesia national transportation safety committee (KNKT) report, human error was the most cause of ferry accident in Indonesia ("Komite Nasional Keselamatan Transportasi," n.d.).

Other more, previous studies said that vessel and craft accident attributed by human errors (Atak and Kingma, 2011; Lu and Tsai, 2010; Lu and Tseng, 2012; Lu and Yang, 2011; Zohar, 1980). Lu and Yang (2011) in their research about safety climate passengers ferry said that safety training has positive effects on safety behavior.

2. Research Hypothesis

2.1 Safety Behavior

Safety behavior is a behavior of individual interest in an effort to minimize or prevent fear of an accident. The behavioral aspects of safety culture can be examined through peer observation, self-reporting actions and/or outcome measures (Cooper, 2000). The concept of safety behavior is a systematic application of psychological research on human behavior in terms of safety at work. Safety behavior places more emphasis on aspects of human behavior towards accidents at work. Safety behavior of employees are feedback from employees to management for the safety efforts given by the company (Zhou and Jiang, 2015) and safety behavior tough by the knowledge, abilities, and the motivation of individuals to carry out these behaviors (Griffin and Neal, 2000). Thus, safety behavior can be interpreted as the actions of individuals to the standard operational procedures of the company to prevent work accident yet brew comfortable and save to obey the safety company rules.

2.2 Safety Knowledge

Safety behavior is determined by safety knowledge and abilities for certain behaviors (Griffin and Neal, 2000) and safety knowledge will help motivated individuals to carry out these behaviors in their environment. Therefore also, Neal and Griffin (2002) dish up that safety knowledge demonstrated safety behavior in their model. Accordingly, this study hypothesizes that:

Hypothesis 1 (H1): Safety knowledge have positive affect on safety behavior

Hence, the Advisory Committee on the Safety of Nuclear Installations (ACSNI, 1993) in (Choudhry et al., 2007) mention that knowledge, attitudes perceptions, competencies and behavior determine the safety management.

2.3 Safety Management

Safety management relates to actual practices, roles, and functions related to safety (Lu and Tsai, 2010) and should be considered as assessment function for safety outcomes (Lu and Tsai, 2010; Mearns et al., 1998). Choudhry et al. (2007) develop an integrative model for safety culture from (Cooper, 2000), wherein the model show that the safety management system has relationship with safety behavior. This relationship becomes the external observable factor in measurement. Accordingly based on thus, hypothesize that:

Hypothesis 2 (H2): Management system will have positive related to safety behavior

2.4 Safety Training

Lu and Yang (2011) studied about safety training that has positively affect self-reported safety behaviors. In order for employees to do their jobs correctly and become active participants in safety programs, they must receive work safety training, such training is a process where lack of skills or knowledge that might have an impact on safety is fulfilled by providing information and helping individuals in practice who supports the skills needed to carry out activities safely (Lu and Yang, 2011). Cooper (2000) mention that one of the composite outcomes that measure behavior in safety is safety training. Lu and Yang (2011) state that ferry companies must institutionalize a system for education and training continuously for their employees. Thus who have well-trained will have more about knowledge in safety which will take effect on behavior and management system in safety. Then, this study hypothesizes that:

Hypothesis 3 (H3): Safety training have positive affect on safety behavior
Hypothesis 4 (H4): Safety training have positive affect on safety knowledge
Hypothesis 5 (H5): Safety training have positive impact on safety management

2.5 Technology and Safety Procedures

Geller (2000) and Cooper (2000) present the model for safety culture which divided into two dimensions; behavior and person. The behavior dimension is shown that observable object is technology, training, and procedures. Otherwise, Reniers (2010) also shows the interactions between technology, procedures, and training to the people behavior. Then also, when employees are well trained regarding safety precautions, regulations and procedures, their safety performance increases (DeJoy et al., 2004; Lu and Yang, 2011; Zohar, 2000) instead of their behavior (Lu and Yang, 2011).

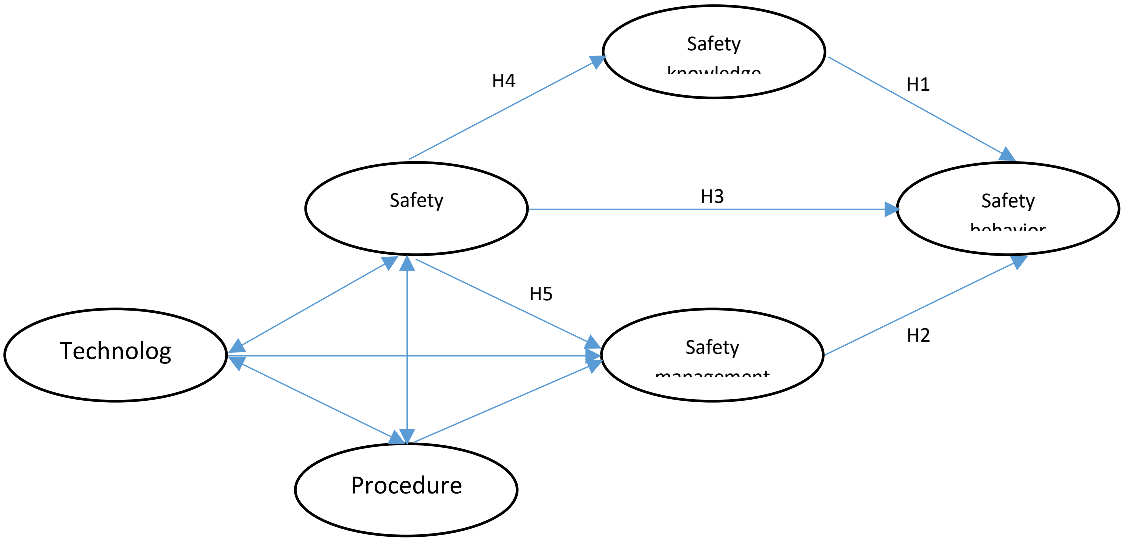

Figure 2: Research Framework

3. Methodology

The participants of this research were 494 ferry staff including management staff and operational staff from 14 ferry companies in Indonesia. Sampling is select by choosing a random regional location based on; commercial ferry number of services, population, and region. Merak port and Bakauheni port are selected because on criteria as:

1. Number of services; as the mention of Indonesia Transportation Statistic Data 2016, ferry commercial track between Merak port and Bakauheni port have the highest production of passengers than others; it's about 18,680,570 people/year or above 28.69% from the total of commercial ferry passengers in Indonesia.
2. Population; Merak port is the nearest port with the capital city of Indonesia, its located in West Java Province. Central Agency on Statistic of Indonesia mentions that West Java Province since 2010 until 2016 as the highest population province in Indonesia, 47,379.4 thousand people or similar with 18.31% from population of Indonesia.
3. Region; commercial ferry track between Merak port and Bakauheni port is the main track, as the connection between two major islands in Indonesia which are Java Island and Sumatera Island. These two islands are the major island with the highest population density.

Questionnaires are collected by survey coordinator to ensure the privacy and confidently of participants. There is no wrong and the right answer for this questionnaire, the respondents answer about them most suitable perceptions of the questions. After receiving the completed questionnaires from participants, the next step was the process to remove incomplete or invalid data. The exclusion criteria used were similar to (Chen et al., 2011) the following are: (1) no entire section completed; (2) fewer than half the items answered; or (3) all items

answered the same. After removing incomplete questionnaires, 469 respondents had completed the questionnaire from ten ferry companies in Indonesia, which mean 94.94% was reached.
The purpose of this study is to examine the hypotheses; there are linkages between safety training, safety knowledge, safety management, and safety behavior. Method for testing hypotheses using the analysis of structural equation modeling (SEM). SEM has been used in every field of research study (Hair et al., 1998). Exploratory factor analysis (EFA) will use first to identify factors of safety management using. EFA aims to find the related factors influence safety management as one of the constructs. Furthermore, confirmatory factor analysis (CFA) will be used to assess model validity, show the constructs reflection their variables and develop overall measurement model. The statistical analysis software; SPSS 23.0 and AMOS 23.0 are used to develop the model analysis.

4. Result and Discussion

4.1 Demographic Statistics

Analyzing descriptive data are provided after collecting data which are shown in table 1. From 469 respondent data, characteristic data show 88.91% of ferry employees are male, and 11.09% are female. This significant with job position data where operational staff (technical staff, terminal operation staff, captain, vessel crew, and ship attendant) above 71.65% and managerial staff (manager/head offices, human resources staff, and finance staff) about 24.95%. Related to the age, more than half about 62.69% of employees in productive age between 26 and 40 years old, while 29.21% are between 41 and 55 years old, 6.82% of data with age younger than 25 and 1.28% are over 56 years old.

Regarding their education, only 0.85% have master degree which is the respondents from manager/head offices position, more of respondents obtain diploma and bachelor degree which is about 38.38% and 36.67%, others about 24.09% obtain senior high school. Most respondents have length of work in the company for more than five years, with less than ten years about 41.58% and less than 25 years about 44.78%. Other respondents with the same number about 1.71% are less than one years and more than 25 years. About 36.03% of respondents stay in their current position level more than five years, about 34.54% stay in their position level between 2.5 until five years, about 23.67% respondents stay in their position level between 1 until 2.5 years, and 5.76% stay in their position level less than one year.

Table 2: Demographic characteristics data

Attributes	Sample number	Frequency (%)	Cumulative (%)
Gender			
Male	417	88.91	88.91
Female	52	11.09	100.00
Age			
Less than 17	3	0.64	0.64
17-25	29	6.18	6.82
26-40	294	62.69	69.51
41-55	137	29.21	98.72
56 and over	6	1.28	100.00
Job Position			
Manager/Head Offices	9	1.92	1.92
Human Resources Staff	44	9.38	11.30
Technical Staff	98	20.90	32.20
Finance Staff	64	13.65	45.84
Terminal Operasional Staff	99	21.11	66.95
Captain	5	1.07	68.02
Vessel Crew	117	24.95	92.96
Ship Attendant	17	3.62	96.59
Others	16	3.41	100.00
Education			

(Continued) Table 2: Demographic characteristics data

Attributes	Sample number	Frequency (%)	Cumulative (%)
Elementary/Junior high school	0	0.00	0.00
Senior high school	113	24.09	24.09
Diploma	180	38.38	62.47
Bachelor	172	36.67	99.15
Master	4	0.85	100.00
Doctor	0	0.00	100.00
Others	0	0.00	100.00
Length of work in company		0.00	0.00
Less than 1 year	8	1.71	1.71
1 - 5 years	48	10.23	11.94
6 - 10 years	195	41.58	53.52
11 - 25 years	210	44.78	98.29
26 - 50 years	8	1.71	100.00
Length of work in this position			
Less than 6 months	6	1.28	1.28
6 months - 1 years	21	4.48	5.76
1 - 2.5 years	111	23.67	29.42
2.5 years - 5 years	162	34.54	63.97
More than 5 years	169	36.03	100.00
Total Employees Data	**469**		

4.2 Exploratory Factor Analysis

EFA analysis is used to identify dimensions in safety management. Twenty-one relevant questions are designed from literature review. EFA used to screening of relevant and dominant variables from the 21 questions, and grouping the variable components based on priority. Firstly, Kaiser-Meyer-Olkin (KMO) are conducted to examine sampling goodness of fit. KMO is a comparison index of the distance between the correlation coefficients and their partial correlation coefficients, if the sum of the squares of the partial correlation coefficient between all pairs of variables is small if compared to the sum of the squares of the correlation coefficient, then KMO value is close to 1 (Hair et al., 1998). KMO value is considered sufficient if factors are loading more than 0.5 and indicate fit data if factors loading greater than 0.8. After KMO analysis, measures the sampling adequacy (MSA) are conducted and show that nine question not required which have communalities number less than 0.5. After deleted nine questions, KMO analysis was conducted again and have proper factors loading more than 0.8 with number 0.885.

Further, factor named with variables is provided after factor analysis (Hair et al., 1998). Three factors are categorized with each factors Cronbach α larger than 0.5 as seen in table 2. Every factors contain four questions item as follows.

Factor 1: Safety communication
Four questions item related to this factors, which are “I am comfortable asking for guidance”, “My company encourages open communication about safety”, “I am freely reporting all unsafe acts or conditions”, and “My company openly accepts ideas for improving safety”. These factors have mean 4.099 and factors loading between 0.534 to 0.713. The eigenvalue is 4.752 with variance explained 39.599%. The four questions item related to safety communication and named same as it; “safety communication”.

Factor 2: Safety leadership
Alike factor 1, this factor 2 have four questions item related, which are “My supervisor demonstrates leadership by keeping people focused on safety”, “My supervisor strictly enforces the safe working procedures in my workgroup”, “My supervisor takes a proactive stance when it comes to safety”, and “My supervisor takes the lead on safety issues”. These factors have mean 4.185, and standard deviation is 0.639. Factors loading between

0.415 to 0.791 and eigenvalues 1.143. The explanatory variance is 9.527% with cumulative 49.127. Most of the questions item related to leadership, therefore this factors named "safety leadership".

Factor 3: Safety commitment
Similarly like other factors, these factors related to four questions item also, which are "Our management provides enough safety programs", "Our management gives the power to do safety in my job", "Our management provides safety equipment", and "After an accident, our management focuses on how to solve problems and improve safety rather than pinning the blame on specific individuals". These factors have mean 4.163 and standard deviation 0.864. Factors loading between 0.678 to 0.867 and eigenvalues 1.098. The explanatory variance is 9.152% with cumulative 58.279%. All the questions item related to management commitment in safety at work, therefore this factors named "safety commitment".

Table 3: Factor analysis of safety management

Item	Factor		
	1	2	3
I am comfortable asking for guidance	.713		
My company encourages open communication about safety	.665		
I am freely reporting all unsafe acts or conditions	.664		
My company openly accepts ideas for improving safety	.534		
My supervisor demonstrates leadership by keeping people focused on safety		.791	
My supervisor strictly enforces the safe working procedures in my workgroup		.772	
My supervisor takes a proactive stance when it comes to safety		.736	
My supervisor takes the lead on safety issues		.415	
Our management provides enough safety programs			.867
Our management gives the power to do safety in my job			.749
Our management provides safety equipment			.695
After an accident, our management focuses on how to solve problems and improve safety rather than pinning the blame on specific individuals			.678
Mean	4.099	4.185	4.163
Standard deviation	0.660	0.639	0.864
Eigenvalues	4.752	1.143	1.098
Variance explained%	39.599	9.527	9.152
Cumulative variance explained%	39.599	49.127	58.279
Cronbach α	0.726	0.536	0.751

4.3 Confirmatory Factor Analysis

Confirmatory Factor Analysis (CFA) was conducted to verify the constructs of the model, which are safety training, safety knowledge, safety management, and safety behavior, also two constructs; technology and procedures that involved with safety training and safety management. CFA was used to tests uni-dimensionality, convergent validity, and divergent validity. The aim of the CFA is to confirm or test the model. This validity test conducted to test the correctness of indicators that have been determined in contributing to the factors. Twenty-nine observed variables and twelve latent variables are considered for measuring the model. The observed variables are four variables (T1-T4) from safety training, three variables (K1-K3) from safety knowledge, and four variables (B1-B4) from safety behavior, also with eight variables from technology (P1-P4) and procedures (P5-P7) as shown in appendix A. Otherwise, twelve latent variables for safety management, namely safety communication, safety leadership, and safety commitment.

CFA is used to test the goodness of fit index for the model as shown in figure 1. The variables on the model have to fit with the indicators criteria (Hair et al., 1998) as shown in table 4. From the analysis showed that χ^2/df = 2.31, goodness of fit index (GFI) value 0.92, comparative fit index (CFI) value 0.94, root mean square error of approximation (RMSEA) value 0.05, adjusted goodness of fit index (AGFI) value 0.90, Tucker-Lewis index (TLI) value 0.94 and normed fit index (NFI) value 0.91. The results show that this model generated an acceptable fit level because all indicators from the analysis of the model meet the requirements.

Table 4: Goodness of fit index for the model

Goodness of fit index	Criteria	Results
χ^2 (chi-square)	-	460.20
χ^2/df	≤ 5	2.31
GFI	≥ 0.90	0.92
CFI	≥ 0.90	0.94
RMSEA	≤ 0.08	0.05
AGFI	≥ 0.90	0.90
TLI	≥ 0.90	0.94
NFI	≥ 0.90	0.91

Note: GFI: goodness of fit index; CFI: comparative fit index; RMSEA: root mean square error of approximation; AGFI: adjusted goodness of fit index; TLI: Tucker-Lewis index; NFI: normed fit index.

CFA using construct validity are provided to show the variance proportion of constructs. Construct validity refers to the extent to which a measure adequately represents the underlying construct that it is supposed to measure (Bhattacherjee, 2012). Moreover, Hair et al. (1998) explain that construct validity provides evidence that a factor is unique and captures several phenomena that are not performed by other actions. The construct validity is fit with the requirement if loading factors in standardize loading estimate more than 0.5 (Hair et al., 1998). Based on the analysis, show that loading factors in this model have values more than 0.6. Therefore the results of loading factors meet the requirement. Furthermore, according to Hair et al. (1998), the average variance-extracted (AVE) acceptable for values at least 3.0. As shown in table 5, the AVE values for construct higher than the minimum of acceptable values for AVE, which the result values from analysis have minimum values in safety knowledge construct about 0.470 and other constructs have values more than that.

Over more, construct reliability for each construct also assessed. According to Hair et al. (1998), the critical ratio (CR) value have requirement more than 1.96 with probability (P) more than 0.05. The results reflect that

CR of the constructs are meet the requirements which all CR values more than 1.96 as shown in table 5 and have probability values significant for all constructs.

Table 5: Composite reliability and average variance extracted values

Dimension	Composite Reliability[a]	Average Variance Exctracted[b]
Technology	0.823	0.483
Procedure	0.770	0.527
Safety training	0.786	0.479
Safety management	0.757	0.512
Safety knowledge	0.726	0.470
Safety behavior	0.764	0.448

Note: [a] Construct reliability = (sum of standardized loadings)^2 / [(sum of standardized loading)^2 + (sum of indicator measurement error)], [b] Average variance extracted (AVE) = (sum of squared standardized loadings) / [(sum of squared standardized loadings) / (sum of squared standardized loadings) + (sum of indicator measurement error)]. Indicator measurement error can be calculated as 1 – (standardized loading)^2

4.4 Hypothesis Results

Critical Ratio (CR) is a t-value obtained of the statistic form by dividing an estimate the standard error (Hair et al., 1998). According to Hair et al. (1998), CR values exceeding 1.96 and highest exemplary significant. The significant value of CR 1.96 will represent the estimated value at the level of 0.05, whereas if above 2.56 it will be significant at the level of 0.001. The structure result is shown in figure 2. The relationship between safety training and safety behavior have the highest CR value among all relationship with 11.593. Other relationship with safety training which safety management and safety knowledge are, have significant CR value as well with value 8.237 and 2.051. The relationship between safety training and safety management have significant at level receding 0.001, other more, the relationship between safety training and safety knowledge only have significant level 0.04 yet still significant because of less than 0.05.

Otherwise, the relationship between safety knowledge and safety behavior have the lowest CR value and have an insignificant level with CR value -0.510 in significant level 0.610. Similar to the relationship between safety knowledge and safety behavior, the relationship between safety management and safety behavior have insignificant value as well, with CR value -1.461 in significant level 0.144. So, from that results indicated positive relationship only between safety training to safety behavior, safety knowledge, and safety management (H3, H4, H5). Other else hypothesis (H1, H2) presented not significant relationship between safety knowledge and safety management to safety behavior.
As shown in table 6, safety training construct has positive and direct effect on the constructs of safety knowledge, safety behavior, and safety management. The relationship between safety training construct and safety knowledge construct have standardized factor loading (λ) value 0.832 and unstandardized factor loading 0.636. Other relationship with safety training; safety behavior construct (λ=3.191) and safety management construct (λ=1.186) also have positive direct. Moreover, relationship with safety training has direct effect with value λ=0.85 for technology construct and λ=0.86 for procedure construct. However, safety knowledge construct has negative and indirect effect on safety behavior construct (λ=-0.056) as well as safety management construct,

and safety behavior constructs (λ=-2.237). Technology construct has direct effect on safety management with low value λ=0.005, otherwise procedure construct to safety management has indirect effect with λ=-0.224.

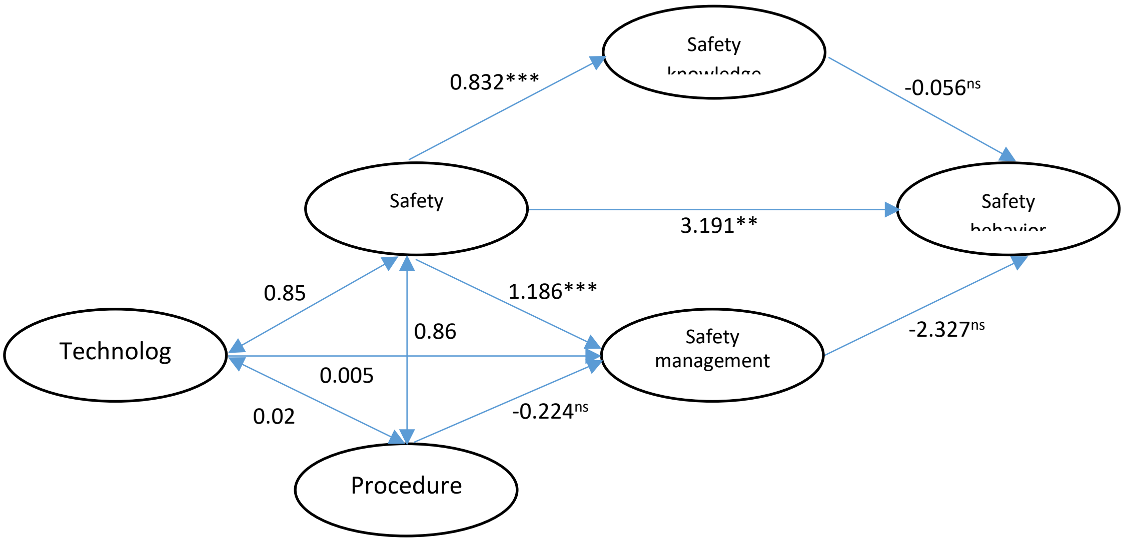

Figure 3: Proposed structured model result

Table 6: The results of structural equation modelling

Factor and scale items	Standardized factor loading	Unstandardized factor loading	Standard error (SE)	Critical ratio (CR)	P
Safety training → Safety knowledge	0.832	0.636	0.055	11.593	***
Safety training → Safety management	1.186	0.791	0.096	8.237	***
Safety training → Safety behavior	3.191	3.236	1.578	2.051	0.040**
Safety management → Safety behavior	-2.327	-3.537	2.421	-1.461	0.144
Safety knowledge → Safety behavior	-0.056	-0.075	0.146	-0.510	0.610

Note: ** P<0.05; *** P<0.001

5. Discussion and Summary

Safety is the staple for passengers ferry services whereas giving services to passenger and also pulse the safety of both passengers and employees in land and waters. Numbers of ferry accidents happen because of employees negligence ("Komite Nasional Keselamatan Transportasi," n.d.). Raise behavior in safety for employees expected to reduce the number of ferry accidents created by work accidents through training, insight, and managerial companies that are well followed by technology and decent safety procedures. This study aims to discuss the relationship between behaviors in safety inflict by safety training, safety knowledge, and safety management eke propped of technology and procedures in the ferry services. The seek of analyzing factors influencing ferry services safety by the employee's safety behavior based on survey in Indonesia as stated above. On the analysis, three factors in safety management are categorized, namely safety communication, safety leadership, and safety commitment. Based on the analysis of the influencing factors, the results find that safety training had a positive impact on safety behavior. This indicates that the results of training on occupational safety will greatly affect the employee's behavior to be safe in carrying out their work. Also, safety training also has a positive impact on safety knowledge and safety management. This indicates that safety training raises employees knowledge and also make the preferable ferry company's safety management. Yet from the results also was found that safety knowledge and safety management did not affect safety behavior, distinct with prior studies of Choudhry et al. (2007), Cooper (2000), Lu and Tsai (2010), Mearns et al. (1998). This issue can be related to Beseler and Stallones (2010) wherein their study alludes safety knowledge related to safety behaviors strongly personal consequences than with safety behaviors that protected the safety of others. Ferry services as the transportation provider for mass in helpful to treating and protect their passengers including their employees. Furthermore, based on this study, technology has a positive impact on safety training, safety management, and procedures, or conversely. The procedure also has a positive impact on safety training and technology but does not affect ferry companies safety management.

5.1 Implications of Study Finding

Even though this study contrary to expectations, this study revealed significant relationship by direct paths between safety training and safety behavior, then also safety training and safety knowledge. Over more indicates that components of safety training also have relationship with safety management. Furthermore, several implications can be drawn from the findings of this study. First, safety training has positive effect on safety behavior; this can obvious that training is very influential on the employee's safety behavior of ferry services. Behavior is the psychological phenomenon works which stimulus from others and training is the action of teaching type or particular behavior. Cause study finding training has a positive impact on employees to behave based on work safety, trough safety training, ferry services can provide professional mentoring in safety to influence safety behavior of ferry services staff to reduce unsafe behavior of ferry employees towards minimalize of accidents by human errors.

Moreover, from analysis also found that safety training has positive effect on safety knowledge, which indicated that training gains the knowledge of employees to apprehend safety. Second, the study findings indicated positive effect from technology and procedure to safety training. Technology and procedures as tools for safety behavior acquainted thru training. Therefore training on technology and procedures become a matter that can be thought material for ferry services stakeholders, to foster safe behavior for their employees. Third, the study indicated that safety training has relationship with safety management whereas consist of safety communication, safety leadership, and safety management commitment. This realizes that training has comprehensive impact on the management of safety as well as the behavior of ferry services employees. It is better to hold up training to hence the understanding of employees about management communication and management commitment enhance leadership on safety in ferry companies.

5.2 Limitations and Future Research

There are several limitations on this study. Almost sample adopted by survey got from self-reported data employees perceptions on safety behavior. The sample may have been subject to bias as respondents reluctance to express actual safety behavior because of potential personal repercussions then also avoiding lawsuit against them by managerial and company. Hence, future research could consider objective methods to measure by actual observation. Another limitation is due to the vast waters in Indonesia and lot of ferry companies, only several limits of ferry services can be reached in densely populated areas with the highest number of ferry services located in the western part of Indonesia. As the data Ministry Of Transportation Indonesia (2016), the eastern part of Indonesia has more ferry trajectories than western Indonesia and even so different as geographic. That's different will affect technology and procedures of safety moreover management. This study no offends ferry service in areas with less ferry service numbers in eastern Indonesia. Future research expected again explore ferry services location in Indonesia to pursue the study. Finally, this study gain lore important contrivance since Indonesia as a developing country. Known that as the largest maritime country with thousands of islands ferry is one of important transportation in Indonesia, yet deficient of ferry research. The findings expected hold valuable for ferry services whereas nethermost of research on ferry services safety factors (Lu and Tseng, 2012). Enhance that the discussion about safety will never recede. That are otherwise opening avenues to seek more research in ferry and safety field.

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The Impact of Mergers and Acquisitions on Profitability and Marketability of Major Airlines

Young-Tae Chang[1,*]*,and Suhyung Lee*[1]

[1] Graduate School of Logistics, Inha University, Incheon, Korea

[*]Corresponding Author

Abstract

Mergers and acquisitions (M&A) are considered one of the most important strategies in sustaining the global airline industry. In the aftermath of the global economic recession in 2008, the airline industry has been facing strong competition due to deteriorating market conditions. There have been 37 M&As since 2008. In 2008 alone, 10 M&As were signed. This study examines the impact of M&A on the profitability and marketability efficiency of 11 major international full-service carriers using a two-step approach. First, it measures profitability and marketability by applying a dynamic network data envelopment analysis (DEA) model. Next, it investigates the impact of M&A on the efficiencies. The results corroborate that M&A has a positive effect on marketability and overall efficiency but does not impact profitability. This implies that as a long-term approach, M&A are a survival strategy and help to attract more investments. This paper also reveals factors that increase marketability and provides managerial implications regarding the airline industry's business strategy.

Keywords: Airlines; Profitability; Marketability; Dynamic network SBM-DEA; Bootstrapped truncated regression

1. Introduction

Mergers and acquisitions (M&A) are considered one of the most important strategies in sustaining the airline industry in management literature. The terms merger and acquisition are used in regard to joining of two companies. A merger refers to a case, in which two different entities combine to make a new joint organization, whereas an acquisition relates to the takeover of one entity by another. M&A has often been used as a "game changing" strategy to sustain the competitiveness of firms. According to study by Haleblian, Devers et al. (2009), the main reason for M&A is value creation, resulting from improved market power (Eckbo 1983) and efficiency (Jarrell, Brickley et al. 1988), resource redeployment (Capron, Dussauge et al. 1988), and market discipline (Jensen 1986). However, M&A do not always have positive outcomes, but rather lead to failures more frequently (Malatesta 1983, Jarrell, Poulsen 1989).

Airline industry underwent major M&A deals when facing economic difficulties. Figure 1 shows M&A transactions from 1991 to 2017. Especially in 2008, world economy suffered global financial crisis. During the recession, airlines signed an unprecedented scale of M&A contracts to overcome the crisis. 21 M&As were signed between 1991 and 2000, 19 transactions were completed from 2001 to 2007, and 10 M&As were signed in 2008 alone. Particularly after the 2008 financial crisis, the trend in M&A accelerated (Nguyen 2015), resulting in 37 M&As from 2008 to 2017. In spite of growing importance of M&A in airline industry as their major business strategy, no studies have examined the impact of M&A on the airline industry's performance such as profitability and marketability. Most studies on performance in aviation literature focused on productivity analysis, namely the operation or profitability side.

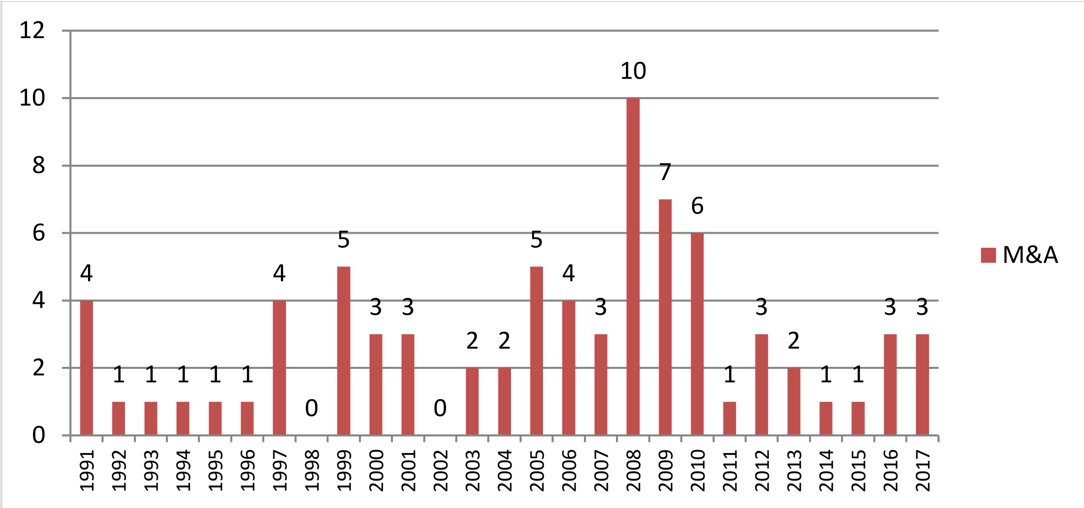

Figure 1: Airline industry M&A trends from 1991 to 2017
Source: CNN news, annual reports of airlines, and Merkert, Morrell (2012).

Profitability and marketability concepts are broadly used in various industries, as detailed in next literature review section. Seiford and Zhu (1999) suggested the profitability and marketability combined concepts in commercial banking sector performance analysis. They defined profitability as a financial performance of the company's profit generation process using employees, assets, stockholders' equity, revenues, and profits. Prior to their study, profitability measurement on performance analysis only considered simple ratios such as return on asset or equity or investment (ROA, ROE or ROI, respectively). Although financial and accounting ratios present useful important information for benchmarking a firm's financial performance, firm performance in reality is the result of interaction among many factors such as labor, revenue, assets, investments, etc. However, simple financial ratios cannot reflect these factors in one measure. In addition, simple ratios cannot consider the economies of scale coming from the companies' size dimension. The new concept of the profitability turned out to be a better alternative for measuring firms' financial performance. Marketability concept was also developed for the same reason. Seiford and Zhu (1999) defined marketability as a performance measure of the firm's stock reflecting market valuation using revenues, profits, market value, total ROI, and earning per shar (EPS) .

This study examines the impact of M&A on the airline industry's profitability and marketability to contribute to the literature. Specifically, our research question addresses how airlines' profitability and marketability have changed before and after the M&A deals under the recent global recession. The research question will be examined using two-step approach, We first calculate 11 global airlines' profitability and marketability from early 2000 to 2017 as this period witnessed unprecedented M&A record (for the details of the M&A cases, see the Appendix). Measurement of profitability and marketability is conducted by developing a robust dynamic network slacks-based measurement data envelopment analysis (DNSBM-DEA) model. Then we examine how global airlines' performances have been affected by M&A deals .This investigation will be carried out using Bootstrap Truncated Regression (BTR) models

Next section reviews relevant literature. Section 3 explains the methodology of DNSBM-DEA and BTR models. Data and variable selection, and results are presented in sections 4 and 5, respectively. Finally, the paper concludes.

2. Literature Review

2.1 Airline efficiency literature

A plethora of previous studies have addressed efficiency issues in the airlines industry. (Baltagi, Griffin et al. 1995) applied a cost model to define and measure the concept of airline efficiency and productivity. (Oum, Yu

1998) proposed an econometric model to estimate airlines' profitability efficiency and found that the North American carriers show faster growth in profitability than their European counterparts. (Marın 1998) introduced a stochastic production function to evaluate 10 European airlines and 9 American airlines from 1980 to 1989. Airline deregulation showed positive effects on productivity. (Oum, Park et al. 2004) estimated and specified a production function for airlines. The research identified airlines' efficiency and network characteristics as the main productivity determinants. (Färe, Grosskopf et al. 2007) used the Malmquist index model to analyze 19 American airlines from 1979 to 1994 and showed that ownership structure affects productivity as public airlines' efficiency was lower than private airlines' efficiency. (Lu, Wang et al. 2012) applied a two-stage DEA model composed of productivity efficiency and marketing efficiency and a truncated regression model. They used data from 30 global airlines and showed that marketing efficiency of low-cost carriers is higher than full-service carriers. (Chang, Park et al. 2014) measured economic and environmental efficiency of 27 international airlines applying SBM DEA models. They showed that revenue structure and fleet fuel efficiency are the major factors contributing to inefficiency in airlines. (Zou, Elke et al. 2014) estimated 15 jet operators' efficiency using ratio-based stochastic frontier approach. The key finding is that fuel consumption significantly correlates with flight departures and revenue passenger miles. (Cui, Li 2015b) evaluated energy efficiency for 11 international airlines using a vertical frontier benevolent DEA cross-efficiency model. They found that capital efficiency is a critical factor affecting the energy efficiency of airlines. (Cui, Li 2015a) measured the safety efficiency of Chinese airline companies using the Malmquist index. They reported changes in efficiency trends and influencing factors during 2008~2012 and found that investment in developing aviation security staff and pilots and training are the most significant factors. (Li, Wang et al. 2015) proposed a new network model in their efficiency study. The network structure was divided into three stages: operations, services, and sales. They applied a virtual frontier network SBM model to estimate the efficiency of each stage, and found that despite the depressed economic conditions from 2008 to 2012, overall efficiency increased for most airlines during that period.

2.2 M&A literature

M&A have been used in various industries as a strategy to improve efficiency and expand market share. Prolific studies have been conducted especially in financial services such as banking and insurance. Seiford and Zhu (1999) estimated profitability and marketability of U.S. commercial banks using a two-step DEA approach. They found that bank size has a negative effect on marketability. (XIAO, Ming 2010) investigated the impact of M&A on the efficiency of four Chinese and five top American commercial banks using DEA model. They found that Chinese banks are more affected by M&A than American banks, and the costs and responsibilities associated with M&As are usually born by the acquiring bank. (Halkos, Tzeremes 2013) estimated the potential efficiency gains from possible M&As among Greek banks. They proposed a bootstrapped DEA procedure to calculate the impact of a potential bank M&A. The study findings revealed that an M&A between efficient banks does not ensure efficiency. (Staub, e Souza, Geraldo da Silva et al. 2010) investigated allocative, technical, and cost efficiencies for Brazilian banks from 2000 to 2007 using the DEA approach. They found that ownership structure affects bank efficiency. (Cummins, Tennyson et al. 1999) analyzed the relationship between M&A, scale economies, and efficiency in the U.S. life insurance industry over the period from 1988 to 1995. They applied the Malmquist index and the DEA to estimate timely changes in efficiency. They showed that M&A activity in the life insurance industry increases efficiency. (Barros, Nektarios et al. 2010) investigated the efficiency of the Greek insurance industry for the period from 1994 to 2003 using a two-stage CRS-DEA model. They found that competition for market share drives a higher efficiency score in the Greek insurance market.

Though M&A has frequently been used in the logistics, shipping, and airline industries, a limited number of studies have addressed M&A in the literature on the airline industry. In the shipping industry, (Cabanda, Pascual 2007) analyzed a merger case of Philippines shipping companies. Three firms, William, Gothong, and Aboitiz, were selected to examine corporate financial and operating performances before and after merger by applying financial approaches and conventional accounting and found that mergers of Philippines shipping companies showed mixed results. The acid test ratio, total turnover ratio, and net revenues showed gains. However, net income, return on assets, return on sales, and return on equity did not record an improvement after mergers. (Midoro, Musso et al. 2005) examined market structure and competition strategies in the liner shipping and stevedoring industry. They found that M&A increases the ship (or vessel) size and decreases freight rates. (N. Y. H. Choi, Yoshida 2013) evaluated M&A effects in Japanese shipping companies: NYK, Showa Line, OSK, and Navix Line. They investigated the purpose and background of M&A and evaluated the effects in terms of long-run business performance and synergy using Economic Value Added. They found that mergers improve financial security and profitability for companies. (Alexandrou, Gounopoulos et al. 2014) conducted a comprehensive study of all shipping M&A activities from 1984 to 2011 and found that the acquiring companies earn abnormal returns of 1.2% while the target companies earn 3.3%, and cross-border mergers create more economic value than domestic deals.

(Kim, Singal 1993) examined price changes in the airline industry following mergers during 1985–1988. They detected price increase when the route was controlled by the merging airlines. (Clougherty 2002) studied domestic airline mergers in the U.S. from the perspective of international competitiveness using empirical tests. The results showed that mergers improve international competitiveness. (Adler, Smilowitz 2007) analyzed airlines' price location competition with regard to hub-and-spoke network alliances and mergers by applying game theory. They revealed that the equilibria outcomes of both mergers and strategic alliances had a positive impact on both the US-based firms and the European firms. (Weinberg 2007) assessed the price effects of horizontal M&A in the airline industry. Surveying the literature, he concluded that airline mergers cause price increases and, therefore, a policy for protecting consumer welfare is imperative. (Merkert, Morrell 2012) investigated airline industry M&A as a "game changer." They applied DEA models to 66 airlines to assess the size effect of the airline. Major finding of analyzing airline M&A is that efficient airline size is between 34 and 52 billion available seat kilometers (ASK) capacity. (Barros, Liang et al. 2013) employed the B-convex model to estimate the technical efficiency of U.S. airlines during 1998-2010 and found that efficiency can be influenced by mergers, size of the airline, and time. (K. Choi 2017) estimated the productivity and efficiency of 14 U.S. airlines during 2006-2015 and found that M&A shows mixed results of success and failure and the cost factor negatively affects the efficiency of U.S. airlines. Table 2 shows DEA variables in previous airline efficiency and other M&A efficiency studies.

Table 1: DEA variables in airline efficiency and M&A studies

	Input	Output
Seiford and Zhu (1999)	Employees Assets Stockholders' equity Revenue Profit	Revenue Profit Market value Total return to invest EPS
(Cummins, Tennyson et al. 1999)	Home office labor Agent labor Business services Equity capital	individual life insurance individual annuities group life insurance group annuities accident and health insurance
(Oum, Park et al. 2004)	Labor Fuel Capital Materials	Passenger services (RPK) Freight services (RTK) Incidental services
(Barros, Barroso et al. 2005)	Wages Capital Total investment income Premiums issued	Claims paid Profits
(Homsombat, Fu et al. 2010)	Labor Fuel	Scheduled passenger services Scheduled freight services

(Continued) Table 1: DEA variables in airline efficiency and M&A studies

	Input	Output
	Flight equipment Ground property Equipment (GPE) Materials	Mail services Nonscheduled passenger freight services incidental services
(Färe, Grosskopf et al. 2007)	Multilateral labor index Fuel Fleet index adjust for aircraft size, age Material input	RPK (Scheduled) RTK (cargo and nonscheduled)
(Barros, Peypoch 2009)	Employees Operational costs Number of aircraft	RPK EBIT
(Barros, Nektarios et al. 2010)	Labor cost Non-labor cost Equity capital	Invested assets Losses incurred Reinsurance reserves Own reserves
Xiao and Ming (2010)	Operational expenses Total deposit Provision for bad debts	Net profit Total loan
(Merkert, Hensher 2011)	Labor ATK FTE_Price ATK_Price	Revenue Passenger-kilometers Revenue Ton-Kilometers
(Merkert, Morrell 2012)	Labor ATK	RPK RTK Revenue
(Barros, Liang et al. 2013)	Total cost Number of employees Number of gallons	Total revenue RPM Passenger load factor
(Halkos, Tzeremes 2013)	Total deposits Labor Physical capital	Securities Loans
(K. Choi 2017)	Cents per available seat miles	Cents per available seat miles Yield Load factor

2.3 Profitability and marketability literature

To evaluate the firm performance, many papers have asserted that a multifactor performance measure model should be applied because the concept of performance is a complicated phenomenon requiring multiple criteria to characterize it (Bagozzi, Phillips 1982, Chakravarthy 1986). Seiford and Zhu (1999) first applied the DEA methodology to evaluate two-stage network structural production process that examines profitability and marketability of the top 55 U.S commercial banks. They used the number of employees, assets, stockholders' equity, profit and revenue to measure profitability, and used revenue, profit, market value, EPS and total return to invest to measure the marketability. Zhu (2000) examined Fortune 500 companies with the Seiford and Zhu (1999) model, and Luo (2003) also followed this model to estimate expanded sample of US 245 banks. Park and De (2004) applied four stage DEA model which measures productivity, profitability, marketability, and overall efficiency of sea port operation. They applied the cargo throughput, number of ship calls and revenue to measure profitability and used revenue and customer satisfaction to measure marketability. Kuo et al. (2012) employed slack-based measure to the two-stage network model which measures profitability and marketability of integrated circuit (IC) design companies. They used equity, liability, employees, revenue and intangible assets to measure profitability, and used revenue, intangible assets, outstanding shares and market value to measure profitability. Literature on profitability and marketability show that the variables selection may vary depending on the industry group, but researchers have common definition of the concept. They defined profitability as financial output generation process such as revenue, profit and assets, and marketability as market evaluation and reputation generation process such as shares and market value. Also, the total process is called value-creating process of the firm.

The literature survey shows that most previous researchers studied airlines efficiency and only a few investigated M&A in the airline industry. Furthermore, most of the studies focused on the concept of productivity by analyzing the operational or profitability side. Therefore, to the best of authors' knowledge, this is the first study examining the impact of M&A on the profitability and marketability of the airline industry using a dynamic network structure from the profit generation process to market evaluation.

3. Methodology

This study proposes a dynamic network slacks-based measure DEA model (DNSBM-DEA) and a bootstrapped truncated regression (BTR) model. The former model measures airline efficiency as the first step and the latter examines how M&As affect airline efficiency in the second step. Section 3.1 explains the DNSBM-DEA model and Section 3.2 the BTR model.

3.1 Dynamic network SBM-DEA model (DNSBM-DEA)

DEA is a non-parametric efficiency assessment tool. It finds an optimum point for every single observation to form a respective piecewise frontier based on input and output of the decision making units (DMU). According to the study of (Farrell 1957), "technical efficiency" is producing the given output with minimum quantities of input or alternatively producing the maximum quantities of output from a given input. Therefore, when a company is efficient, it operates on its frontier of production curve and it records efficiency value as 1. DEA calculates the distance from the frontier, which consists of efficient DMU, to other DMU, and find out proportion value that can reduce all inputs by the same proportion or increase all output by the same proportion for that observation. This is called ratio model or radial efficiency model. In this process, multiple efficient observations, which record efficiency value 1, can exist. Although value of 1 in efficiency is recorded, it does not mean that additional inputs cannot be reduced or additional outputs cannot be increased. There is still a possibility of improvement in inputs and outputs. This additional possibility of improvement is called slack.

The SBM DEA model calculates the ratio of the average inputs waste reduction to the output increase. The meaning of minimizing the ratio is that SBM DEA model pursues simultaneous improvements in both input reduction and output increase. Therefore, it is called non-radial and non-oriented model. In other words, it does not make the input and output to be enhanced equi-proportionally or uniformly, letting the maximum potential improvement in each DMU be calculated by the model. All the possible improvements are adequately taken into account in the model.

In our research, the value creation process of the airlines is separated by profitability and marketability stages based on SBM DEA calculation. Therefore, we can simultaneously consider improvement of the airlines' input waste and output at each stage in the context of M&A.

The DNSBM-DEA model has following advantages:
First, this model is a slacks-based model, which allows DMUs to improve output or input in an asymmetric proportion. Due to such characteristics, a slacks-based model reveals the operational aspects of DMUs more close to reality than other radial models (Chang, Lee et al. 2017, Tone 2001). Second, a two-stage network model is appropriate to describe income statement and balance sheet structure. Each company has a profit production structure, which is from resource inputs to profit output. However, if the company is a stock company, the final output of the production process can be an evaluated stock price by the stock market. In that case, operating expenses and asset items are considered as inputs and market capitalization and earnings per share (EPS) are considered as final outputs. Revenue and net income are considered as intermediate inputs/outputs. Third, a dynamic network structure reflects asset-related items such as assets, liabilities, and share holders' equity, whose values are changing over time. As described in Figure 2, the previous quarter's term-end asset becomes an input for the current quarter and the current quarter generates the term-end asset, which is an output for the current quarter and input for the next term. By reflecting this financial structure on the model, it allows comparing quarterly changes in an airline's profitability and helps understand the airline's profit generation stage more realistically. Following the structure in Figure 2, this study designs a dynamic network SBM-DEA model. The model analyzes airline business in two phases - profitability and marketability, so *network* model and additionally it captures time-variant changes of input and output variable, therefore, *dynamic* model. The quarterly data was the most detailed level capturing both the dynamic and network characteristics of the airline business.

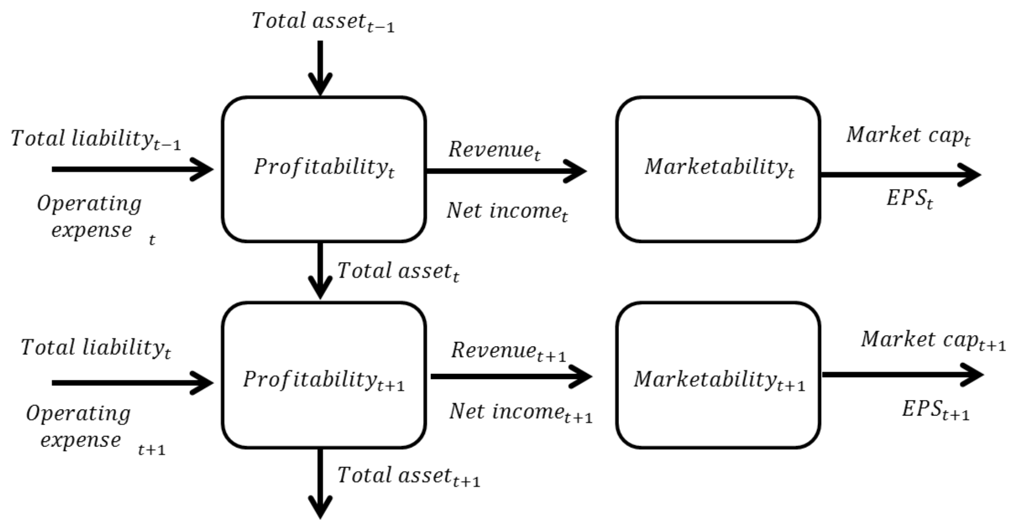

Figure 2: Dynamic network SBM-DEA model

Figure 2 shows the model structure and selected variables of dynamic network SBM-DEA model. We used different time subscript *t* in profitability stages. This is because the time that each item is reflected in the balance sheet and the financial statement is different. When an annual report is published at the end of the year, the recorded items such as total asset, revenue, net income, total liability and operating expense are the result of the year operation. Therefore, year-end total asset and total liability are output of the operation, and previous year-end total asset and total liability are the input of corresponding year.

We built a network SBM model following the prior works of (Tone, Tsutsui 2010, Tone, Tsutsui 2014), to estimate airline efficiencies. The efficiency of an airline is obtained by solving the following liner program.

$$\text{(i)}\quad \text{Minimize } \theta = \frac{1-\sum_{t=1}^{T}\sum_{k=1}^{2}\sum_{i=1}^{m_k}\frac{w^t w^k s_{kio}^{t-}}{m_k x_{kio}^t}}{1+\sum_{t=1}^{T}\sum_{k=1}^{2}\sum_{i=1}^{r_k}\frac{w^t w^k s_{kro}^{t+}}{r_k y_{kro}^t}}$$

s.t.

$$\text{(ii)}\quad \sum_{j=1}^{n}\lambda_{kj}^t x_{kij}^t = x_{kio}^t - s_{kio}^{t-},\quad k=1,2,\quad i\in I_k,\quad \forall t$$

$$\text{(iii)}\quad \sum_{j=1}^{n}\lambda_{kj}^t y_{krj}^t = y_{kro}^t + s_{kro}^{t+},\quad k=1,2,\quad r\in R_k,\quad \forall t$$

$$\text{(iv)}\quad \sum_{j=1}^{n}\lambda_{1j}^t z_j^t = \sum_{j=1}^{n}\lambda_{2j}^t z_j^t\ ,\quad \forall t$$

$$\text{(v)}\quad \sum_{j=1}^{n}\lambda_{1j}^t z_j^t = z_0^t,\quad \forall t$$

$$\text{(vi)}\quad \sum_{j=1}^{n}\lambda_{kj}^t = 1,\quad k=1,2\quad \forall t$$

$$\text{(vii)}\quad \sum_{j=1}^{n}\lambda_{1j}^t \alpha_j^t = \sum_{j=1}^{n}\lambda_{1j}^{t+1}\alpha_j^t,\quad k=1,2,\quad \forall t$$

$$\text{(viii)}\quad \sum_{j=1}^{n}\lambda_{1j}^t \alpha_j^t = \alpha_0^t,\quad \forall t$$

$$\lambda_{kj}^t \ge 0,\quad k=1,2,\forall j,t$$
$$s_{kio}^t \ge 0,\quad k=1,2,\quad i\in I_k,\quad \forall t$$
$$s_{kro}^t \ge 0,\quad k=1,2,\quad r\in R_k,\quad \forall t, \qquad (1)$$

Where λ_{kj}^t is a weight that denotes how much an airline o benchmarks efficient airline j= 1,…, n at term t of stage $k = 1,2$. Subscripts i = 1, 2,…,I_k , r = 1,2,…, R_k, are respectively the set of inputs and outputs of stage κ. $\theta \in [0,1]$ is the efficiency score of the airline. z is an intermediate input/output from the profitability stage to the marketability stage. α is the carryover total asset (link) to the next term $t+1$. s_k^{t-} is the input slack at time t of stage k. s_{kro}^{t+} denotes the output slack at time t of stage k. The numerator in the object function shows the mean "slack" of the input.

The objective function (i) is nonlinear, and thus cannot be solved using linear programming. Therefore, a fractional programming technique is used to linearize the function. The detailed procedures of this method are explained in studies by Tone (2001) and (Chang, Roh et al. 2014). Calculating efficiency scores through the linearization technique, we can obtain the airline's efficiency score at time t of stage k as follows:

(i) $\theta_k^t = 1 - \frac{\sum_{i=1}^{m_k}\frac{w^t w^k s_{kio}^{t-}}{m_k x_{kio}^t}}{\sum_{i=1}^{r_k}\frac{w^t w^k s_{kro}^{t+}}{r_k y_{kro}^t}}$: efficiency of stage k at time t,

(ii) $\theta_k = 1 - \frac{\sum_{t=1}^{T}\sum_{i=1}^{m_k}\frac{w^t w^k s_{kio}^{t-}}{m_k x_{kio}^t}}{\sum_{t=1}^{T}\sum_{i=1}^{r_k}\frac{w^t w^k s_{kro}^{t+}}{r_k y_{kro}^t}}$: average efficiency of stage k over periods,

(iii) $\theta^t = 1 - \frac{\sum_{k=1}^{2}\sum_{i=1}^{m_k}\frac{w^t w^k s_{kio}^{t-}}{m_k x_{kio}^t}}{\sum_{k=1}^{2}\sum_{i=1}^{r_k}\frac{w^t w^k s_{kro}^{t+}}{r_k y_{kro}^t}}$: average efficiency at time t

(iv) $\theta = 1 - \frac{\sum_{t=1}^{T}\sum_{k=1}^{2}\sum_{i=1}^{m_k}\frac{w^t w^k s_{kio}^{t-}}{m_k x_{kio}^t}}{\sum_{t=1}^{T}\sum_{k=1}^{2}\sum_{i=1}^{r_k}\frac{w^t w^k s_{kro}^{t+}}{r_k y_{kro}^t}}$: overall efficiency (2)

The frontier used in this research is a pooled frontier to reflect efficiency changes during the entire period. We avoid the sequential frontier as it can cause upward-biased efficiency measurement during periods of economic depression. In view of this potential bias, it is not proper to compare the scores between different timely frontiers (Chang, Park et al. 2018).

3.2 Bootstrapped truncated regression (BTR) model

A regression model has been frequently used in the literature to find the factors determining airline efficiency. Many studies used the Tobit model, which supposes a censored normal distribution as the efficiency scores range between 0 and 1. However, (Simar, Wilson 2007) criticized the Tobit model as it ignores the data-generating process (DGP) of observed variables. For example, the logical DGP for input/output should be the determinants of efficiency, which influence a company's internal efficiency that consequently affects the company's input/output levels. In other words, the Tobit regression attempts to find determining factors of efficiency scores assuming that estimated efficiency scores are unbiased, whereas the BTR corrects for the estimation bias arising from sampling bias. The mathematical expression is given in (3)

$$f(X_i, N_i, \vartheta_i, Z_i) = f(X_i, N_i|\vartheta_i, Z_i)f(\vartheta_i, Z_i)f(Z_i) \quad (3)$$

Where $f(\cdot)$ is the probability density function (PDF) of observations, X_i denotes the vector of observed input, N_i is the output reparametrized vector, ϑ_i is the true unknown efficiency, Z_i is the matrix that determines firm performance. Subscript i is a specific firm. The right hand side of Eq. (3) is the logical sequence of the DGP. Supporters of BTR believe that what we observe about business performance is consequential outcome of environmental factors (Z), the interaction between the environmental factor and innate efficiency (ϑ) and finally observed performance given the environmental factor and its interaction with the innate efficiency. Following Simar and Wilson (2007), the ideal model is expressed as $\vartheta_i = Z_i\beta + \varepsilon_i$. β is the vector for deriving the marginal effects of determinants and ε_i is an error term. Therefore, the Tobit model leads to

$$\vartheta = \hat{\vartheta} - \text{Bias}(\hat{\vartheta}) - u_i = z\beta + \varepsilon_i \rightarrow \hat{\vartheta} = z\beta + \varepsilon_i + \text{Bias}(\hat{\vartheta}) + u_i \quad (4)$$

where $\text{Bias}(\hat{\vartheta}) = E(\hat{\vartheta}) - \vartheta$ represents the difference between true unknown efficiency ϑ and the calculated efficiency$\hat{\vartheta}$. u_i is an error term with the mean of zero. We conducted BTR using STATA 12.
The estimation model is as follows:

$$\text{Stage1 Efficiency}_{it} = \beta_0 + \beta_1\,\text{Oilprice}_t + \beta_2\text{USD/CNY}_t + \beta_3\text{Economic crisis}_t + \beta_4\text{M\&A}_{it} + \beta_5\text{U.S.DP}_{\ t} + \beta_5\text{Revenue}\varepsilon_{it} \quad (5)$$

$$\text{Stage2 Efficiency}_{it} == \beta_0 + \beta_1\,\text{Oilprice}_t + \beta_2\text{Net income}_{it} + \beta_3\text{Economic crisis}_t + \beta_4\text{M\&A}_{it} + \beta_5\text{U.S.DP growthrate}_t + \varepsilon_{it} \quad (6)$$

$$\text{Overall Efficiency}_{it} == \beta_0 + \beta_1\,\text{Oilprice}_t + \beta_2\text{Net income}_t + \beta_3\text{Economic crisis}_t + \beta_4\text{M\&A}_{it} + \beta_5\text{U.S.DP growthrate}_t + \varepsilon_{it} \quad (7)$$

Subscript i denotes a specific airline. Stage1 Efficiency, Stage2 Efficiency, and Overall Efficiency represent the efficiency scores of each stage measured by the efficiency measurement model. β_i (i = 0,1,…5) are the coefficients. The selection of variables for the efficiency and regression models is explained in the next section. The selected control variables are usual and popular variables in transportation and aviation industry sector used in the literature. (Barkema, Schijven 2008) proposed future research agenda with potentially available firm level control variables such as experience effect, culture, order of M&A etc. These variables are not applied in our model because of their qualitative characteristics.

4. Data

4.1 Variable selection for airline efficiency estimation model

Seiford and Zhu (1999) introduced a two-stage process to analyze the profitability and marketability of the banking industry and estimated the performance of 55 U.S. commercial banks. In their study, the commercial bank's value generation process was divided into two stages. The first stage measured a bank's ability to generate profit and revenue in the financial items of its assets, labor, and capital stock. The second stage estimated a bank's stock market performance in terms of revenue and profit. This study also adopted the two-stage approach to estimate the effects of acquisition on a company's production process, including the profit generation process, and examine the attractiveness of M&A in the stock market.

Following Seiford and Zhu (1999), we selected the previous quarter ending balance of total assets, total liabilities, and operating expenses as input variables for the profitability stage. As explained before, the quarterly data was the most detailed available source to be used for our model. Initially, we planned to use shareholders' equity, but realized that many airlines experienced bankruptcy and recorded negative shareholders' equity. This caused a serious bias as airlines in poor financial health show less input value for profitability, therefore, higher efficiency scores ironically. To solve this problem, we used total liability as an alternative, which can also reflect the level of current input. Revenue, net income, and current quarter ending total assets were selected as the output variables of the profitability stage. Therefore, we constructed total assets as a dynamic variable, which carry over to the next financial quarter. Revenue and net income were the intermediate outputs/inputs of the model between the profitability and marketability stages. Final outputs for marketability were market capitalization and EPS. By designing the model this way, we could disassemble the airlines production process as a general type of stock holding company. Profitability shows how efficiently airlines operate their resources to generate profits. Marketability illustrates how the market reflects and evaluates the airline's value on the profit generated. All the input and output data were collected from each airline's annual report. Table 3 lists a summary of all the variables.

4.2 Negative data problem

DEA implicitly assumes non-negativity of all input and output variables. However, this assumption is not always met in the case of financial data because of the deficit recorded. Airlines have been facing serious challenges over the last decade. From 2008 to 2015, 10 global airlines among the 11 major airline companies recorded deficit at least once. Nearly 112 quarterly net income data recorded negative values among the 399 available data. Tone (2001) proposed the negative data transformation method. As DEA cannot handle negative data, they were transformed by dividing the minimum positive data for a variable by 10. This approach is based on the concept of penalty for negative data. However, when there are too many negative values, the discrimination power of the model decreases because all the negative data are transformed to the same value. To address this issue, this study applied an alternative method proposed by (Bowlin 1998). To eliminate non-positive values, we added a sufficiently large positive constant to the net income data and EPS. This method guarantees higher discriminatory power among the DMUs having negative values while ensuring untainted efficiency results by the data transformation. Table 3 summarizes the data used in DEA models after treating the negative data.

Table 3: DEA data summary

Variable	Obs.	Mean	Std. Dev.	Min	Max
Revenue	399	5481.439	2949.278	462.760	11530
Net income	399	6569.902	769.720	1.000	14870
Total assets	399	27907.620	12626.720	1150	54000
Total operating expenses	399	5240.299	2855.730	245.670	21390
Total liability	399	22710.140	12503.350	688.630	49620
EPS	399	27566.420	12572.440	963.370	54000
Market cap	399	22.598	2.483	1	35.400

4.3 Variable selection for BTR

Selection of variables for the BTR was based on literature (Carter, Rogers et al. 2006, Kumar, Singh 2016, Grosche, Rothlauf et al. 2007, Neven, Röller 1996, Rey, Myro et al. 2011). Oil price is considered a traditional variable for analyzing the airline industry. The U.S. GDP and the GDP growth rate (Oum, Fu et al. 2005) were selected to capture the general trend for the biggest airline market that generated 42.6% of the net profit of the global airline industry (IATA, 2018). The two dummies for economic crises and M&A, net income, and USD/CNY exchange rate were selected as the other independent variables for the regression. The dummy for M&A was assigned a value of one after M&A and zero before M&A. The dummy for economic crisis was reflected yearly and quarterly. For 2008Q1, the quarter dummy was selected to measure the effect of financial crisis on marketability. To estimate the effect of the 2008 economic crisis on profitability, dummies for year 2008, 2009, and 2010 were included. A dummy for the 2012 Euro crisis was also included. However, the reason we applied different forms of the dummy which were yearly and quarterly on profitability and marketability stages is that marketability is much more sensitive and volatile than profitability because of the characteristics of the stock market changes. Therefore, we used the quarterly dummy to examine the effect of the financial crisis on marketability. Revenue was also included in the model to reflect the firm size factor. Table 4 describes the summary of the independent variables.

Table 4: Bootstrapped truncated regression data summary

Variable	Obs.	Mean	Std. Dev.	Min	Max
Profitability	399	0.748	0.122	0.000	1
Marketability	399	0.482	0.238	0.003	1
Overall	399	0.578	0.194	0.014	1
U.S. GDP	399	0.472	0.533	-2.113	1.675
U.S. real GDP growth rate %	399	1.932	2.029	-8.200	5.200
Oil price	399	80.656	26.717	38.580	160.250
USD/CNY	399	6.629	0.524	6.054	8.277
Net income	399	178.902	769.720	-6390	8479
Revenue	399	5481.439	2949.278	462.760	11530

5. Results and discussion

5.1 Efficiency measurement result

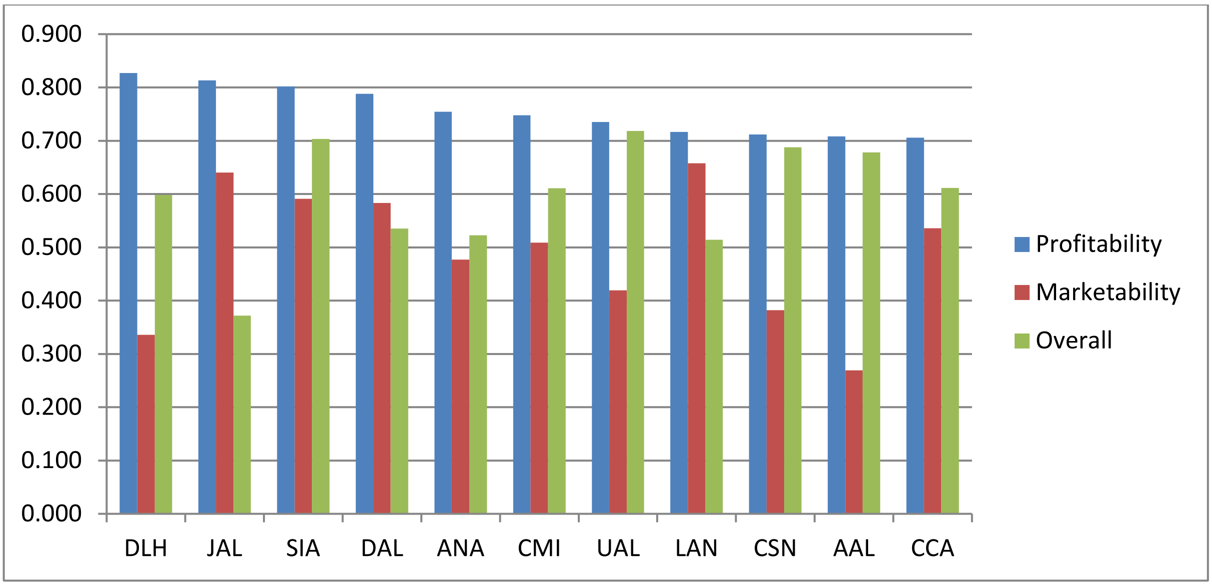

Figure 3: Average efficiency score by airline

Figure 3 and Table 5 show the average efficiency scores for the airlines industry. The Deutsche Lufthansa (DLH) shows highest profitability (0.827) among the airlines and Air China (CCA) has the lowest profitability score (0.706). In terms of marketability, LATAM Airlines Group (LAN) recorded the highest score (0.658) and the American Airlines Group (AAL) had the lowest score (0.269). In overall efficiency, United Continental Holdings (UAL) shows the highest score (0.718) and Japanese Airlines (JAL) shows the lowest score (0.372). For comparison between profitability and marketability, the average profitability score was 0.748 and marketability score was 0.482. The difference in score between the leading company and the lowest company shows a meaningful gap. The profitability gap between the leading airline and the lowest airline shows 0.121. However, marketability shows a gap of 0.389. Standard deviation also shows considerable difference. The standard deviation of profitability is 0.045 and marketability is 0.127. This implies that marketability, which is affected by the stock market, can be almost thrice as volatile as profitability, which is affected by operation.

Table 5: Average efficiency scores of airline companies

	Profitability	Marketability	Overall
DLH	0.827	0.336	0.598
JAL	0.813	0.640	0.372
SIA	0.802	0.591	0.703
DAL	0.788	0.583	0.535
ANA	0.754	0.477	0.522
CMI	0.748	0.509	0.611
UAL	0.735	0.419	0.718
LAN	0.716	0.658	0.514
CSN	0.712	0.382	0.688
AAL	0.708	0.269	0.678
CCA	0.706	0.536	0.611
Average	0.748	0.482	0.577

Figure 4 presents the quarterly changing trends in profitability, marketability, and overall scores. As we have collected quarterly data, it shows seasonality. The trends are gradually increasing from March 2009 to June 2017. The coefficient of profitability trend shows 0.0035, marketability trend shows 0.0066, and overall efficiency records 0.0066. All the three coefficients were positive and profitability scores were always higher than marketability. From September 2009 to December 2010, the graphs show an increasing trend. It can be conjectured that the efficiency of airlines was recovered from the dip caused by the 2008 financial crisis in the

U.S. In 2012, however, the Euro crisis hit the global economy again, impacting the marketability and overall efficiency of the airline industry.

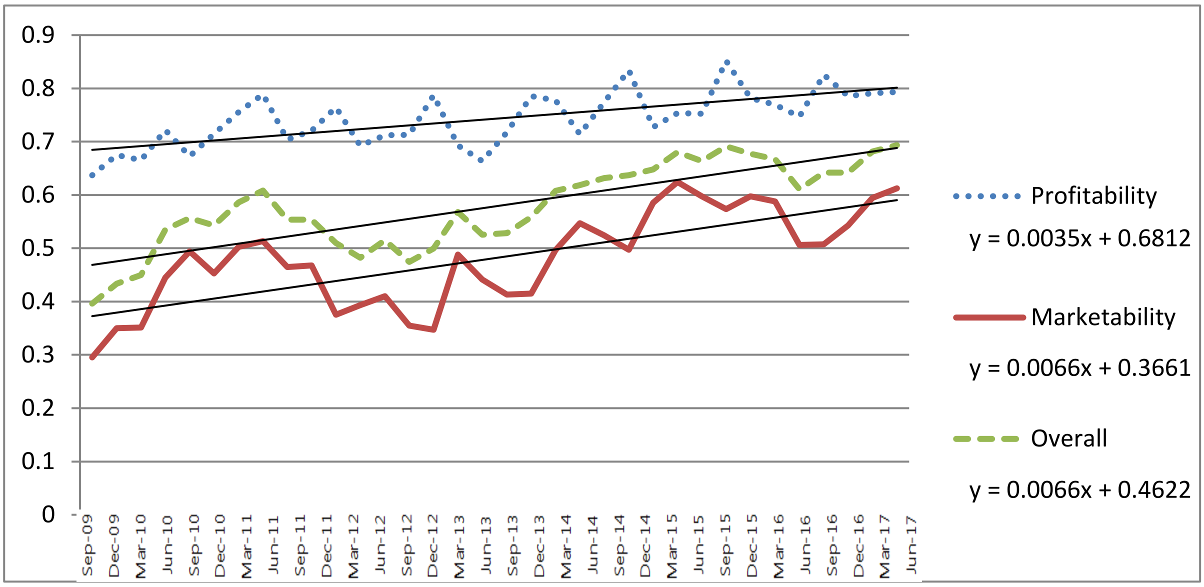

Figure 4: Quarterly change in efficiency scores

Table 6: Average efficiency score change before and after M&A

Airlines	M&A types	Profitability	Marketability	Overall
Merger				
Delta Air Lines	After merger	0.830	0.652	0.730
	Before merger	0.631	0.328	0.367
Japanese Airlines	After merger	0.798	0.648	0.717
	Before merger	1	0.531	0.729
LATAM Airlines Group	After merger	0.653	0.463	0.546
	Before merger	0.760	0.793	0.770
United Continental Holdings	After merger	0.778	0.547	0.644
	Before merger	0.661	0.200	0.350
Acquisition				
American Airlines Group	After acquisition	0.839	0.699	0.757
	Before acquisition	0.653	0.090	0.212
ANA Holdings	After acquisition	0.781	0.502	0.625
	Before acquisition	0.727	0.450	0.571
Deutsche Lufthansa	After acquisition	0.797	0.586	0.683
	Before acquisition	0.827	0.327	0.517
Air China	After acquisition	0.718	0.544	0.621
	Before acquisition	0.571	0.439	0.499

(Continued) Table 6: Average efficiency score change before and after M&A

Intl Cons Airlines Group	After acquisition	0.751	0.527	0.625
	Before acquisition	0.704	0.291	0.452

Table 6 lists average efficiency changes before and after M&As. In case of mergers, 4 airlines conducted the merger transactions. In profitability of merger cases, 2 cases improved their profitability from the merger and the other 2 cases recorded decrease of profitability score. In marketability of merger cases, except for LATAM airline group, 3 airlines recorded improvement of marketability scores. In case of acquisitions, 5 airlines conducted the acquisition contracts. Among them, 4 airlines recorded improvement of profitability score and all 5 airlines recorded improvement of marketability scores. Comparing profitability and marketability changes by the type of M&A, there are no significant differences detected between mergers and acquisitions. The results seem to imply that M&A may have affected the performance of airlines. But the test of this effect can be validated by the results of following BTR models.

5.2 Bootstrapped truncated regression results

Table 7: Bootstrapped truncated regression result (Profitability)

Profitability	Coef.	Std. Err.	z	P>|z|	[95% conf.	Interval]	VIF
Oil price	-0.001***	0.000	-4.670	0.000	-0.002	-0.001	1.32
USD/CNY	-0.011	0.014	-0.820	0.410	-0.038	0.015	1.35
2008	-0.014	0.055	-0.260	0.793	-0.122	0.093	1.49
2009	-0.048	0.025	-1.870	0.061	-0.097	0.002	1.16
2010	-0.002	0.024	-0.100	0.921	-0.050	0.045	1.07
M&A	-0.011	0.013	-0.890	0.372	-0.037	0.014	1.42
U.S. GDP	0.022	0.014	1.650	0.099	-0.004	0.049	1.43
revenue	0.000***	0.000	5.950	0.000	0.000	0.000	1.16
Constant	0.842	0.102	8.270	0.000	0.643	1.042	

Dependent variable: Profitability.
*** $p<0.01$, ** $p<0.05$, * $p<0.10$.

Table 7 reports estimated results for the regression analysis of profitability. As variance inflation factor (VIF) for all the variables was less than the cutoff of 5, no serious multicollinearity was detected. Oil price was negative and significant at the 1% level in the profitability model. This is reasonable, as oil prices are one of the major factors contributing to the airline industry's operating expenses, which impact net income—output variable for profitability. The M&A dummy, which is our focus variable, was not significant in profitability. This implies that M&A could not generate any synergies in the airline industry's profit generation process.

(Zollo, Meier 2008) mentioned that M&A performance could be varied over time, and therefore it should be estimated under different time horizons. We tested this argument by evaluating the profitability under half year, 1 year, and 2 years time windows. We only tested the profitability as the marketability is expected to show more prompt response than profitability due to sensitive stock price movements to the M&A events. On the other hand, the impact on the profitability can be less reflected and/or delayed for various reasons such as the fiscal period, postponement of the consolidation, and post-aquisition integration. (Zollo, Meier 2008) classified the time horizon to short term, which is defined the first year or at the end of the transaction, or long term, which is defined entire relevant period of business plan. Tables 8, 9 and 10 list the results of 6 month, 1 year and 2 year time window. Even undertaking time windows shows insignificance of M&A factor and different time window models show significance of year fixed effect. This implies that the financial crisis seems to have affected the profitability of the airlines, but the M&A did not affect it even considering the time lag effect up to two years.

Table 8: Bootstrapped truncated regression result (Profitability 6 months time window)

Profitability	Coef.	Std. Err.	z	P>|z|	[95% conf. Interval]		VIF
Oil price	0.000	0.000	-0.900	0.366	-0.001	0.000	1.580
USD/CNY	0.031	0.031	1.010	0.314	-0.029	0.091	1.370
2008	-0.104	0.093	-1.110	0.265	-0.287	0.079	1.840
2009	-0.110***	0.041	-2.700	0.007	-0.190	-0.030	1.120
2010	0.010	0.034	0.280	0.779	-0.058	0.077	1.070
M&A	-0.033	0.023	-1.430	0.151	-0.078	0.012	1.440
U.S. GDP	-0.053	0.028	-1.880	0.060	-0.109	0.002	1.860
revenue	0.000***	0.000	6.450	0.000	0.000	0.000	1.150
Constant	0.500*	0.218	2.300	0.022	0.073	0.927	

Dependent variable: Profitability.
*** p<0.01, ** p<0.05, * p<0.10.

Table 9: Bootstrapped truncated regression result (Profitability 1 year time window)

Profitability	Coef.	Std. Err.	z	P>|z|	[95% conf. Interval]		VIF
Oil price	0.000	0.001	0.200	0.843	-0.001	0.002	2.040
USD/CNY	0.050	0.047	1.060	0.287	-0.042	0.142	1.320
2008	-0.142**	0.059	-2.410	0.016	-0.258	-0.026	1.170
2009	-0.024	0.055	-0.440	0.656	-0.132	0.083	1.220
2010	0.004	0.065	0.060	0.955	-0.125	0.132	1.460
M&A	-0.033	0.034	-0.960	0.337	-0.100	0.034	1.450
U.S. GDP	0.003	0.049	0.060	0.951	-0.093	0.099	1.590
revenue	0.000***	0.000	4.270	0.000	0.000	0.000	1.170
Constant	0.358	0.336	1.070	0.287	-0.301	1.017	

Dependent variable: Profitability.
*** p<0.01, ** p<0.05, * p<0.10.

Table 10: Bootstrapped truncated regression result (Profitability 2 year time window)

Profitability	Coef.	Std. Err.	z	P>|z|	[95% conf. Interval]		VIF
Oil price	0.001	0.002	0.560	0.573	-0.003	0.005	3.820
USD/CNY	0.030	0.103	0.290	0.773	-0.172	0.231	1.500
2008	0.026	0.145	0.180	0.861	-0.259	0.310	1.330
2009	-0.084	0.071	-1.190	0.235	-0.222	0.055	1.100
2010	-0.047	0.136	-0.350	0.729	-0.313	0.219	1.620
M&A	-0.019	0.052	-0.360	0.721	-0.121	0.084	1.580
U.S. GDP	-0.104	0.133	-0.780	0.437	-0.365	0.158	4.360
revenue	0.000***	0.000	2.250	0.025	0.000	0.000	1.190
Constant	0.532	0.716	0.740	0.457	-0.871	1.936	

Dependent variable: Profitability.
*** p<0.01, ** p<0.05, * p<0.10.

Table 11: Bootstrapped truncated regression result (Marketability)

Marketability	Coef.	Std. Err.	z	P>|z|	[95% conf. Interval]		VIF
M&A	0.116***	0.023	5.000	0.000	0.071	0.161	1.130
U.S. GDP %	0.011**	0.006	1.970	0.049	0.000	0.022	1.030
Oil price	-0.001	0.000	-2.930	0.003	-0.002	0.000	1.110
Net income	7.23E-05**	0.000	2.480	0.013	0.000	0.000	1.190
2008 Q1	0.249	0.325	0.770	0.443	-0.388	0.886	1.080
Constant	0.483***	0.036	13.370	0.000	0.413	0.554	

Dependent variable: Marketability.
*** p<0.01, ** p<0.05, * p<0.10.

Table 11 lists the regression results for the marketability stage. The U.S. GDP growth rate and net income are significant at the 5% level and have a positive influence on marketability. Net income is an intermediate input/output for the total model. This provides information on how well an airline operates during a financial quarter. This is an important variable because the final outputs of marketability are EPS and market cap, which are severely affected by net income (Erickson, Wang 1999). The M&A variable shows significance at 1% level and reports positive influence, contributing 11.6% toward average marketability increase. The result implies that airlines show an increase in marketability after an M&A. This indicates that the stock market is affected by market expectation and M&A is usually an attractive deal for investors.

Table 12: Bootstrapped truncated regression result (Overall)

Overall	Coef.	Std. Err.	z	P>|z|	[95% Conf. Interval]		VIF
Oil price	-0.001***	0.000	-4.250	0.000	-0.002	-0.001	1.430
USD/CNY	-0.039	0.026	-1.540	0.124	-0.090	0.011	1.320
2008	-0.115	0.066	-1.750	0.081	-0.245	0.014	1.580
2009	-0.081	0.043	-1.900	0.057	-0.164	0.002	1.190
2010	0.025	0.034	0.720	0.470	-0.042	0.091	1.090
2012	-0.055	0.032	-1.710	0.088	-0.118	0.008	1.220
M&A	0.097***	0.017	5.840	0.000	0.064	0.129	1.370
U.S. GDP(q)	0.014	0.022	0.660	0.507	-0.028	0.056	1.510
Constant	0.916***	0.174	5.280	0.000	0.576	1.257	

Dependent variable: Overall.
*** p<0.01, ** p<0.05, * p<0.10.

Table 12 shows the overall stage's regression result. Oil price shows a significant negative effect on overall efficiency. The increase in oil price compounds operating expenditure, which is the input for overall efficiency and is detrimental to net income, which in turn affects EPS and the final output. Oil prices could also influence market cap because once oil prices are officially announced, the related stock price sensitivity also changes (Sadorsky 1999). The M&A activity shows significant positive effects on the overall stage and contributes 9.7% increase toward overall efficiency.

To synthesize the results, oil price has a negative effect on both profitability and overall efficiency, as both reflect operating expenses in the model. This finding supports previous literature (Morrell, Swan 2006, Nandha, Brooks et al. 2013). The U.S. GDP growth rate positively affects marketability. This supports that market attractiveness of the airline industry depends on the general market flow and demand (Oum, Fu et al. 2005). Net income also records a positive effect on marketability. This indicates that investors' evaluation of an airline's stock price is likely to depend on its operational performance. In addition, net income directly affects EPS, which is calculated by net income and total number of outstanding shares. The types of M&As which are distinguished between merger and acquisition do not show significant difference in the result.

The impact of M&A on efficiency shows interesting results. It indicates a positive effect on marketability and overall efficiency. On the other hand, we could not detect significant effects of M&A on profitability. This result implies that after an M&A, there were no significant improvements in the profit generating process, but airlines were benefited from increased stock prices, which may have stemmed from high expectations regarding the M&A's outcomes. As explained in the Introduction, there are various motives driving M&A. A common motive is the expectation of potential synergies created between the two merging entities. This means consolidating the two organizations can reduce labor and other expenses and create new business opportunities and values through newly incorporated strategic assets such as aircrafts and new networks.

Reaching the ideal objective of an M&A is not simple. Therefore, findings that M&A did not enhance acquiring firms' value are typical in the literature. Several studies that estimated and analyzed the post effects of M&A reported negative post-merger returns either in the short term (Malatesta 1983, Jarrell, Poulsen 1989) or long run (Agrawal, Jaffe et al. 1992, Loderer, Martin 1992). Some M&As tend to focus more on raising the stock price than securing financial stability. In the case of M&A in the airlines industry, after the 2008 financial crisis, American Airlines and United Airlines recorded negative values for shareholders' equity or capital impairment. American Airlines recorded capital impairment from September 2003 to December 2006 and December 2008 to December 2010. United Airlines recorded capital impairment from June 2008 to September 2010. These major airlines were able to avoid capital impairment at the time of merger. During the merger process, they could raise funds from investors to recover from capital impairment. This is funneled into additional paid-in capital, which is recorded in shareholders' equity on the balance sheet. This supports the result that after 2008, M&A in the airlines industry did not result in profitable synergies, but only increased marketability.

Even though M&A helped airlines to achieve the expected effect of securing financial stability, M&As are not deemed to have been fully successful. In principle, companies should seek long-term interests of shareholders by reflecting net profits into market valuation such as stock prices. Therefore, an ideal M&A scenario is when a company generates profitability through the synergy effects of M&A and improved profitability is reflected in marketability. However, in this study, an improvement is found only in terms of marketability rather than profitability. The link between profitability and marketability should be further examined in future studies.

6. Conclusions

This paper investigated the effects of M&A on the profitability and marketability of 11 leading global airline companies. First, a dynamic network SBM-DEA model was developed to estimate the efficiency. Second, several bootstrapped truncated regression (BTR) models were run to determine the statistical relation between airlines' efficiency and M&A, while controlling for micro and macroeconomic indicators, such as the U.S. GDP, oil price, exchange rate, and net income.

The results suggest that M&A increased marketability and the overall efficiency scores of airlines by 0.116 and 0.097, within a range of 0 to 1 for the efficiency scores. Compared with the current average marketability and overall efficiency score of airlines, this efficiency gain is substantial, accounting for 24.06% of the average marketability scores and 16.8% of average overall efficiency scores. However, contrary to our expectation, no synergies were found for profitability.

These results are interesting and have implications for decision makers and industrial managers, especially for major airline companies in the U.S. that are seriously considering M&A. Some M&As are effective in stimulating stock market attraction rather than generating profit. This finding can be also used for policy-makers, who are examining the applications of the airlines in United States to approve the M&A applications.

Some limitations in this study suggest future research direction. Although this study investigated the effect of M&A in aggregated level, every contract has its own specificity. This can be investigated by even study in the future research. In addition, due to necessity of collecting quarterly data to reflect both profitability and marketability as detailed as possible, we had to exclude some major airlines, e.g. Lufthansa, Korean Airline and Cathay Pacific due to unavailable data. Future study can expand the coverage when these data are available.

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Global Shipping in Asia in the 21st Century

Dr., Professor Mariner Wang

Graduate School of Management (MBA), Ritsumeikan Asia Pacific University, Oita Prefecture Beppu, Japan

Abstract

1990's saw the robust expansion of international trade in East Asia region generating a remarkable record high and sustained economic growth which is unmatched by any other region in the world. In line with this, container tonnage in the region has been ever increased annually.

In light of the economic growth miracle, the governments in the region have plunged substantial investment into expanding and developing new container terminals with an aim to deal with the annually ever increased containerized outbound/inbound cargoes in the region.

Though Lehman Shock has given tremendous impact on the container volumes in Asia in 2008, container ports in the East Asia region still continued to handle the lion's share of global container business. In 2017, the container throughput of East Asia accounted for 53.6 percent out of the world total, becoming the center of world container traffic.

2019 is seen to be a volatile year from the perspective of logistics, shipping and port development in Asia region when the container traffic will make a further leap by driving the another Asian port to join the world top ten league.

This paper explicates the surge of container tonnage in East Asia region, analyzes the weight of East Asia region out of global container tonnage, illustrates the expansion and development of main container ports of East Asia region, and discusses the possible sustainability of container tonnage in East Asia region toward the 21st century.

Key Words: East Asia region, International Trade, Plaza Accord, FDI, real GDP growth rate, Group of 5, Container throughput, TEU, transshipment center, port development, port expansion, Distripark, Free Trade Zone, Pusan Port, Guang Yang Port, Shanghai Port, Kaohsiung Port, Hong Kong Port, Singapore Port

1. Introduction

After World War II in the period between 1960s to 1970s East Asia region (Japan, China, the Asian NIEs, ASEAN 4) [1], excluding Japan, was the niche in the world market and the economic activities was extremely constrained. However, since 1985 the region has enjoyed a remarkable record of high and sustained economic growth which grew extremely fast than any other region in the world [2]. East Asia region's economic prosperity can be reflected by its real GDP growth rate.

In the period between year 2001-2017, the Asian NIEs (Hong Kong, Singapore, Taiwan, Korea), ASEAN 4 (Philippines, Malaysia, Thailand, Indonesia) and China have experienced average real GDP growth rate of 3.8, 4.5, 9.3 percent respectively compared to an average 1.0 percent in Japan, 1.9 percent in the U.S. and 3.8 percent in the world (Figure 4).

The contrast is even more pronounced when the growth of per capita income across developing regions being compared. The drastic economic growth in East Asia region, particularly the Asian NIEs, which has been demonstrating high real GDP growth rate in comparison with other regions or countries during the same period is, de facto, closely related to the booming international trade being dealt regionally and globally. This is the very reason imparting to East Asia region an extraordinary dynamism which greatly changed the international shipping in East Asia region [3].

East Asia region's economic prosperity can be dated back to the "*Plaza Accord*" in September 1985 convened by the Group of 5 (the U.S., U.K, Germany, France, Japan) intervening in the foreign exchange market to drive the dollar drastically low against the Japanese yen, expediting the second wave (1991-1995) of Japanese companies' overseas forays (Foreign Direct Investment=FDI) in East Asia region [4] (Figure 42). As a consequence, the international trade in terms of exports and imports in the region has grown enormously, generating a significantly economic growth unmatched by any other region in the world (Wang, 2003).

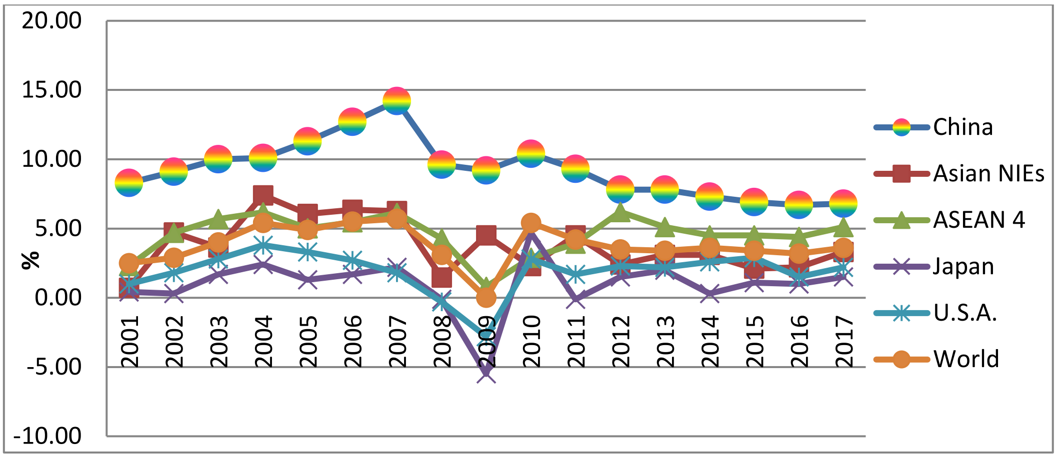

Figure 4: Real GDP Growth Rate of Asia, U.S. and World
Note: Real GDP growth rates are calculated by simple average.
Source: International Financial Statistics Yearbook, 2003- 2014, IMF, Trading Economics.

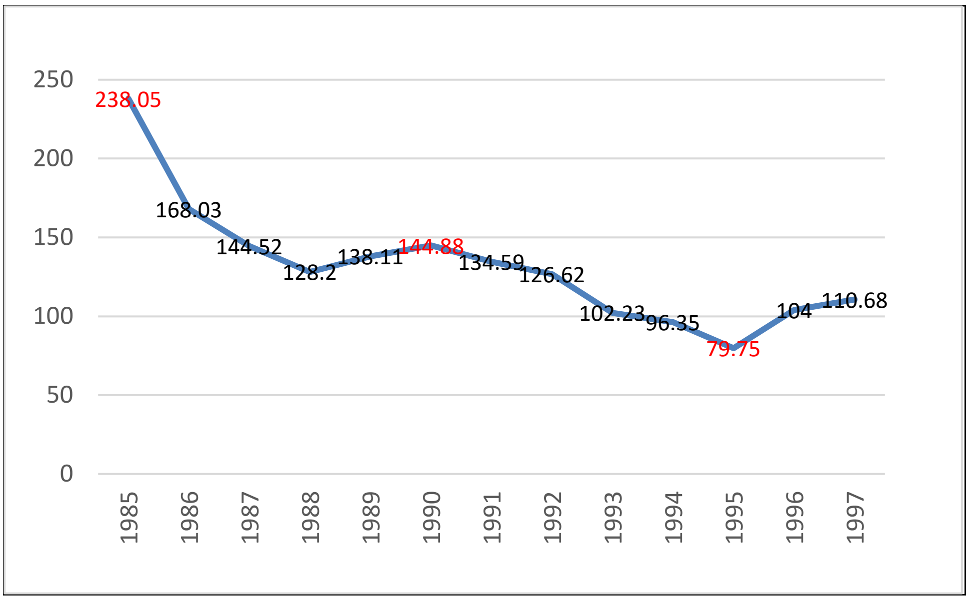

Figure 2: Japanese Yen Appreciated against US Dollar before and after Plaza Accord (1985-1997)
Source: International Financial Statistics Yearbook, 1990- 2000, IMF, Trading Economics.

Triggered by this dynamism the cargo throughput, particularly the container tonnage of East Asia region after Plaza Accord, has been rising steeply. Of particular, in year 2003, Port Shanghai (China) had surpassed port of Busan (Korea) joining port of Hong Kong, Singapore, as the top three of the world top 10 container ports (Figure 43). What's more, in 2007, Shanghai Port replaced Hong Kong Port becoming the world top 2 container port and in 2010 overtaking Singapore Port ranking the world champion (Figure 44).

Of particular note is in 2017 nine container ports in East Asia region accounted for the world top ten container ports, namely, 90% of the world top 10 container ports are out of East Asia region which demonstrated incredible dynamic and has become the key player in global container tonnage. This is virtually an unprecedented miracle in the history of world shipping (Figure 44).

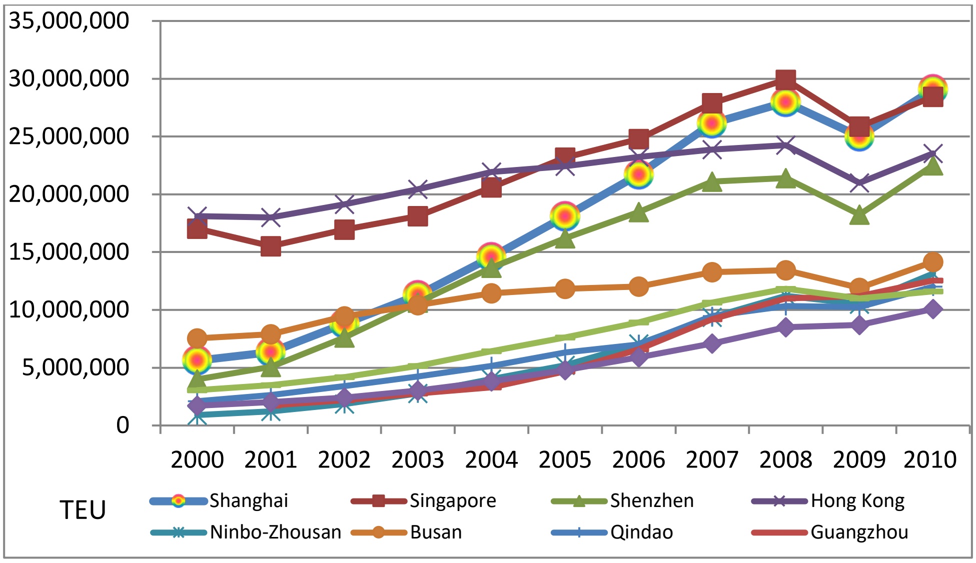

Figure 3: World Top 10 Container Port (2000-2010)
Source: Containerisation International Yearbook, 2002-2010.
Containerisation International, March, 2011.

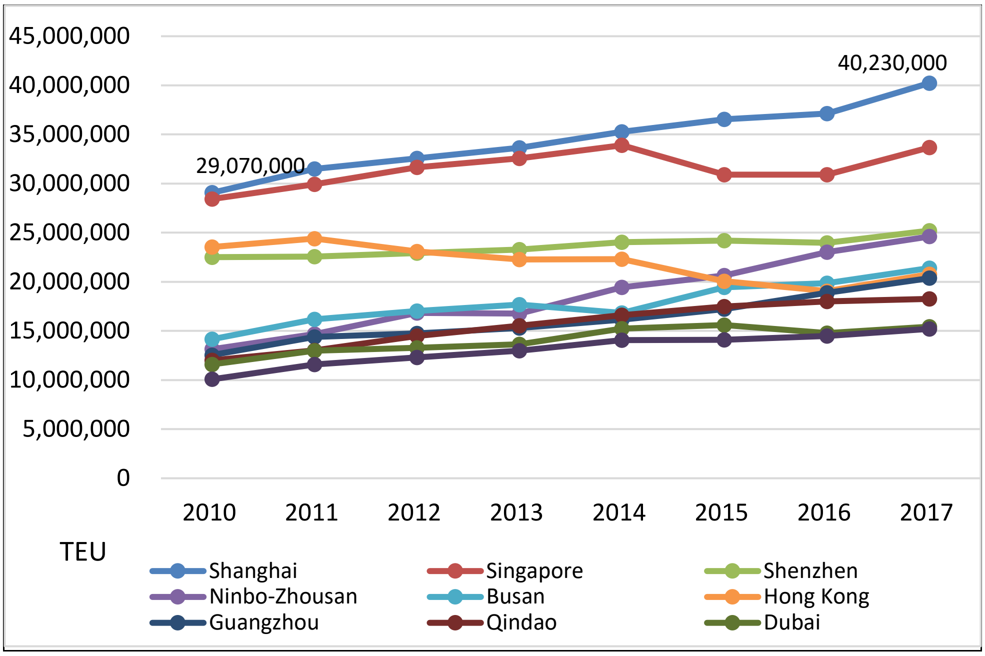

Figure 4: World Top 10 Container Port (2010-2017)
Source: Containerisation International Yearbooks, 2011-2017.
Containerisation International, March, 2018.

Certainly, the drastic economic growth of East Asia region was not accomplished overnight. In the 1960's, Japan became the focus of global attention as an emerging economic power catching up with the U.S. and Europe. The economic growth in Japan was soon followed by Asian NIEs (particularly, Taiwan and Korea), then ASEAN countries came to realize their vast potential for dynamic progress. Next, China started a giant stride.

In other words, in East Asia region, one country after another has played the role as the forerunner, driving the swift economic growth of the entire region. This is the single most crucial factor behind the rapid upswing of

East Asia region on the global scene.

This paper falls into four main sections. The first explicates the surge of container tonnage in East Asia region. The second analyzes the weight of East Asia region in global container tonnage. The third illustrates the expansion and development of main container ports in East Asia region, while the final section concludes by discussing the possible sustainability of container tonnage in East Asia region toward the 21st century.

2. The Surge of Container Transportation in East Asia

Figure 5 illustrates the world's container traffic flow in 1990 and 2017. In 1990, the world's busiest trade line—the Trans-Pacific (Asia/North America) service handled 5.3 million TEUs, however, in 2017 the traffic volume reached to 23.2 million TEUs, an increase of 4.4 folds over 1990 [5].

In 2017, westbound cargo tonnage demonstrated the historical high of 16.42 million TEUs (70.7%). In country wise, cargo exporting from China and Vietnam ascended to historical high of 10.64 million TEUs (65%) and 1.07 million TEUs (6.5%) which was an increase of 5.6 percent and 16.9 percent respectively over 2016. In comparison, east bound cargo accounted for 6.8 million TEUs (29.3%). in country wise, cargo destined to Japan, Korea, Taiwan and India demonstrated an increase of 0.2 percent 2.0 percent, 3.4 percent, 5.5 percent respectively, while China demonstrated an decrease of 3.8 percent over 2016[5].

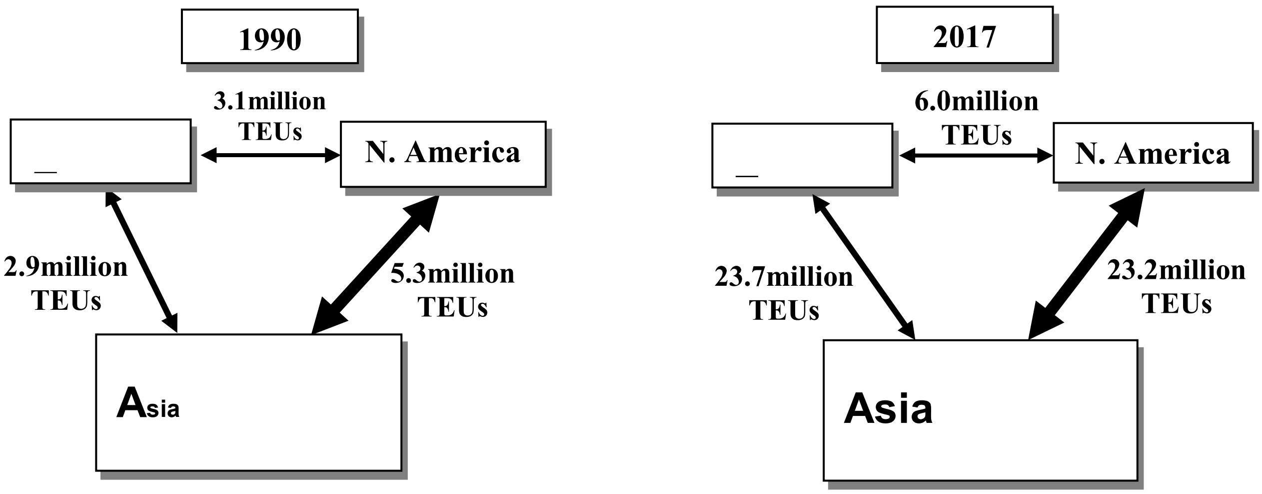

Figure 5: Container Traffic of Trunk Line and Intra-Asian Service

Note : 6.0 million TEUs in North Atlantic trade line and 39.2 million TEUs in intra- East Asia trade line are in 2016.

Source: Maritime Report 2005, 2014, 2018, Ministry of Land, Infrastructure, Transport and Tourism, Japan.

On the other hand, in the same period (1990 and 2017), the container volume handled in the Asia/Europe service was from 2.9 million TEU to an increase of 8.2 folds of 23.7 million TEU over 1990. In 2017, the cargo tonnage of Europe bound and Asia bound demonstrated historical high of an increase of 4.1 percent and 5.1 percent respectively over 2016. The increase was never before in the maritime history [5].

Looking more minutely into Europe bound tonnage, in country wise, over 70 percent (4.4% increase) of exporting cargo are loaded from China, while Korea, Vietnam and Thailand demonstrated an increase of 7.3 percent, 7.5 percent and 1.7 percent respectively. However, cargo exporting from Japan demonstrated 5.7 percent decrease.

In comparison, the Asia bound cargo destined to China and Vietnam demonstrated a big increase of 5.9 percent and 18.8 percent respectively. However, cargo destined to Japan and Hong Kong fell 1.7 percent and 12.9 percent compared with 2016[5].

Another perspective of main trade line is the newly emerged intra-East Asia service (Japan, China, Asian NIEs, ASEAN10) [6]. As is evident from Figure 5, in 1990 container throughput of the service registered 3.5 million TEU [7], the scale of intra-East Asia service was below trans-Pacific service, however, it surpassed the traffic volume in the Asia/Europe service (2.9 million TEU) and the trans-Atlantic service (3.05 million TEU).

In comparison, in 2016, the container traffic volumes in the intra-Asian service went up to 39.2 million TEU, demonsstrating an increase of 11.2 folds compared with 1990. The figure could hardly rival the scale of the trans-Pacific service's 21.92 million TEU, however, it paralleled Asia/Europe service (19.61 million TEU) and outpaced the trans-Atlantic service (6.3 million TEU). And in 2014, the weight of container tonnage in Asia region has already accounted for 55.4 percent of world container tonnage, clearly, the intra-Asian service, with its buoyant economic growth, has become the newly emerging force of the world container traffic services [8].

The factors behind the drastic rise of container tonnage in the intra-Asian region are seen to be attributed to structural adjustments in the liner shipping sector and shifts in the economic make-up of the region continue to evolve. In particular, the annually economic growth in China, being the driving force, the export of substantial volume of cargo globally [9]. Undoubtedly, long-term port development and expansion planning by Asia's major powers (port authorities, The Ministry of Land and Transportation) is another key factor driving dynamism in the sector across the region.

3. The Weight of East Asia Region in Global Container Tonnage

As has been stated earlier, East Asia region has enjoyed remarkable economic growth triggered by the Plaza Accord (1985) which drove the Japanese companies' (particularly the manufacturing companies) foray into the region. Given the dynamism, cargo tonnage in the region has been ever increasing annually supported by the international trade (both exports and imports) from behind.

Table 3: Status of East Asia in World Container Throughput (Unit: 1,000 TEU)

Country/ Region	1985	1990	1995	2000	2005	2010	2017	2017/1985 (folds)
Japan	5,517	7,956	10,604	13,129	17,055	17,727	21,904	4.0
(%)	9.9%	9.3%	7.7%	5.7%	2.3%	3.2%	2.9%	
Asian NIES	8,309	18,124	36,748	54,736	73,698	84,326	96,762	11.6
(%)	14.9%	21.2%	26.8%	23.6%	18.8%	15.0%	12.9%	
ASEAN 4	1,657	4,298	7,977	15,348	26,279	34,741	57,508	34.7
(%)	3.0%	5.0%	5.8%	6.6%	6.7%	6.2%	7.6%	
ASEAN 10	N.A	N.A	N.A	N.A	N.A	47,094	105,036	
(%)	N.A	N.A	N.A	N.A	N.A	8.4%	14.0%	
China	446	1,204	4,682	22,884	67,245	125,103	213,720	479.2
(%)	0.8%	1.4%	3.4%	9.8%	17.2%	22.3%	28.4%	
East Asia	15,928	31,582	60,011	106,097	184,277	247,250*	403,858*	25.4
(%)	28.5%	36.9%	43.7%	45.8%	47.0%	48.9%*	53.6%*	
U.S.A.	11,533	15,245	19,104	27,315	38,498	35,601	51,425	4.5
(%)	20.6%	17.8%	13.9%	11.8%	9.8%	6.4%	6.8%	
World	55,903	85,597	137,239	231,689	391,883	560,328	752,714	13.5

Source: Based on the statistical data on *Containerisation International Yearbook*, 1987-2018. https://unctadstat.unctad.org/wds/TableViewer/tableView.aspx?ReportId=13321

Note 1: ASEAN 10 denotes Singapore, Malaysia, Thailand, Indonesia, Philippine, Vietnam, Myanmar, Brunel, Laos, and Cambodia.

Note 2: * Calculated based on ASEAN 10 and the duplication of the throughput of Singapore Port is excluded as Singapore Port is incorporated both in the Asian NIES and ASEAN 10.

Table 1 demonstrates the container throughput by region/country as well as the weight out of world's total container traffic spanning from 1985 to 2017. It also can be realized that during the same period, the weight of ASEAN 4/ASEAN 10 rose from 3.0 percent to 7.6 percent/14.0 percent, while China rose from 0.8 percent to 28.4 percent accounting for over one quarter of world container traffic by demonstrating 479.2 folds of super drastic growth over 1985. In contrast, container tonnage in the U.S. declined from 20.6 percent to 6.8 percent [10].

What's more, during the same period the container throughput in East Asia region rose from 15.9 million TEUs to 403.9 million TEUs, an increase of 25.4 folds. It is definitely worth to note that the weight of the region has already accounted for 53.6% out of world container traffic, namely over half of the world container traffic has been generated from East Asia region.

It is axiomatic that main ports in Asian NIEs, ASEAN10 as well as China have contributed largely to the substantial growth of container tonnages in East Asia as a whole. Apparently, East Asia region has become the hub (loading center) of world container tonnage.

4. Ports Development in Asia

For the last past two decades, ports development has become a growing priority in Asian region. The development of modern and well managed port sector is extremely crucial to Asia's sustainable economic growth. The factors behind the ports development are with an aim to provide more space for handling the yearly ever increased export and import containerized cargoes as well as to provide container terminals with deep draft which can accommodate super large container vessels.

4.1 Port of Shanghai

In recent year, the exports of China have moved into high gear to supply the needs of expanding world economy, and the port of Shanghai has become the big beneficiary from drastically increasing trading to Asia, Europe and North America. It has been retaining its status as the leading container port in China.

Port of Shanghai has been tipped to attain pivotal position in the global container ports league since 2010, and container throughput was even more surprisingly resilient in 2017, it handled 40.23 million TEU, an increase of record high to 8.3 percent over 2016, the figure was never before since its operation in December 2005.

Located on two large islands known as Little Yangshan Island and Big Yangshan Island, Yangshan container terminal (deep-water port) operated by the Shanghai International Port Group (SIPG), is connected to the mainland by the six-lane, 32.5 km (25km is elevated on offshore) Donghai Bridge believed to be the longest bridge in the world.

Yangshan Deep-Water Port so far is the biggest port in China, involving a total planned investment of some RMB 100 billion (US$12 billion). Development (phase1-phase 4, 50 berths) will continue until 2020, when completed, the facility will be equipped to have an annual handling capacity of more than 25 million TEU.

Phase 1 comprises five berths with a capacity of 4 million TEU, while phase 2 consists of four berths with a capacity of 3.2 million TEU. Phase 3A/3B [11] comprise 7 berths with a length of 2,600 meters and an alongside water depth of 17.5 meters, the deepest berths in Shanghai.

Figure 6: Yangshan Deep-Water Port (southern side) in Shanghai, China
Source: Shanghai International Port Group (SIPG) Shanghai International Port Group (SIPG).

Being appointed by Shanghai Tongsheng Investment Group, the developer of Yangshan CT, SIPG operates three of the phase 3B berths capable of handling 2.4 million TEU annually starting operation in 2009. Phase 3 is of the handlig capacity of 5.6 million.

The phase IV project of the Yangshan Deep-Water Port is the largest automated container terminal in the world starting trial operations on December 2017. The port covers 2.23 million square meters and has a 2,350 meters shoreline, once it enters full operation, the phase IV will initially be able to handle 4 million TEUs. The handling capacity will expand to 6.3 million TEUs later on [12].

Figure 7: Aerial View of Phase IV Yangshan Deep-Water Port in Shanghai, China
Source: Shanghai International Port Group (SIPG).

The automated terminal not only increases the port's handling efficiency, but also reduces carbon emissions by up to 10 percent. The automated handling equipment applied in the project are designed and manufactured in China. Shanghai Zhenhua Heavy Industries Company is responsible for making the machinery installed in loading and unloading, including a bridge crane, an Automated Guided Vehicle (AGV) and a rail-mounted gantry crane.

The port also introduced domestically developed automated management system to ensure safety and efficiency. The terminal will boost Shanghai port's status as the busiest container port and loading center in the world.

4.2 Port of Singapore

The port of Singapore, blessed by its geographic advantage, has been playing the pivotal role as the transshipment center (load center) of container ports in Southeast Asia. PSA International [13], a wholly-owned affiliated company of state-operated Temasek Holdings Pte. Ltd. [14], with an aim to attract the world leading mega shipping lines to call its port, has invested some S$5 billion (US$3.5 billion) to develop 23 container berths and three dedicated PCC (Pure Car carrier) berth (Pasir Panjang Automobile Terminal=PPAT) for Phase 1 and 2 at Pasir Panjang (Long Sand)Terminal (PPT) 1-3 (Figure 8).

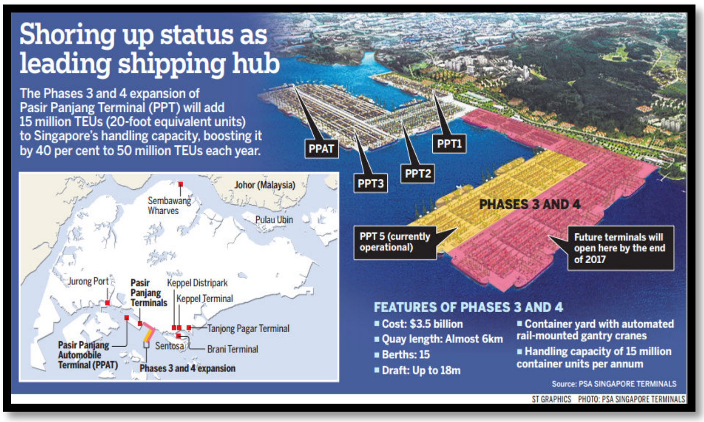

Figure 8: Terminal Layout of Pasir Panjang Terminal
Source: PSA International.

With an aim to meet the needs of shipping lines, the $3.5 billion PPT Phase 3 and 4 expansion projects (198ha, reclaimed land) [15], comprising 15 deep-water berths (draft up to 18 meters) started operations in June 2015. The new expansion including the already-operational Pasir Panjang Terminal 5 and two future terminals, which will be running by the end of 2017, will add 15 million TEUs (twenty-foot equivalent units) to Singapore's handling capacity, lifting the Port of Singapore's total capacity to over 50 million TEU (49 million TEU from PSA Singapore Terminals and 1.8 million TEU from Jurong Port).

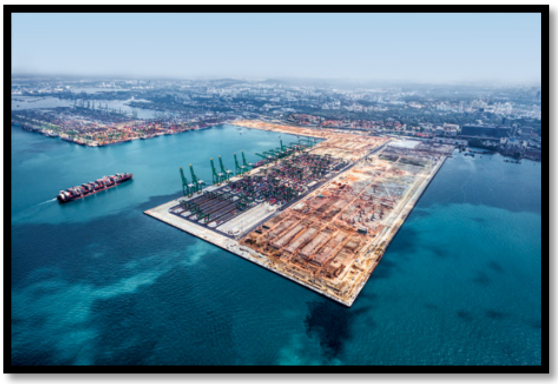

Figure 9 Aerial View of Pasir Panjang Phase 3/Phase 4 (left) and Future Terminal (right)
Source: PSA International.

PSA International, with an aim to provide dedicated berths for shipping lines, has signed joint venture contracts with COSCO (China), MSC (Swiss), PIL (Singapore), CMA CGM for COSCO-PSA Terminal (CPT), MSC-PSA Asia Terminal (MPAT), PIL-PSA Singapore Terminal (PPST), and CMA CGM-PSA Lion Terminal Pte. Ltd. (CPLT) at Phase 3 and 4 which began operation from year 2003, 2006, 2008, 2016 respectively.

PSA Singapore container terminals will eventually be consolidated at a single location in Tuas (west coast) (Figure 10). The new Tuas Port will be able to handle the world's biggest container ships and will be the largest automated container terminal in the world, with an annual handling capacity of 65 million TEUs. Reclamation began in April 2016 and Phase 1 is expected to be completed in December 2020.

As a maritime hub encompassing the whole range of services, PSA Singapore Terminals, with on-going liberalization of financial and telecommunication services, will be an even bigger attraction to more carriers to call.

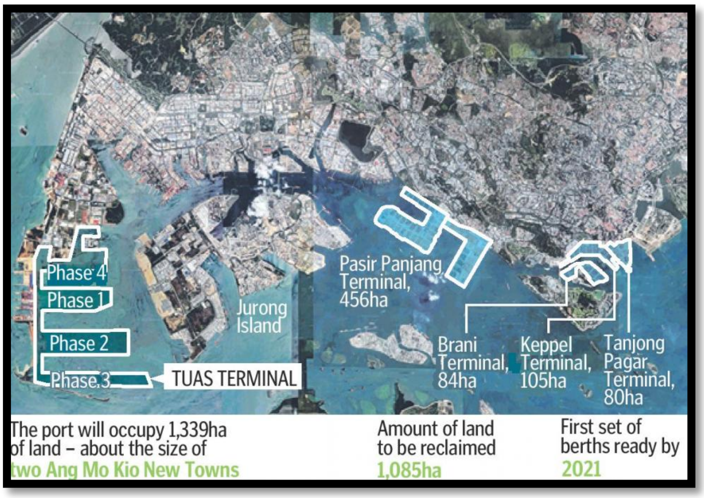

Figure 10: Location of TUAS Terminal
Source: PSA International.

4.3 Port of Hong Kong

Port of Hong Kong, like Port of Singapore, blessed by its geographic advantage bearing mainland China as the hinterland, has been playing the crucial role as the hub port serving the South-East and East Asia region. Port of Hong Kong also plays the vital role as the entrepôt for container transshipment for both Asia/North America and Asia /Europe traffic lines as well as the important economic gateway to southern mainland China.
Port of Hong Kong set a record in its container throughput in 2007 by handling 23.9 million TEUs, attaining its status as the largest container port in the world. However, in 2004 its championship status was replaced by Port of Singapore, and being surpassed by Port of Shanghai, Shenzhen (Southern China), Ninbo-Zhoushan (Central China), and Busan in 2007, 2013, 2015, and 2016 respectively (Figure 3, 4). The recession of Port of Hong Kong is in striking contrast to the ever increasing container tonnage of the above listed main ports.

In October 1989, the plan of new port development in Hong Kong incorporated in the Port and Airport Development Strategy (PADS) was announced publicly. The plan is incorporated in the "Recommended Outline Development Plan" submitted by APH Consultants to Hong Kong Government in 1993.

In the plan, the development of new CT (container terminal) 9-13 (Figure 11) are of necessity in order to handle the annually increasing cargoes to/from Shenzhen Special Economic Zone (SSEZ, 40 minutes by train from Hong Kong) and the neighboring Pearl River Delta (PRD). However, due to the development of Yantian International Container Terminals (YICT) [16] situated at eastern SSEZ, a certain volume of export cargoes including Mattel Inc., the world largest toy maker, have been shifted to YICT instead of loading from Kwai Chung Terminal, Hong Kong. The factors behind the shift can be attributed to less lead time and inland transportation charge from SSEZ/PRD to Hong Kong. Under the unexpected circumstances, the preplanned project of CT 10-13 development was unfortunately cancelled leaving CT 9 [17] for being constructed which started operations in 2003.

The development of the $ 2 billion invested CT 9 is operated by HIT (Hong Kong International Terminals) and MTL (Modern Terminals Ltd.) (Figure 12). The terminal is located in Tsing Yi areas which is the opposite side of the Kwai Chung container terminal. The new facility occupies an area of 70 hectares of reclaimed land consisting of four deep-sea berths and two feeder berths (to/from Pearl River Delta).

Figure 11: Layout of New Port Development in Hong Kong
Source: Hong Kong Port and Maritime Board.

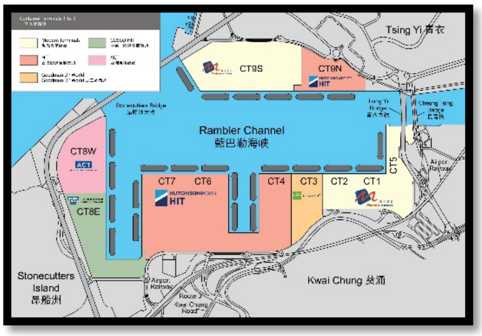

Figure 12: Layout of Kwai Tsing Container Terminal in Hong Kong
Source: Hong International Terminals (HIT).

4.4 Port of Pusan

Port of Pusan, lying on the southeast coast of Korean peninsula facing the Japan Sea, has been playing a pivotal role as the transshipment hub in northeast Asia. The 2000 increase of 17.1percent in containers throughput recorded the highest margin since the 1995 Kobe earthquake when port of Pusan won a big piece of Japan's transshipment cargo. In 2014, it handled 21.4 million TEUs ranking 5th in the world (Figure 4). Blessed by its geographic location, container tonnage is expected to increase annually.

In addition, the Korean government, with an aim to attain balanced national land development and to smoothly cope with the drastic increase of container tonnage resulting from brisk Korean economic growth, in 1994 consigned Korea Container Terminal Authority (KCTA) to launched an intensive short, middle and long term port development projects.

The short and middle term projects include port development and expansion projects in Gamman port known as Busan port phase 4 development (1991-1997); Pusan New Port Container Terminal (PNCT, 2001-2007) and Kwangyang CT (phase1:1987-1997, phase 2:1996-2004, phase 3-1, 3-2:1999-2011)； and South port of port of Inchoen (2001-2003).

PNCT comprise 25 new container berths and is of possibilities for future expansion (Figure 13). The new port will be able to handle megaships of 12,000 TEU and can increase Pusan's overall handling capacity by more than 15 million TEUs.

Costing US$7.2 billion, PNCT is the very first port development project in South Korea to be funded by private capital [18] including DP World, Samsung Group, Hanjin shipping and Hyundai Merchant Marine. It is a nine-berth facility, with the six berths of phase 1 stretching along 2,000 meters of quay length, an initial depth alongside of 16 meters and a capacity of 3.6 million TEUs. The left three berths of phase 1-2, stretching along 1,200 meters with an initial depth alongside of 17 meters and a fully automated yard operation system, were completed in May 2009, boosting the complex's annual capacity to 5.5 million.

Figure 13: Layout Pusan New Port Container Terminal in Korea
Source: Yeosu Gwangyang Port Authority.

PNCT signed contract with world conglomerate shipping lines—MSC (Switzerland) in April 2009 and in May, MSC began moving its vessels to PNCT, which will contribute to an annual throughput increase of about 600,000 TEUs. In addition, CMA CGM (France) [19] shifted three services to PNCT on May, 2009. In the same month, Hanjin Shipping's Pusan New Port phase 2-1 terminal, operated by Hanjin New Port Company, was officially opened. PNCT has three berth with a depth of 18 meters, capable of accommodating three 12,000 TEUs megaships simultaneously [20]. The terminal has also introduced the world's first automated horizontal yard crane system.

The long term project is Port of Gwangyang Port Container Terminals (GPCT, 1987-2000) [21] (Figure 14) which is about 125 kilometers west-southwest of port of Pusan. The port lies on a naturally protected deep-water harbor (Cat Island), and its channels allow vessels up to 300,000 DWT to arrive and depart at any time. The terminal's 16 meter water depth allows to accommodate 8th generation container vessels and operate throughout the year.

In 1998, phase 1 of the terminal began operation then followed by phase 2-1, phase 2-2 and phase 3-1 opened in 2002, 2004, 2007 respectively. Port of Gwangyang boasts state-of-the-art logistics services, including a 100% on-dock system and ample equipment to handle megaships with fast loading/unloading rates. The advanced IT backing terminal operations and automated gate services make operations efficient and affordable.

A joint logistics center built behind GPCT transforms port of Gwangyang into a high value-added center based on an effective business model which covers the full range of logistics functions including storage, assembly, processing, and distribution. The joint logistics center was completed in 2007 containing total floor space of 33, 200 square meters. GPCT is continuing its aim of becoming a global logistics hub through its Distripark (3.88 million square meters), an enormous project comprising the Eastern and Western Distripark complexes. Designated as a FTZ (Free Trade Zone), the Distripark is being developed in phases on reclaimed land behind GPCT.

Figure 14: Aerial View of Gwangyang Container Terminal in Korea
Note: From right to left is from phase 1 to phase 3.
Source: Yeosu Gwangyang Port Authority.

As South Korea enhances container capacity, this will fuel the preference for shipping lines to use GPCT as a hub to avoid expensive Japanese port charges and also access the increasingly attractive China market. In addition, the restoration of rail links between North and South Korea triggered by the Seoul-Pyongyang rapprochement in 2000 will be an opportunity for both South and North to make another great leap forward [22].

When the talk between South and North Korea goes smoothly, GPCT will be linked by rail between South and North Korea to the Trans-Siberian Railway and the Trans-China Railway. GPCT is seen to strengthen the Korean Peninsula's claim to be a major hub of northeast Asia.

4.5 Port of Kaohsiung

Port of Kaohsiung, with its geographical advantage located along the southwestern coast of Taiwan on the key trade lines running through the Taiwan Strait, is the largest international seaport in Taiwan handling 73% of its container throughput. The port is ideally located as the transshipment hub for the export cargoes between the west coast of North America and Southeast Asia.

Furthermore, owing to the opening of direct sailing between Port of Kaohsiung and port of Xiamen and Fuzhou (Fujian Province) in China in 1997, it provides port of Kaohsiung with more room for securing the transshipment cargoes from North America and China.

The historic agreement signed in November 2008 permitting completely direct cargo transport between Taiwan and China saw the trade route re-open in December 2008, after an interruption of nearly 60 years. This means that freight (cargoes) can be shipped directly across the Taiwan Strait from 63 Chinese ports, without having to make a detour via the port of Ishigaki (Okinawa Island, Japan). This saves between 16 and 27 hours of lead time as well as around 15-30% on cost for Taiwanese shipping lines (Yang Ming, Evergreen).

As a driving force, Port of Kaohsiung expects cargo flows to increase significantly. In order to add capacity to cope with these potential increased volumes, port of Kaohsiung is constructing a sixth container terminal (Figure 15) with four berths, 17 meters depth alongside and a capacity of 2.8 million TEU, on a 50 year operation concession (on BOT basis). Named the Kaohsiung International Container Terminal (KICT) [23] (Figure 16), it is operated by Kao Ming Container Terminal Corporation (KMCT) [24], a wholly-owned subsidiary Taiwan's national sipping line-Yang Ming.
KMCT has agreed a US$500 million loan to finance the project and the first two berths, capable of accommodating 10,000 TEU super-size container vessels commencing operation in 2011, with the remaining two began operation in 2013. KMCT is a semi-automated terminal and its four berths are equipped with 12 quay cranes and sets of automated tail-mounted gantry cranes (ARMGs).

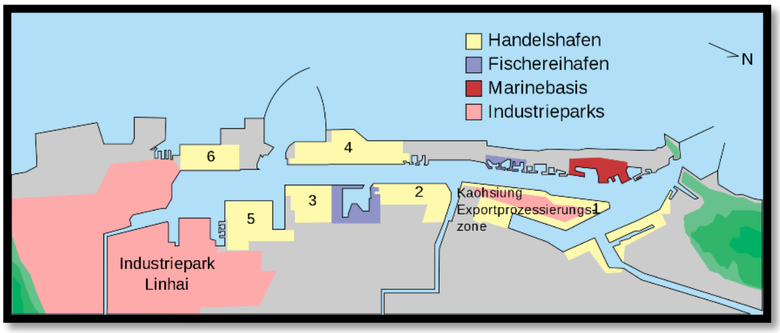

Figure 15: Layout of Container Terminal at Port of Kaohsiung in Taiwan
Note: Handeldhafen denotes trade port.
Source: https://commons.wikimedia.org/wiki/File:Port_of_Kaohsiung_map_de.svg.

Figure 16: Layout of Kaohsiung International Container Terminal in Korea
Source:https://www.twport.com.tw/en/cp.aspx?n=47F9D4ED41A05211.

5. Conclusion

The surge of container tonnage in East Asia region and the intensity of operations are significant not only regionally but globally. Thought a worldwide downturn in demand triggered by Lehman Shock in September 2008 saw global export volumes plummeted by some 20 percent in the last half of 2009, the world market was on the rebound from early 2010 following months in the doldrums. The economic crisis-induced stagnant growth has come to an end. The Asian region has generally turned the corner and is now heading towards economic recovery though demonstrating slow growth.

Taking the container throughput (2008-2017) of major ports in China for instance, despite the recession-hit world economy, most of the top 10 container ports registered smooth growth annually (Figure 17).

Despite the challenges posed by the Sino-US trade war [25] that continue to negatively impact on logistics and shipping industry, the outlook still looks promising for maritime sector in 2019. On the other hand, new port development has been on the going. Presently, Southeast Asia is seen being the busiest for port development globally, with no less than five major projects underway on the shores of the strategic Malacca Strait. In additional, there are ongoing capacity expansion projects at Malaysia's two main international ports of Tanjung Pelepas (Cape of Release) and Port Klang.

With the ongoing trade war between US and China since May 2018, the import and export trade, taking Hong Kong for example, has still seen a healthy growth in 2018 as compared to 2017. This is because many US importers placed more orders for the exporters in Hong Kong (most cargo originated from Shenzhen Special

Economic Zone and Pearl River Delta) to keep stock before the implementation of new import taxes as well as to avoid paying higher import duty [26].

What's more, according to the report of the *United Nations Conference on Trade and Development* (UNCTAD) that in the first half of 2018, FDI flows to China grew six percent to US$70 billion, or about fifteen percent of the global total topping the world in attracting FDI from overseas. In sharp contrast, the global sum during the same period slumped by forty one percent to its lowest in a decade [27]. According to the forecast of the Chinese Academy of Social Science, the economy in China will grow by 6.3 percent in 2019. It is not exaggerating to say that China has become the main index for the world economy.

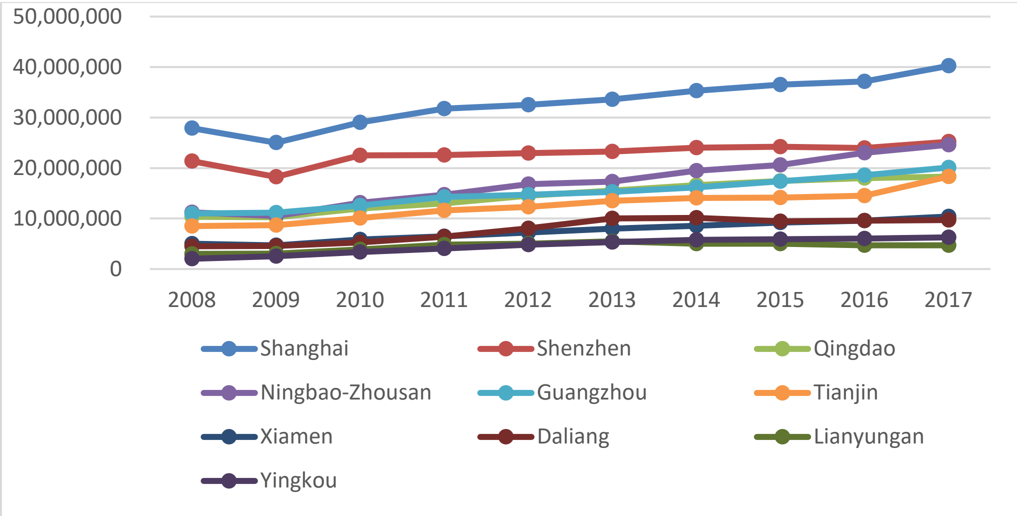

Figure 5: Container throughput at the Major Chinese Ports (2000-2018)
Source: Yearly statistics data of Ministry of Transportation, China.

On October 26, 2018, companies from China and Japan have signed over fifty deals for cooperation in areas such as infrastructure and services to further develop third-party markets. The agreement also cover digital technology, healthcare, finance, regional development and manufacturing. Both countries have already begun to work with the Thai government on a high-speed railway project in eastern Thailand, as well as smart city projects [28].

As the two major manufacturing giants and investors for outbound direct investment, China and Japan can definitely find more business potential to develop markets in Asia region, Africa and Latin America to meet their rising demand for industrialization and urbanization. The joint development of third-party markets will boost the efficiency of the industrial structure in China and Japan as well as the construction ability in related markets.

To conclude, the economy and markets in Asia are seen to be optimistic toward 2019 which undoubtedly will boost the international trade in terms of imports and exports. Accompanied by the driving force, the container traffic will be in the rise from intra-Asia region and outside the region as a whole.

It is surmised that 2019 will be a volatile year from the perspective of logistics, shipping and port development in Asia region when the container traffic will make a further leap by driving the another Asian port to join the world top ten league.

Footnotes

1. The Association of Southeast Asian Nations, or ASEAN, was established on 8 August 1967 in Bangkok, Thailand, with the signing of the ASEAN Declaration (Bangkok Declaration) by the Founding Fathers of ASEAN, namely Indonesia, Malaysia, Philippines, Singapore and Thailand. Brunei Darussalam then joined on 8 January 1984, Viet

Nam on 28 July 1995, Lao PDR and Myanmar on 23 July 1997, and Cambodia on 30 April 1999, making up what is today the ten Member States of ASEAN.

2. Major elements which contributed to the phenomenal economic development of East Asia: a) In most countries of East Asia there is a strong national aspiration toward development which is shared not only by the government but also by the vast majority of the people. b) In the process of realization of the national aspiration, public and private business sector successfully maintained an efficiently cooperative division of labor and established an export-oriented industrial structure. With few exceptions, East Asian governments demonstrated enlightened leadership with a right set of policy objectives. And at the same time, there was market-oriented private sector dynamism with abundant innovative entrepreneurship. Furthermore, both public and private sectors did not confront each other rather, they supported each other. c) Most East Asian countries enjoyed a high savings ratio, which enabled vigorous accumulation of domestic capital. Additionally, labor ethics in general were sound, which generated high productivity. d) East Asia could enjoy favorable external support. In the first place, the U.S. provided a vast open market for the East Asian exports. It was also the U.S. which guaranteed the security of the region. Japan also played a crucial role in stimulating East Asian economic development by supplying capital, technology and managerial know-how since the 1980's.
3. Wang, M. (1997). The Rise of International Trade and Global Logistics in East Asia: The Case Study Emphasizing Asian NIEs. *Study of Shipping Economy* (pp. 117-135), Japan Society of Shipping Economics.
4. Wang M. (2012). 汪 正仁『最新図解 東アジア国際物流の知識』(*The Knowledge of Global Logistics in East Asia*) (2nd ed.). Beppu, Japan: TENDODO BOOKs. Wang M. (2014). 汪 正仁『最新図解 東アジアの国際物流システム 改増訂版』(*The System of Global Logistics in East Asia*). Beppu, Japan: TENDODO BOOKs.
5. http://sea-logistics.sakura.ne.jp/category6/entry162.html.
6. ASEAN was preceded by an organization formed in 31 July 1961called the Association of Southeast Asia (ASA), a group consisting of Philippines, Malaysia, and Thailand. ASEAN was created on 8 August 1967 when the foreign ministers of five countries: Indonesia, Malaysia, Philippines, Singapore, and Thailand signed the ASEAN Declaration. In 1984, Brunel became ASEAN's sixth member and on 28 July 1995, Vietnam joined as the seventh member. Laos and Myanmar (Burma) joined two years later on 23 July 1997.Cambodia was to have joined at the same time as Laos and Burma, but its entry was delayed due to the country's internal political struggle. It later joined on 30 April 1999, following the stabilization of its government.
7. The container throughput of intra-East Asia service in 1990 included Japan, China, Asian NIES and ASEAN 4 (Philippines, Malaysia, Thailand, and Indonesia) only.
8. http://www.jpmac.or.jp/img/relation/pdf/pdf-p35-43.
9. https://fairplay.ihs.com/ports/article/4279521/asia-ports-outlook-2017-southeast-asia-dynamic-with-port-developments.
10. According to the *Global Port Development Report* (2017) of Shanghai International Shipping Institute, the pick-up of container traffic in 2017 was mainly attributed to the recovering global economy and trade environment in East Asia region.
11. China Shipping and Singapore based PSA International are each to finance 30% of the 9 billion RMB ($1billion) needed for the development of seven berths with a total quay length of 2,600 meters. Additional investors are Shanghai International Port Group (SIPG: 20%), COSCO Group (10%) and CMA-CGM (10%). PSA International is a new investor in the Yangshan project unlike China Shipping, PSA International was involved in Phase 2 of the development. Berths at the container terminal is of the capacity to handle five million TEUs annually. http://www.seatrade-maritime.com/news/asia/Yangshan-CT-Phase-3-investors-announced.html.
12. https://www.straitstimes.com/asia/east-asia/worlds-largest-automated-container-terminal-opens-in-shanghai.
13. PSA International, being one of the world leading terminal operators, took the first step in becoming a global terminal operator in 1996 when it embarked on its first overseas venture in Dalian, China. Today, PSA International has been involved in developing, managing and operating participates in over 50 terminals in 17 countries across Asia (Singapore, Thailand, Vietnam, Indonesia, China, South Korea, India), Europe (Belgium, Italy, Portugal, Portugal) and the Americas (Argentina, Panama, Columbia) with flagship operations in PSA Singapore Terminals and PSA Antwerp.
14. An investment company owned by the Government of Singapore. Incorporated in 1974, Temasek owns and manages a net portfolio of S$266 billion (US$177 billion; as of 31 March 2014), mainly in Singapore and Asia. It is an active shareholder and investor, and its portfolio covers a broad spectrum of sectors including financial services, telecommunications, media, technology, transportation, industries, life sciences, consumer, real estate, as well as energy and resources. Temasek has a multinational team of over 490 people, in 11 offices globally including London and New York. See https://en.wikipedia.org/wiki/Temasek_Holdings for more details.
15. The Maritime and Port Authority of Singapore (MPA) is in charge of reclamation for Phase 3 and 4.
16. Opened in 1994, YICT (373 hectare, 16 berths), is the joint venture container terminal by Hong Kong conglomerate Hutchison Whampoa and Guangdong Province Government, China. It is operated by Shenzhen Yantian Port Group and Hutchison Port Holdings.

17. Both HIT and MTL plunged 10 billion 387.5 million Hong Kong dollar on the investment and land acquisition.
18. PNCT is a BTO (Build, Transfer, and Operate) project. In June 2009, Busan Port Authority (BPA) announced an international bid to buy the operational rights for the three berths of PNCT's phase 1-1, which has been operating far below the maximum capacity since its opening in 2006.
19. CMA CGM acquired a 12% stake in PNCT, with a concession to operate phase2-3 of Busan New Port for a period of 29 years—CMA CGM's initial port investment in South Korea. The new terminal began operation in late 2012 and operated in partnership with Macquarie, Bouygues, Hyundai Development, KMTC, Busan Port Authority and local operators KUKJE and KCTC.
20. Refer to "World Top Container Port" *Container Management*, 2009 for more details.
21. Yeosu Gwangyang Port Authority is committed to expanding Port of Gwangyang Port Container Terminals (GPCT), adding annual handling capacity of more than 12.4 million TEUs to make the port an international container hub for Northeast Asia. PNCT is a BTO (Build, Transfer, and Operate) project too.
22. The 318 km rail line from the South's capital of Seoul to the North's Sinuiju city bordering China, will lay the groundwork for an international railway. Not only will inter-Korea business generate more container throughput, but shippers in Japan and Korea will also get a faster, cheaper route to Europe initially via Pusan or GPCT then via the Trans-Siberian Railway.
23. KICT is scheduled to have an annualized throughput capacity of 2.8 million TEU with phase 1 of the development becoming operational in 2012. All four of the 350m berths, with a depth alongside of 17.5m, should be in service by 2014. The new terminal will be capable of handling 10,000 TEU-sized super-sized container vessels. COSCO, the national shipping in China, is said to be interested in obtaining a 20% stake in KICT.
24. Ports in Taiwan are managed by Taiwan International Ports Co. Ltd. established in March 2012
25. The dispute has roiled financial markets including stocks, currencies and the global trade of commodities from soybeans to coal and is threating to get out of control, which could lead to a collapse in confidence and trigger a global financial crisis. *Shippers Today*, the Hong Kong Shippers' Council, Sep-Oct 2018, Vol.41/No.5, p.10.
26. Shippers Today, *Shippers Today*, the Hong Kong Shippers' Council, Jan-Feb 2019, Vol.42/No.1, p.22.
27. Shippers Today, *Shippers Today*, the Hong Kong Shippers' Council, Nov-Dec 2018, Vol.41/No.6, p.32.
28. Shippers Today, *Shippers Today*, the Hong Kong Shippers' Council, Nov-Dec 2018, Vol.41/No.6, p.30.

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An Integrated Fuzzy ANP-QFD Approach for Port Selection Considering Intermodal Transportation: A Case Study about China-Africa line under Belt and Road Initiative

Huiling Zhong [a], Xinyi Zou [b] and Yimiao Gu [c1]

[a] Department of Logistics Engineering, School of Economics and Commerce, South China University of Technology, Guangzhou, China. Email: hlzhong@scut.edu.cn
[b] Department of Logistics Engineering, School of Economics and Commerce, South China University of Technology, Guangzhou, China. Email: ecxinyi@mail.scut.edu.cn
[c] Department of Logistics Engineering, School of Economics and Commerce, South China University of Technology, Guangzhou, China. Email: guymcheers@scut.edu.cn

Abstract

In recent years, port competition is becoming more and more fierce especially among those ports vying for the same container flows. Port authorities must continuously make an effort to understand what factors influence port selection and shipping lines needs to know how to evaluate and choose an appropriate port. This study adopts a comprehensive evaluation approach incorporating Fuzzy ANP-QFD to identify these qualitative and quantitative assessment criteria. Data are collected by means of questionnaires and interviews. It is useful for both port authorities and shipping lines. It can provide port authorities policy implications on how to develop their ports and provide shipping lines suggestions for port selection. In this study, we identify four main port selection criteria, mainly include port cost, port efficiency, port service level and intermodal transportation connection. And we choose eight major representative ports along the China-Africa line under BRI, including three Chinese ports (Hong Kong Port, Shenzhen Port and Guangzhou Port), two Indian ports (Mumbai Port and Chennai Port) and three African ports (Dar es Salaam Port, Mombasa Port and Durban Port). Results show that port cost and service level are the most important factors, intermodal transport connection also is getting many attention. And in this model, Hong Kong Port ranks first, Shenzhen Port and Guangzhou Port rank upstream, while Durban Port has the lowest ranking.

Keywords: Fuzzy ANP-QFD; Port Selection; Intermodal Transportation; Belt and Road Initiative

1. Introduction

Port competition is becoming stronger especially among those ports rivaling for the same container flows and serving overlapped secondary markets and hinterlands. For the sake of keeping the competitiveness in the overlapped hinterland, ports are generally keen on enhancing their appealing by upgrading the Port-to-Port shipping services to the Door-to-Door services. Hence intermodal transportation has become one of the most important considerations for port selection. Although intermodal transportation has become more and more important, no researchers has considered intermodal transportation into port selection criteria. This study represents the first attempt to consider intermodal transportation into port selection criteria and apply an integrated Fuzzy ANP-QFD method to port selection.

Besides, there have been many studies on the incorporation of fuzzy AHP to QFD, but the applications of fuzzy ANP to QFD are rather limited. Since there is interrelationship between CRs and DRs and also inner dependence among CRs and among DRs, ANP is a preferable methodology than AHP to be used with QFD. In order to take into account, the impreciseness and vagueness in human judgments and information, fuzzy set theory is applied. This study adopts a comprehensive evaluation approach incorporating Fuzzy ANP-QFD for shippers to identify

[1] Corresponding Author's Full Address: Yimiao GU, Department of Logistics Engineering, School of Economics and Commerce, South China University of Technology, Guangzhou, China. Email: guymcheers@scut.edu.cn

these qualitative and quantitative assessment criteria. It can help them to evaluate and select a more suitable port. It can provide the relevant policy implications for port authorities on how to develop their ports as well. On the other hand, although there are a lot of papers on port selection, few studies pay attention to the port in Africa, researchers seems more passionate about the port in the Asia and Europe. However, with the integration of the global economy and trade, African ports plays more and more important role in the world, especially the rapid development of the trade of China-Africa has needs more researches with respect to China-Africa ports. In addition, there is a strategy remains a very high priority in the trade of China-Africa we have to mentioned——BRI.

As we know, the Belt and Road Initiative (BRI), proposed by President Xi Jinping in 2013, would connect 65 countries, 29 percent of global GDP, and 60 percent of the world's population through a sprawling network of ports, roads, and other infrastructure projects—a modern-day equivalent of the ancient Silk Road. In this study, we choose eight major representative ports along the China-Africa line under BRI, including three Chinese ports (Hong Kong Port, Shenzhen Port and Guangzhou Port), two Indian ports (Mumbai Port and Chennai Port) and three African ports (Dar es Salaam Port, Mombasa Port and Durban Port). These ports are the important nodes in the China-Africa line under BRI, which have strategic geographical positions and huge container throughputs.

The rest of this study is organized as follows. In Section 2, a literature review is presented. The subsequent section generalize a decision-support model by the FANP-QFD approach and applying the different steps of the methodology: choice criteria determination, criteria ranking, and port scoring on the criteria. Section 4 conducts a case study of eight international ports along BRI and the results discussion is given in Section 5. The final section draws conclusions and lessons for further research.

2. Literature Review

Many influential factors are considered for the selection of container port. Slack (Slack 1985), Gi-Tae Yeo (Yeo, Roe et al. 2008), Marzieh Nazemzadeh (Nazemzadeh and Vanelslander 2015) proposed the most common characteristics of a port are related to (mainly include): port cost, service Level, port location, port risks and port efficiency. Port cost and service level are the two most concerned and crucial factors among those researches. Chien-Chang Chou (Chou 2009) proposed shippers always focus on total logistics costs when making decisions about port choices in practice. Myung-Shin Ha (Ha 2003) identified the important service quality factors and presented the comparison among container ports that are chosen. Jose L. Tongzon (Tongzon and Sawant 2007) have shown port charges and port services to be the only significant factors in their port choice from the shipping line's perspective. Matthew B. Malchow (Malchow and Kanafani 2004) find that the most significant characteristic of a port is its location by using an alternative form of the discrete choice model. Jose Tongzon (Tongzon 2001) provided an port efficiency measurement for four Australian and twelve other international container ports.

Furthermore, Port competition is becoming stronger especially among those ports rivaling for the same container flows and serving overlapped secondary markets and hinterlands. For the sake of keeping the competitiveness in the overlapped hinterland, ports are generally keen on enhancing their appealing by upgrading the Port-to-Port shipping services to the Door-to-Door services. Hence intermodal transport has become one of the most important considerations for port selection. The previous literature that studies intermodal transport in port selection mainly from inland intermodal transport and feeder network. Theo Notteboom (Notteboom 2011) considered feeder connections and inland intermodal services as two important criteria for port selection to shipping lines according to various empirical studies. Tom Vermeiren (Vermeiren and Macharis 2016)concentrates on the intermodal land transportation systems which link Antwerp and Rotterdam with a shared hinterland in the long and medium distance range and reiterate the importance of intermodal land transport systems in the competition between load centres. Although intermodal transport has become more and more important, no researchers has considered intermodal transport into port selection criteria.

Based on the literature addressing port selection, there are three main methods dealing with this problem: questionnaires and interviews, regression analysis and operations research. A number of studies have combined questionnaires and interviews with other methods to study problems, and some have used questionnaires and interviews as the main research method. Slack (Slack 1985) investigated the criteria shippers employ in the port selection process through survey questionnaires. Manuel Acosta (Acosta, Coronado et al. 2011) reveal that fuel prices and geographical advantage are the two main factors determining port choice, derived from Gibraltar Strait port operator's perspective by utilizing interviews and questionnaires. Multinomial logit (MNL) model and discrete choice model are the most commonly used methods in regression analysis. An-shuen Nir (Nir, Lin et al. 2003) used the revealed preference multinomial logical model to analysis shipper's choice behavior. Simme Veldman (Veldman, Garcia-Alonso et al. 2011) applied multinomial logit model to establish such a demand choice function for the Spanish container port services. Matthew B. Malchow (Malchow and Kanafani 2004) use an alternative form of the discrete choice model to analyze the distribution of maritime shipments among US ports. Donatus E. Onwuegbuchunam (Onwuegbuchunam 2013) use discrete choice model to help Nigerian shippers, who engage liner services available at the nation's coastal ports, select the alternative port with the highest utility among those available at the time a choice is made.

A large proportion of literatures which focus on port selection would utilize operations research method, in which AHP and ANP are the most widely used. Chien-Chang Chou (Chou 2010) constructed an Analytic Hierarchy Process (AHP) model for simulating the behaviors of carriers' port choice and identifying the importance weight of every influential factor influencing carriers' port choices in the multiple-ports region. Jasmine Siu Lee Lam (Lam and Dai 2012) proposes a decision support system (DSS) for port selection using AHP methodology. But as most of the factors did not have clear quantitative value and the judgments of experts can't be truly reflected, the fuzzy-AHP method and the fuzzy-ANP was proposed to solve the problem. Ying Wang (Wang, Jung et al. 2014) applied FAHP to identify the main factors motivating cruise lines to select specific ports of call. Semih Onut (Onut, UmutR.Tuzkaya et al. 2011) selected container port in the Marmara Region, Turkey via a fuzzy ANP-based approach.

There is a vast and abundant literatures on the study of port selection around the world, but a high percent of researches are focus on the port located in the Asia and Europe, in particular, so many papers concentrates on the port situate in China. For example, Anderson (Anderson, Park et al. 2008) used the ports of Busan and Shanghai as the case to apply the new model. Chou (Chou 2009) is proposed a mathematical programming model for port choice which is tested using a Taiwanese port in China region. Onut (Onut, UmutR.Tuzkaya et al. 2011) is determined seven alternative container ports located in the Marmara Sea, Turkey as the study case. Veldman (Veldman, Garcia-Alonso et al. 2013) did a statistical tests on port choice with respect to the Spanish container ports in Europe. Only few studies pay attention to the port in Africa. Notteboom (Notteboom 2011) finds an application of multi-criteria analysis to the location of a container hub port in South Africa. Onwuegbuchunam (Onwuegbuchunam 2013) investigated empirically port choice criteria of Nigerian shippers. Gohomene (Gohomene, Yang et al. 2016)investigated the attractiveness of ports in West Africa through the development of a container shipping lines' port choice methodology.

Actually, with the further intensification of economic and trade globalization process, African ports became more and more vital in the trade of the world, but the research about those ports still is scarce. Hence, it is of great value to learn African ports. In the meantime, with the rapid development of China-Africa trade, research on China-Africa ports has become an urgent task. In this paper, we choose eight major representative ports along the China-Africa line under BRI, including three Chinese ports (Hong Kong Port, Shenzhen Port and Guangzhou Port), two Indian ports (Mumbai Port and Chennai Port) and three African ports (Dar es Salaam Port, Mombasa Port and Durban Port). These ports are the important nodes in the China-Africa line under BRI, which have strategic geographical positions and huge container throughputs.

3. FANP-QFD model for port selection

In this section, we propose the integrated analytical approach FANP-QFD for port selection considering intermodal transport. FANP enables prioritizing the CRs and the DRs with the relative importance weights obtained by pairwise comparisons and consider the degree of inter-dependences among them (Büyük€ozkan and Berkol 2011). The main purpose of QFD is to establish a 'house of quality' (HOQ), which translates customer requirements (CRs) into design requirements (DRs) and shows the importance degrees of the DRs. This paper builds a HOQ which connects the CRs and DRs to choose the most appropriate port.

The FANP-QFD model for port selection comprises the following main steps.

1. Identify the CRs and the DRs by survey questionnaire, in-depth port case analysis and relevant literature study.
2. Compare CRs in pairs assuming that there is no interaction between the CRs, determine the importance degree of each CR and constructed one importance degree pairwise comparison matrix for CRs (eigenvector W_1).
3. Compare DRs in pairs with respect to each CR assuming that there is no interaction between the DRs, determine the importance degree of each DR and constructed one importance degree pairwise comparison matrix for DRs (eigenvector W_2).
4. Conduct pair-wise comparisons of CRs with respect to each CR, determine the importance degrees of CRs and constructed the inner dependency matrix of the CRs (eigenvector W_3).
5. Similar to step 4, Conduct pair-wise comparisons of DRs with respect to each DR, and constructed the inner dependency matrix of the DRs (eigenvector W_4).
6. Calculate the inter-dependent priorities of the CRs by using formula: $W_C=W_3\times W_1$.
7. Calculate the inter-dependent priorities of the DRs by using formula: $W_A=W_4\times W_2$.
8. Determining the integral priorities of the DRs, reflecting the inter-relationships within the HOQ by calculating of $W_{ANP}=W_A\times W_C$.

4. Case study results of FANP-QFD approach

4.1.1. Customer requirements and design requirements for port selection

The first step of the FANP-QFD approach is to identify the CRs and DRs as the selection criteria for choose the most suitable port. At the beginning of this step, we reviewed relevant literature, analyzed latest sea transportation reports and different port authority polices about various aspects of port select and competition to generate a tentative list of CRs and DRs for port selection. Then, a tentative list of CRs and DRs was used for the interviews conducted with shipping practitioners and researchers to enhance content validity.

In terms of port selection from the customer requirements (CRs), four key factors are considered critical: port cost, efficiency, service level, and intermodal transportation (see Table 1).

1. Port Costs

The most commonly cited criteria for port selection in the literature are costs, which consisting of loading fees, storage costs, demurrage fees, towage fees and so on.

2. Service Level

Ports provide services rather than producing physical products, so port service level is a crucial indicator to measure the comprehensive capacity of the port(Talley and Ng 2016). Port services involve multifarious aspects, main include logistics, finance, entertainment and so on, more detail may include cargo, vessel and vehicle services and some others(Talley, Ng et al. 2014).

3. Port Efficiency

Improving port operations has become a priority for many countries. One of the ways to achieve this objective is evaluating the present efficiency as per the parameters laid down for port industry(Kamble, Raoot et al. 2010). The progress is made in the measurement of port efficiency in relation to port productive activities - port throughput, total area of warehouses, number of Port infrastructures and so on(Wu and Goh 2010, Pjevcevic, Radonjic et al. 2012).

4. Intermodal Transport

Intermodal transport is an important means to achieve port and hinterland connectivity(Xu, Zhang et al. 2018). Especially nowadays port competition is growing severe as the global economy has stepped into a new era characterized by the slower economic growth and weak global trade(Notteboom and Rodrigue 2005). In order to increase or maintain port market share and to stabilize their position in global trade, more ports shift their focus to hinterland freight intermodal transport in terms of port regionalization which help port operators to improve their competitiveness to attract more customers(Roso and Lumsden 2010).

The design requirements (DRs) for port selection considering Intermodal transport includes eight significant factors as follows (see Table 2):

1. Port Charges, which include ship parking berthing fees, cargo port fees, loading fees, cargo storage fees, service fees, etc.
2. Service Quality, such as whether it is 24-hour service, 365 days without holidays, which could greatly improve port operation efficiency.
3. Basic Infrastructure Conditions. Actually with infrastructure becomes more modern and equipped, port congestion will become lower and lower. Measuring the modernization of a port infrastructure mainly includes berth tonnage and quantity, shoreline length, maximum draft, quantity of cargo handling facilities and so on.
4. Information Technology Ability, such as the change from the previous paper written declaration to electronic declaration, port information transmission is becoming more rapid, port service level is improved and the degree of convenience has increased.
5. Port Operational Efficiency. Port operational efficiency is deemed to play an important role among sectors in port development. The improvement of Port operational efficiency will bring about an increase in the service level of the entire port.
6. Total Transit Time, which includes the time from the start of the port to transport the cargo to the port of destination to unload the cargo. Total transit time is matter to customers could receive cargo in time or not, so it is a critical key.
7. Better intermodal integration level. Shippers across the nation discovered in recent years that intermodal transportation proactively addresses the need to meet both current and future business demands as the economy continues to expand.
8. Feeder Network, A possible effect of the integration of intermodal flows could therefore be a better connection of peripheral regions to the network. So there will help to better integrate transportation needs across all freight modes.

Table 1: Customer Requirements for port selection considering intermodal transport.

Notation	Customer requirements
CR1	Port Costs
CR2	Service Level
CR3	Port Efficiency
CR4	Intermodal Transport

Table 2: Design Requirements for port selection considering intermodal transport.

Notation	Design requirements
DR1	Port Charges
DR2	Service Quality
DR3	Basic Infrastructure Conditions (e.g. Berth Availability)
DR4	Information Technology Ability
DR5	Port Operational Efficiency
DR6	Total Transit Time
DR7	Inland Intermodal Transport
DR8	Feeder Network

4.1.2. Case study results by FANP-QFD model

This section discusses the results of the proposed FANP-QFD model to select the most suitable ports. As mentioned before, the FANP-QFD approach is applied to integrate customer needs with design needs and to make comparison of the criteria with prioritized actions. The collected data are in the form of fuzzy intervals instead of a specific value proposed by the decision makers (The scoring rules and mean of fuzzy numbers see table 3). The steps of calculating the significance degree of dimensions are examined as follows:

Step1: compare CRs in pairs by asking shipping lines the following question: “Which CR should be emphasized more in port selection, and how much more?” Assuming that there is no interaction between the CRs, the importance degree of each CR is determined by performing pairwise comparisons with respect to the goal of satisfy the needs of shipping lines. And one importance degree pairwise comparison matrix for CRs (eigenvector W1) is constructed. For instance, the shipping lines in our case study considers that CR1 (Port Costs) is more important than CR2 (Service Level), and has an even stronger impact than CR4 (Intermodal Transport). So the eigenvector of CR1 0.377 is the highest among the four which shows that CR1 is more important, followed by CR2 which has an eigenvector of 0.331. The results of this step are listed in Table 3. The importance degrees of CRs (eigenvector W1) are also depicted in the last column on the right in the HOQ of the case study (see Figure 1).

Table 3: The fundamental scale for making judgments

Criteria	Triangular fuzzy number	Triangular inverted fuzzy number
Equal	(1,1,1)	(1,1,1)
Between equal and moderate	(1,2,3)	(1/3,1/2,1)
Moderate	(2,3,4)	(1/4,1/3,1/2)
Between moderate and strong	(3,4,5)	(1/5,1/4,1/3)
Strong	(4,5,6)	(1/6,1/5,1/4)
Between strong and very strong	(5,6,7)	(1/5,1/6,1/7)
Very strong	(6,7,8)	(1/6,1/7,1/8)
Between very strong and extreme	(7,8,9)	(1/7,1/8,1/9)
Extreme	(9,9,9)	(1/9,1/9,1/9)

Table 4: Pairwise comparisons of CRs (W_1).

W_1	CR1	CR2	CR3	CR4	e-vector
CR1	(1,1,1)	(1.3,2.1,2.7)	(1/2.5,1/1.8,1/1.1)	(2.4,2.9,3.1)	0.377
CR2	(1/2.7,1/2.1,1/1.3)	(1,1,1)	(1.4,2.2,2.7)	(1.7,2.2,2.6)	0.331
CR3	(1.1,1.8,2.5)	(1/2.7,1/2.2,1/1.4)	(1,1,1)	(1/2.3,1/1.8,1/1.2)	0.173
CR4	(1/3.1,1/2.9,1/2.4)	(1/2.6,1/2.2,1/1.7)	(1.2,1.8,2.3)	(1,1,1)	0.119

Step 2: compare each DRs in pairs with respect to each CR. For the sake of determine the importance degree of each DR and construct one importance degree pairwise comparison matrix for DRs (eigenvector W2), one of the questions asked is as follows: “What is the relative importance of DR2 when compared to DR1 with respect to CR1?” Similar questions were asked with the remaining CRs while determining the importance of each DR. Table 5 shows that the results of pairwise comparisons of DRs with respect to CR1. Using the first row of Table 5 as an example, under DR2 (Service Quality), a score of (1/1.7, 1/1.2, 1) is given to indicate DR2's higher importance. DR1 has the highest eigenvector of 0.167, which reflected DR1 is the most important factor among those DRs in the case of CR1. Conversely, DR7 (Inland Intermodal Transport) gets the lowest eigenvector of 0.062, means DR7 is the least appreciated factor in the condition of CR1. We followed the same step to construct other three pairwise comparison matrixes related to the remaining three CRs which are shown in the Appendix. These final computed importance degrees of DRs with respect to each CR are shown in Table 6. In addition, the matrix of eigenvector W2 is presented in the central matrix of the HOQ (see Figure 1).

Table 5: Pairwise comparisons of DRs with respect to CR1 Port Costs.

	DR1	DR2	DR3	DR4	DR5
DR1	(1,1,1)	(1/1.7,1/1.2,1)	(1.1,1.6,1.8)	(2.1,2.6,3.1)	(2.4,3.7,4.6)
DR2	(1,1.2,1.7)	(1,1,1)	(1/4.9,1/3.2,1/2.3)	(1/5.8,1/3.5,1/2)	(2.8,3.3,5.2)
DR3	(1/1.8,1/1.6,1/1.1)	(2.3,3.2,3.9)	(1,1,1)	(3.4,5.5,6.7)	(1/6.3,1/5.1,1/2.8)
DR4	(1/3.1,1/2.6,1/2.1)	(2,3.5,4.8)	(1/6.7,1/5.5,1/3.4)	(1,1,1)	(1/7.1,1/5.2,1/3.6)
DR5	(1/4.6,1/3.7,1/2.4)	(1/5.2,1/3.3,1/2.8)	(2.8,5.1,6.3)	(3.6,5.2,7.1)	(1,1,1)
DR6	(1/4.5,1/2.3,1/1.7)	(1/4.8,1/4.5,1/3)	(1/2.9,1/1.6,1)	(1/3.4,1/2.7,1/1.4)	(1/7.1,1/5.9,1/5.1)
DR7	(1/6.9,1/5.6,1/2.3)	(5.5 7.7 8.5)	(1/4.7,1/3.4,1/1.6)	(1/4.3,1/3.5,1/2.1)	(1/2.3,1/1.9,1/1.3)
DR8	(1/3.5,1/2.5,1/1.9)	(1/3.2,1/2.5,1/1.4)	(1/6.8,1/5.7,1/3)	(1/7.1,1/5.7,1/4.8)	(3.1,4.5,6.2)

(Continued) Table 5: Pairwise comparisons of DRs with respect to CR1 Port Costs.

	DR6	DR7	DR8	e-vector
DR1	(1.7,2.3,4.5)	(2.3,5.6,6.9)	(1.9,2.5,3.5)	0.167
DR2	(3.0,4.5,4.8)	(1/8.5,1/7.7,1/5.5)	(1.4,2.5,3.2)	0.109
DR3	(1.0,1.6,2.9)	(1.6,3.4,4.7)	(3.0,5.7,6.8)	0.174
DR4	(1.4,2.7,3.4)	(2.1,3.5,4.3)	(4.8,5.7,7.1)	0.144
DR5	(5.1,5.9,7.1)	(1.3,1.9,2.3)	(1/6.2,1/4.5,1/3.1)	0.165
DR6	(1,1,1)	(5.7,7.2,8.1)	(2.3,3.5,4.3)	0.107
DR7	(1/8.1,1/7.2,1/5.7)	(1,1,1)	(1/3.2,1/4.6,1/5.3)	0.062
DR8	(1/4.3,1/3.5,1/2.3)	(5.3,4.6,3.2)	(1,1,1)	0.072

Table 6: Column eigenvectors with respect to each CR (W_2).

W_2	CR1	CR2	CR3	CR4
DR1	0.167	0.143	0.201	0.067
DR2	0.109	0.158	0.147	0.118
DR3	0.174	0.116	0.192	0.030
DR4	0.144	0.133	0.141	0.142
DR5	0.165	0.146	0.137	0.165
DR6	0.107	0.110	0.067	0.177
DR7	0.062	0.100	0.047	0.150
DR8	0.072	0.094	0.071	0.151

Step 3: build the inner dependency matrix of the CRs with respect to each CR (eigenvector W3). Pairwise comparison is applied to determine the influence of CR on each other. Consequently, the next question is raised: "What is the relative importance of CR1 when compared to CR2 in achieving CR1, CR2 and CR3 respectively?" If CR has no connection with other CRs, it will not be included in the comparison matrix. All process matrices for pairwise comparisons are shown in the Appendix. And as shown in Table 7, the inner dependency matrix of the CRs with respect to each CR (eigenvector W3) is finished, which is also presented as a matrix on the left side of the HOQ (see Figure 1).

Similarly, the inner dependency matrix of the DRs with respect to each DR (eigenvector W4) can be calculated in the same way, which is determined through analyzing the influence of each DR on other DRs by using pairwise comparisons. Taking Table 8 as an example, the following question is asked: "What is the relative importance of DR2 service quality when compared to DR3 basic infrastructure conditions on achieving DR1 port charges?" DR5 and DR7 which have not influence on DR1 are excluded from the pairwise comparison. Based on Table 8, DR2 is shown to be more important than DR1 but less important than DR3; thus justifying the given score of (1.2, 2.4, 5.3) and (1/6.2, 1/4.4, 1/3.2) respectively. The same technology is applied to construct the pairwise comparison matrices of the remaining DRs with respect to each DR. constraints. Table 9 reveals that the inner dependency matrix of the DRs (eigenvector W4) and the score 0 is given means the DRs are irrelevant. The inner dependency matrix of the DRs (eigenvector W4) is appeared as the roof matrix in the HOQ of the case study (see Figure 1).

Table 7: Inner dependency matrix of CRs (W3).

W_3	CR1	CR2	CR3	CR4
CR1	0.264	0.367	0.285	0.315
CR2	0.323	0.311	0.115	0.188
CR3	0.225	0.078	0.277	0.124
CR4	0.188	0.244	0.323	0.374

Table 8: Pairwise comparisons of DRs with respect to DR1 Port Charges.

	DR1	DR2	DR3	DR4
DR1	(1,1,1)	(1/5.3,1/2.4,1/1.2)	(1.4,2.7,3.2)	(2.8,3.5,4.7)
DR2	(1.2,2.4,5.3)	(1,1,1)	(1/6.2,1/4.4,1/3.2)	(3.5,6.7,7.2)
DR3	(1/3.2,1/2.7,1/1.4)	(3.2,4.4,6.2)	(1,1,1)	(1/6.1,1/4.6,1/3.7)
DR4	(1/4.7,1/3.5,1/2.8)	(1/7.2,1/6.7,1/3.5)	(3.7,4.6,6.1)	(1,1,1)
DR6	(1/4.1,1/3.2,1/2.7)	(1/2.5,1/1.6,1/1.1)	(1/2.9,1/1.5,1)	(2.0,3.6,5.2)
DR8	(1/7.3,1/5.4,1/3.6)	(1/3.6,1/2.4,1/1.7)	(1/4.5,1/2.2,1/1.2)	(1.3,2.7,3.9)

(Continued) Table 8: Pairwise comparisons of DRs with respect to DR1 Port Charges.

	DR6	DR8	e-vector
DR1	(2.7,3.2,4.1)	(3.6,5.4,7.3)	0.269
DR2	(1.1,1.6,2.5)	(1.7,2.4,3.6)	0.247
DR3	(1.0,1.5,2.9)	(1.2,2.2,4.5)	0.186
DR4	(1/5.2,1/3.6,1/2)	(1/3.9,1/2.7,1/1.3)	0.091
DR6	(1,1,1)	(1.9,3.1,4.7)	0.165
DR8	(1/4.7,1/3.1,1/1.9)	(1,1,1)	0.043

Table 9: Inner dependency matrix of DRs (W4).

W_4	DR1	DR2	DR3	DR4	DR5	DR6	DR7	DR8
DR1	0.269	0.296	0.427	0.455	0.000	0.347	0.000	0.330
DR2	0.247	0.346	0.000	0.000	0.000	0.263	0.000	0.000
DR3	0.186	0.000	0.330	0.000	0.000	0.027	0.000	0.000
DR4	0.091	0.000	0.000	0.336	0.175	0.000	0.349	0.108
DR5	0.000	0.000	0.000	0.076	0.535	0.000	0.133	0.000
DR6	0.165	0.359	0.243	0.000	0.000	0.261	0.000	0.194
DR7	0.000	0.000	0.000	0.080	0.291	0.000	0.343	0.091
DR8	0.043	0.000	0.000	0.053	0.000	0.102	0.175	0.277

Step 4: determine the internal dependency priority of the CRs, denoted as W_C ($W_C=W_3*W_1$), which based on the values of W_3 and W_1 we got from previous counting process.

$$W_1 = \begin{bmatrix} 0.377 \\ 0.331 \\ 0.173 \\ 0.119 \end{bmatrix} \tag{1}$$

$$W_3 = \begin{bmatrix} 0.264 & 0.367 & 0.285 & 0.315 \\ 0.323 & 0.311 & 0.115 & 0.188 \\ 0.226 & 0.078 & 0.277 & 0.124 \\ 0.188 & 0.244 & 0.323 & 0.374 \end{bmatrix} \tag{2}$$

$$W_C = W_3*W_1 = \begin{bmatrix} 0.308 \\ 0.267 \\ 0.174 \\ 0.252 \end{bmatrix} \tag{3}$$

Step 5: determine the internal dependency priority of the DRs as W_D ($W_D=W_4*W_2$), and W_4 and W_2 we could obtained from previous procedures.

$$W_2 = \begin{bmatrix} 0.167 & 0.143 & 0.201 & 0.067 \\ 0.109 & 0.158 & 0.146 & 0.118 \\ 0.174 & 0.116 & 0.192 & 0.030 \\ 0.144 & 0.133 & 0.141 & 0.142 \\ 0.165 & 0.146 & 0.137 & 0.165 \\ 0.107 & 0.110 & 0.067 & 0.177 \\ 0.062 & 0.100 & 0.047 & 0.150 \\ 0.072 & 0.094 & 0.071 & 0.151 \end{bmatrix} \tag{4}$$

$$W_4 = \begin{bmatrix} 0.269 & 0.296 & 0.427 & 0.455 & 0.000 & 0.347 & 0.000 & 0.330 \\ 0.247 & 0.346 & 0.000 & 0.000 & 0.000 & 0.263 & 0.000 & 0.000 \\ 0.186 & 0.000 & 0.330 & 0.000 & 0.000 & 0.027 & 0.000 & 0.000 \\ 0.091 & 0.000 & 0.000 & 0.336 & 0.175 & 0.000 & 0.349 & 0.108 \\ 0.000 & 0.000 & 0.000 & 0.076 & 0.535 & 0.000 & 0.133 & 0.000 \\ 0.165 & 0.359 & 0.243 & 0.000 & 0.000 & 0.261 & 0.000 & 0.194 \\ 0.000 & 0.000 & 0.000 & 0.080 & 0.291 & 0.000 & 0.343 & 0.091 \\ 0.043 & 0.000 & 0.000 & 0.053 & 0.000 & 0.102 & 0.175 & 0.277 \end{bmatrix} \quad (5)$$

$$W_D = W_4 * W_2 = \begin{bmatrix} 0.278 & 0.264 & 0.289 & 0.242 \\ 0.107 & 0.119 & 0.117 & 0.104 \\ 0.091 & 0.068 & 0.102 & 0.027 \\ 0.122 & 0.128 & 0.113 & 0.151 \\ 0.108 & 0.102 & 0.090 & 0.119 \\ 0.151 & 0.155 & 0.163 & 0.136 \\ 0.087 & 0.096 & 0.074 & 0.125 \\ 0.057 & 0.068 & 0.050 & 0.097 \end{bmatrix} \quad (6)$$

Step 6: determine the overall priority weight of the DRs as W_{ANP} ($W_{ANP}=W_D*W_C$), which reflecting internal correlation in the HOQ model.

$$W^{ANP} = \begin{bmatrix} 0.267 \\ 0.111 \\ 0.071 \\ 0.129 \\ 0.106 \\ 0.150 \\ 0.097 \\ 0.069 \end{bmatrix} = \begin{bmatrix} DR1 \\ DR2 \\ DR3 \\ DR4 \\ DR5 \\ DR6 \\ DR7 \\ DR8 \end{bmatrix} \quad (7)$$

$$
\begin{bmatrix}
0.269 & 0.296 & 0.427 & 0.455 & 0.000 & 0.347 & 0.000 & 0.330 \\
0.247 & 0.346 & 0.000 & 0.000 & 0.000 & 0.263 & 0.000 & 0.000 \\
0.186 & 0.000 & 0.330 & 0.000 & 0.000 & 0.027 & 0.000 & 0.000 \\
0.091 & 0.000 & 0.000 & 0.336 & 0.175 & 0.000 & 0.349 & 0.108 \\
0.000 & 0.000 & 0.000 & 0.076 & 0.535 & 0.000 & 0.133 & 0.000 \\
0.165 & 0.359 & 0.243 & 0.000 & 0.000 & 0.261 & 0.000 & 0.194 \\
0.000 & 0.000 & 0.000 & 0.080 & 0.291 & 0.000 & 0.343 & 0.091 \\
0.043 & 0.000 & 0.000 & 0.053 & 0.000 & 0.102 & 0.175 & 0.277
\end{bmatrix}
\Rightarrow
$$

$$
\begin{bmatrix}
0.264 & 0.367 & 0.285 & 0.315 \\
0.323 & 0.311 & 0.115 & 0.188 \\
0.226 & 0.078 & 0.277 & 0.124 \\
0.188 & 0.244 & 0.323 & 0.374
\end{bmatrix}
\Rightarrow
$$

Design Requirements (How) / Custmer Requirements (What)	DR1	DR2	DR3	DR4	DR5	DR6	DR7	DR8	Relative importance of CRs
CR1	0.167	0.109	0.174	0.144	0.165	0.107	0.062	0.072	0.377
CR2	0.143	0.158	0.116	0.133	0.146	0.110	0.100	0.094	0.331
CR3	0.201	0.146	0.192	0.141	0.137	0.067	0.047	0.071	0.173
CR4	0.067	0.118	0.030	0.142	0.165	0.177	0.150	0.151	0.119
Overall priorities of DRs	0.267	0.111	0.071	0.129	0.106	0.150	0.097	0.069	

Table 10: the final ranking of the eight selected ports along the China-Africa line under BRI

	Mombasa	Durban	Dar es Salaam	Mumbai	Chennai	Shenzhen	Hong Kong	Guangzhou
DR1	6	4	5	6	6	7	9	8
DR2	5	3	6	4	5	8	7	7
DR3	4	5	3	6	6	7	8	7
DR4	5	4	4	4	5	8	9	7
DR5	2	3	3	4	5	8	8	6
DR6	7	6	6	6	4	7	8	7
DR7	3	4	4	6	6	8	3	9
DR8	4	5	5	6	6	8	5	8
Final Score	4.92	4.22	4.68	5.31	5.35	7.51	7.59	7.42

The study aims to evaluate the priority of the eight major representative ports along the China-Africa line under BRI. In other words, this research is intended to rank the port with regard to the indices proposed by customer needs and design requirement through using fuzzy ANP-QFD, to place the selected ports along the China-Africa line under BRI. As can be seen from Table 10, the result reveals that Hong Kong Port, Shenzhen Port and Guangzhou Port were respectively ranked from first to third, while Durban Port has the lowest ranking. This means that Hong Kong Port, compared to the other eight ports, showed the best performance in the views of shipping lines, and Durban Port is considered the most unsuitable port. It is shows that shipping lines is more willing to select Hong Kong Port, Shenzhen Port and Guangzhou Port as port of departure or port of transshipment, and Dar es Salaam port and Durban port is the worst option.

5. Conclusion

With the integrated process of global economic and trade is accelerating, seaport become more and more important as the transfer center of global cargo. Indeed, the port choice in the multiple-ports region is one of important issues in the international trade container transportation system, which not only with respect to the total transportation cost, but also related to the cargo transfer time, security and other factors. Hence, port selection is a very significant research topic. This paper focus on port selection, and with port competition is becomes more fiercer, hear the customer voices and interpret them accurately if such goal is to be achieved with the right designed and delivered to meet the customer requirements fully became more important. So this study uses an approach that integrates FANP and QFD to combine customer needs and design requirements. In the meantime, this paper investigate the vital factor of port selection through analyzing the interviews conducted with shipping practitioners and researchers and identify four main port selection criteria, mainly include port cost, port efficiency, port service level and intermodal transportation connection, eight sub criterions includes port charges, service quality, basic infrastructure conditions, information technology ability, port operational efficiency, total transit time, inland intermodal transport and feeder network. It provides empirical analysis to support the finding that the most important factors influencing shipping lines' port choice decisions are port cost, followed by service level, and in the sub criterion, the most value indicators is port charges, the second is total transmit time. And the most attractive container ports along the China-Africa line under BRI are Hong Kong Port and Shenzhen Port.

Nevertheless, the paper illustrated how the FANP-QFD approach can be adapted to provide shipping lines with a powerful and transparent decision-making tool to select their most suitable ports from an analytical perspective. The decision support tool can be used to assist in the selection of ports of call for specific shipping lines and to evaluate and benchmark the attractiveness of the competitive ports in the region through a longitudinal study, which is crucial for regions such as China and Africa that experience rapid economic growth and have dynamic business and political environments.

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