IFSPA 2015

INTERNATIONAL FORUM ON SHIPPING, PORTS AND AIRPORTS

EMPOWERING EXCELLENCE IN MARITIME & AIR LOGISTICS: INNOVATION MANAGEMENT & TECHNOLOGY

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Proceedings of the

International Forum on Shipping, Ports and Airports (IFSPA) 2015

Empowering Excellence in Maritime and Air Logistics: Innovation Management and Technology

29 November – 2 December 2015

Hong Kong

Edited By:

Chin-Shan Lu

Petrus Choy

Kee-hung Lai

Y.H. Venus Lun

Tsz Leung Yip

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

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

Preface

The Eighth International Forum on Shipping, Ports and Airports (IFSPA) 2015 was successfully held from 29 November – 2 December 2015, in Hong Kong. The proceedings contained a collection of 38 papers presented during the Conference. The topics covered include shipping economics, port strategy, airport management, logistics development, environmental issues in logistics, port efficiency and competition, and maritime safety and security.

The theme of IFSPA 2015 was "Empowering Excellence in Maritime and Air Logistics: Innovation Management and Technology". It aimed at providing an interactive platform for international academics to discuss important issues related to shipping, ports, and airports. It also advocated the adoption of innovation management and technology for maximisation of competitive advantage, economic benefits and sustainable developments of transport, logistics, shipping and trading industries worldwide. This year the Forum comprised 3 Keynote Sessions, 1 Industrial Session and 14 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 Chile, Greece, Belgium, Canada, Germany, Japan, Korea, Taiwan, Poland, Norway, the U.K., and the U.S.

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

The Conference gratefully acknowledges the support from our Conference Sponsors including Department of Logistics and Maritime Studies of PolyU, Modern Terminals Limited, Tai Chong Cheang Group, Clarksons Platou Asia Limited, The Caravel Group Limited, Yang Ming Line (Hong Kong) Limited and Chinese Maritime Research Institute, especially Routledge for exhibiting at IFSPA 2015.

The IFSPA 2015 Organising Committee greatly appreciates the invaluable contribution from the invited speakers, paper authors, paper reviewers, conference co-organizers and partners.

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

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Market Potential for Transport Airships in Service to Hong Kong

Barry E. Prentice[1] and Yui-yip Lau[2]

[1]Department of Supply Chain Management, I.H. Asper School of Business, University of Manitoba, Canada
[2]Division of Business, Hong Kong Community College, The Hong Kong Polytechnic University, Hong Kong

Abstract

The airplane carriage of international trade is based on complex supply chains and keen competition between hub-and-spoke transport operations. Air transport has developed steadily over the past 70 years into a mature industry. It could now be subject to disruption as technological advances that are leading to the development of transport airships. The emergence of transport airships has the potential to create a significant expansion of the trans-oceanic air freight markets, increase geographical coverage and alter world trade patterns.This paper explores the current state of the Hong Kong airfreight industry and examines how transport airships could influence the future of Hong Kong aviation services. A new conceptual model, the value-density cargo pyramid, is developed to conduct comparative analysis among dedicated cargo airplanes, sea-air logistics, sea containers and transport airships, notably in the busy trade corridors between Hong Kong and Europe, as well as, Hong Kong and North America. Based on reasonable assumptions, transport airships could capture up to a half of the existing "dedicated cargo aircraft" capacity. The race is on to create this new transportation mode and the first-movers will have an advantage. This paper provides valuable insights on an immense opportunity that awaits Asian shippers and could take Hong Kong and all of Asia to a new higher level of development and economic prosperity.

Keywords: Transport airships, Innovation, Value-density cargo pyramid, Hong Kong

1. Introduction

Advances in aerospace technology and the expansion of international trade make transport airships one of the most promising modes of freight transport that has yet to experience widespread use. Transport airships could fly over land or sea, which makes them a challenge to both airfreight and ocean container shipping. They could also overfly ports and deliver to inland distribution centres that obviate the need for trucking or rail moves to the hinterland. The transport airship is a disruptive technology that has the potential to modify freight transport markets, change geographical advantage and alter world trade patterns.

Technological changes that lower transportation costs can stimulate a rapid growth of trade because new opportunities are created. Shippers want to use more of the new transportation alternative because lower freight costs translate into higher profits for their production. At the same time, consumers who find that the prices of their purchases have decreased because of the lower cost transport want to increase consumption. Consequently, transportation innovations generate a double stimulus for trade that is the basis for an explosive demand of new transportation services. This paper explores the potential market for large transport airships that are soon to enter service.

Naturally every mode of transport has its niche. Transport airships will not be carrying heavy low-value commodities, like coal, or extremely time sensitive air cargo, like human organ transplants. In this study, we develop a value-density cargo pyramid to conduct comparative analysis among dedicated cargo airplanes, sea-air logistics, sea containers and transport airships, notably in the busy trade corridors between Hong Kong and Europe, and Hong Kong and North America. Also, we examine how transport airships could influence the Hong Kong aviation service. This paper provides valuable insights on an immense opportunity that awaits Asian shippers and could take Hong Kong and all of Asia to a new higher level of development and economic prosperity. The discussion begins with some background on the development of the air transport industry.

1.1 Development of World Air Freight Markets

The transportation system links geographically separated partners and facilities in a firm's supply chain. Hence, transportation encourages the creation of time and place utility (Coyle, et al., 2013). During the last half of the 20th century, air transport emerged to facilitate trade between persons and to establish the foundation of global supply chains. Increased population mobility achieved through air transport allowed site selection in response to consumer functions and dispersion of urban population agglomerations with consequent development of outlying territories and suburban population.

Isard and Isard (1945) foresaw the development for air transportation in global trade. They proposed that the reduction in the cost of air transport would lead to increased geographic specification, generate mass production economies and reallocate market areas, source material and labor at the lowest cost around the world. Table 1 summarizes the costs of air transport from 1920 to the postwar period (1945). The productivity that they observed has continued to grow with modern aircraft that can carry 20 times more cargo than the largest aircraft available following the World War 2.

Table 1: Costs of Air Transport, 1920-1945

Aircraft	**Payload lbs**	**Direct Cost in Cents, Capacity Payload**		**Total Cost (direct[1] and indirect) in Cents, Capacity Payload**	
		Per Mile	Per Ton-Mile	Per Mile	Per Ton-Mile
DH (1920)	600	26.4	88.1	48.3	161.0
Boeing 40 (mid-twenties)	1,200	20.2	33.7	43.6	72.7
Ford (1925)	3,200	34.1	21.3	69.3	43.3
Lockheed Vega (1929)	1,350	15.1	22.4	38.1	56.5
Boeing 247 (1933)	2,800	21.1	15.1	51.9	37.2
Douglas DC-3 (1936)	5,000	26.7	10.7	68.6	27.4
Postwar Aircraft (2 to 4 years after war)					
Passenger	12,000	N/A	N/A	102	17
Cargo	16,000	N/A	N/A	76	9.5

Source: Isard and Isard (1945)

Kindleberger (1962) refers to impact of transportation innovation as a double stimulation to trade. The rapid growth of the railway industry in the 19th Century is an example of the disruptive nature of transportation innovations. As railway lines were extended into the undeveloped interiors of the continents, farming opportunities emerged that were previously uneconomic. This encouraged trade and settlement away from the coastal regions and made the demand for the railways self-perpetuating.

A similar experience has been occurring over the past three decades in ocean transport. Advances in container ships, double-stack trains and faster port handling equipment have lowered unit costs of ocean transport (Levison, 2006). The cause and effect of trade can easily be confused. However, the economic stimulus of innovations in container shipping cannot be ignored in the rapid growth of trade between Hong Kong, North America and Europe. It is arguable whether the modern economy of Asia would have been possible without the dramatic drop in ocean freight rates that accompanied the growth of containerized ocean shipping.

Comparable advances in technology make airships one of the most promising modes of freight transport. Cargo airships have yet to experience an explosive growth of demand, but the time is near. Prentice and Knotts (2014) describe the international competition to develop the first commercial transport airship that is underway on three continents.

Both technical and economic reasons lie behind the 80-year delay in the commercialization of large freight carrying airships. The principal reason is the huge military investments that were made in fixed-wing aircraft

[1] Direct cost including fuel cost, pilot salaries, maintenance cost, depreciation, insurance and cash reserve

development during the World War 2 and the Cold War period. The aviation industry experienced a turning point in 1949 with the introduction of the de Havilland *Comet* the first modern jet airliner. Civilian airplane manufacturers (e.g., Boeing and Douglas) adapted jet engines and advances in avionics, structures and the design of former military aircrafts into civilian passenger airliners (Wells and Wensveen, 2004).

As explained by Davies (1994) "the [jet] engine efficiency and consequent effect on lower costs, combined with the benefits of higher utilization and productivity" made air transport more economic and affordable to the masses. During this period, fuel was cheap, carbon emissions were of no concern, travellers were focused on speed, trained pilots were plentiful, former military runways became civilian airports and the myriad of airplane safety problems experienced during the pre-war period had been resolved. Hence, no compelling reasons existed to build rigid airships again. They were considered too slow, unsafe and generally obsolete in the "jet age".

The introduction of the *Airline Deregulation Act* of 1978 stimulated competition to attain the objectives of innovation, efficiency, low prices and a wide variety of service options in the air transportation systems (Wells and Wensveen, 2004). It is worth noting that until the mid-1980s no market existed for dedicated cargo airplanes. Most air freight moved in the bellies of passenger airliners, and the high costs limited demand. Over the past 35 years air freight demand has changed. Older passenger jets are modified to carry freight, and the integrators, like FedEx Corporation, United Parcel Service (UPS), DHL Express and TNT Express have created new air cargo markets.

Air transport is considered a barometer of the global economy in the 21st century. Most air-shipped products have high value, high priority or extreme perishability (Coyle, et al., 2013). Air transport supports a wide variety of industries pertaining to food, flowers, clothes, entertainment, technology and leisure. Although air cargo volume represents only 0.5% of global trade by weight, by value air transport generates 34.6% (USD 6.4 trillion) of global trade. Air freight traffic is forecasted to outpace passenger traffic growth in most major world markets. The average annual traffic growth rate (2011-2030) of the Asia-Europe air cargo market could reach 6.2%, while the Asia-North America air cargo market is expected to grow by 6.1% yearly. Globally, the growth rate of airfreight demand now exceeds passenger demand growth (International Civil Aviation Organization, 2013).

A number of air supply chain challenges are emerging among the Asian, European and North American trading partners. The air transport industry relocation, directional imbalances, surface competition, airport curfews, terrorism, fuel prices, air and surface labor stoppages, lack of airport access, currency revaluations, trade restrictions and environmental regulations (International Civil Aviation Organization, 2013).

When it comes to the environment, transport airships are on the right side of history. Grote et al, (2014) observe that the world's airlines burn 5 million barrels of oil daily, and that their contribution to anthropogenic CO2 emissions is increasing. "Even if all the mitigation-measures currently on the table were to be successfully implemented, it is doubtful that a reduction in civil aviation's overall absolute CO2 emissions could be achieved if forecast traffic-growth in the sector is realised." (Grote et al, 2014). The need to cut carbon emissions will ultimately cause the cost of Jet-A fuel to increase. This could be largely avoided by cargo airships. Not only do airships burn less fuel, they are so large that low pressure hydrogen fuel tanks are possible. The potential for a zero-carbon emissions transport airship is already within the reach of existing technology.

1.2 Transport Airship Technology

In the 1930s, the German Zeppelins were able to offer 70 tons of useful lift and travel at 80 miles per hour across the Atlantic Ocean on a regular schedule. All the advances of modern aviation can be applied to a new generation of transport airships. The competitive advantages they could offer are striking. They consume only one quarter of the fuel need for an airplane, and potentially they could operate on hydrogen with zero carbon emissions. Capital costs of the airship are much lower than airplanes and their cargo capacity can be much greater. While airships are much slower than jet airplanes, speed is not as important for freight transport. The first generation of cargo airships is likely to have a payload capacity in the range of 20 and 50 metric tonnes

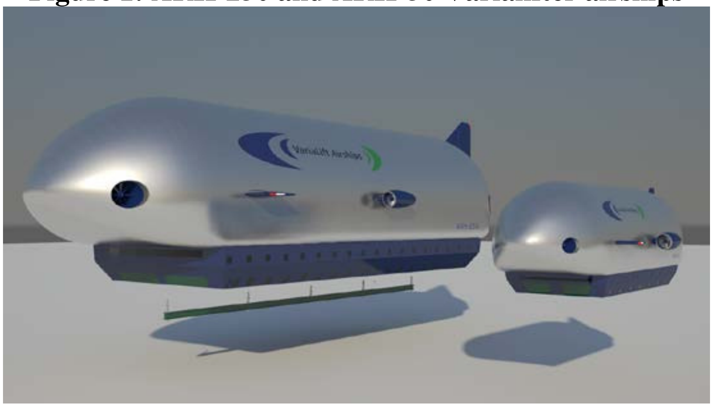
(Prentice and Knotts, 2014). Vehicles with over 100 tonne payloads are on the drawing boards, and will be introduced once the technology becomes established. These larger transport airships will be able to operate over existing intercontinental shipping lanes.

The competition for the dominant design of a transport airship is producing many different variants. Two of the most important elements are buoyancy control and structure. The structural issues revolve around whether the airship will have a rigid, or semi-rigid, structure like a pre-World War 2 airship, or an inflatable non-rigid envelope with gondola and engines attached. Both designs work and each has merits as well as drawbacks (Prentice and Knotts, 2014). For example, the rigid structure is heavier such that the airship must be bigger to carry the same weight, but it is also more robust and less sensitive to temperature changes. The other advantage of the rigid airship is that the lifting gas is contained at atmospheric pressure, whereas the non-rigid (blimps) are pressurized. Consequently, the non-rigid airships leak more than the rigid designs.

Just as ships that can float on the sea, airships float in an ocean of air. The natural buoyancy of an airship reduces the energy needed to transport freight. If cargo is removed however, some method must be used to control the ascendency of the vehicle. Buoyancy control can be obtained in many ways, from releasing gas, pressurizing gas, heating gas, adding/subtracting ballast or using the engines to force the airship up or down. The other approach is to employ a heavier-than-air design that avoids the need for ballast. In this case the airships have an aerodynamic structure that obtains enough lift from engine thrust to carry the cargo. When unloaded the airship remains heavier-than-air eliminating the need for ballast. All these methods are being explored.

Airships enjoy significant economies of size. Larger airships are not that much more expensive to build and they are much more productive. The decline in average total cost is quite sharp as the airships increase in size. Figure 1 presents an illustration of the Varialift airship that is being developed in the U.K. The picture contains two airships. The smaller version (on the right) is designed to lift 50 tonnes and the larger one (on the left) will carry 250 tonnes. These vehicles have very large cargo bays that actually form an important part of the vehicle's structure. They are also very large. The smaller ARH-50 is 150 meters long and 52 meters wide, while the larger ARH-250 is 300 meters long and 110 meters wide. The benefits of size are obvious. While the larger airship is twice the size, it will carry 5 times the cargo weight, and 10 times the cargo volume. On the cost side, the larger airship burns about 2.5 times as much fuel. Crew size is basically the same.

Figure 1: ARH-250 and ARH-50 Varialifter airships



Source: http://varialift.com/

Any airship greater than 50 tonnes lift could cross the Pacific Ocean, but in order to compete with fixed-wing aircraft they must be larger, and likely in the 150-250 tonne range. The reason is utilization. The large rigid airships of the 1930s cruised at approximately 135 kmph, which was the most economical in terms of fuel consumption. Better engines that may change, but in any case, it is only one-sixth the speed of a Boeing 747 airplane. So, in the time required for the airship to complete one circuit, the airplane might do five or six roundtrips. The airplane may be four times more expensive to purchase and burn four times more fuel, but unless the airship carries more than twice the freight, the unit freight cost is not necessarily less. Of course this ignores the nature of the cargo which is the subject of the next section.

Direct comparisons between modes of transport are generally imperfect because each vehicle has its strengths and weaknesses. Airships are slower than airplanes, but their enormous size permits large cargo bays. Whereas an airplane can reach its volume limit (cube-out), before it weighs-out, an airship has the capacity to carry very low density cargo.

It is also true that an airplane cannot load any cargo that does not fit through its door. Transport airships are being designed with large cargo doors that can accept difficult, awkward pieces of freight. Transport airships could reduce economic barriers for the carriage of low-density and low value-perishable cargoes. This is a sizeable market, and one that does not necessarily erode the markets of established carriers.

A question that has vexed airship investors for years is the potential size of the market for transport airships. It is beyond the resources of the authors to estimate the demand for a non-existent vehicle, but we can set out the methodology by which such demand could be considered.

2. Conceptual Economic Model

Inter-continental freight markets cannot offer the variety of options available to shippers in continental markets. On the continents, shippers can choose from barge or coastal shipping, truck, rail and pipelines, as well as airplane transport. Virtually every combination of price and time is available to continental shippers. In the case of trans-oceanic transport however, only two extremes exist: slow and inexpensive marine transport, or very fast, expensive airplanes. Transport airships offer a mid-range of speed and cost for ocean transport that is not currently available.

The latent demand for another option between the extremes of marine and air transport is illustrated by the sea-air shipping combination of ocean container and jet aircraft delivery. Goods are shipped from Hong Kong to European cities via Dubai in about 14 days. The first leg from Hong Kong to Dubai is by container ship, from where the goods are transshipped to air cargo jets and flown to their European destination. This service is advertised to be at least 7 days faster than the sea route and 30 percent less expensive than a pure air freight option. Goods from Hong Kong can also be flown on to North America via Dubai in a total time of 15 days, or travel east across the Pacific and transship via Vancouver to North America in 18 days[2].

The full demand for transport airships is greater than just the sea-air component. Some products may be too low in value to justify the use of a sea-air combination, even at a 30 percent discount over direct air transport. Some merchandise may too perishable to withstand two weeks in transit. Finally, some cargoes may be too bulky to consider airplane transport. Transport airships could take the lower value goods moving by airfreight that are too perishable for sea-air, and the higher value goods moving by ocean containers that are too low in value or too bulky for air transport. In addition, there is a third market segment that does not currently move into intercontinental trade because the product is too perishable for ocean transport, but too low in value to consider sea-air or pure air transport alternatives.

Figure 2 presents a conceptual model of the Value-Density Cargo Shipping Pyramid that illustrates different transportation market segments, with and without transport airships. The pyramid in part (A) suggests the current pattern of shipping via air, sea-air, containers and bulk marine freight. The various cut-off points are estimates of transit time and cubic value volume that defines each market segment. The lower bound for dedicated cargo airplanes could be less than five days and above some minimum value, such as $15 per kilogram ($/kg). Also, the cubic capacity of airplanes may be such that the freight must be greater than some value per cubic centimeter ($/cc). The surcharge on cargo with a lower density would make it uneconomic.

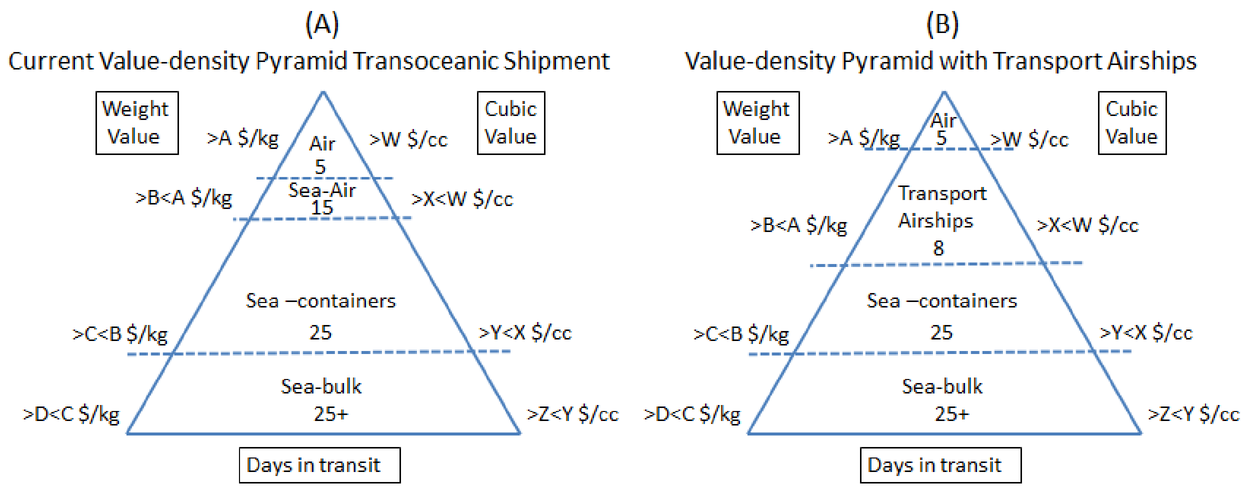
[2] Details on the sea-air service and a map of the routes can be found at http://www.emirates.com.hk/cargoflow.htm. Evereast Logistics also offers a sea-air service from Shenzhen to over 60 destinations in Latin America via LAX and MIA. They claim to be 60% cheaper than Airfreight and 60% faster than LCL http://www.evereastlogistics.com

The segment given to sea-air transport is smaller, and the largest segment would be for containerized cargoes. We do not make any attempt in this paper to quantify the boundaries of this pyramid, which is a larger study on to itself.

Figure 2 part (B) illustrates the transoceanic shipping market with transport airships. These vehicles would take over all the sea-air market. Conceptually, transport airships would eat into the lower part of the existing cargo airplane market. A lot of freight does not have to be delivered in hours, if can be delivered in days rather than weeks. Many freight shippers would be happy to wait three or four days longer if the price were significantly lower. Air cargo moving in the belly holds of passenger airplanes would not likely be affected because this is a by-product that is priced to fill the available space.

Transport airships would also attract the higher value goods moving by ocean containers. Ocean shipping times from Asia to Europe or North America are at least 30 to 40 days from dispatch to receipt. This is long time for inventory-in-transit, but products that do not have the value to density ratio required to be shipped economically by jet aircraft have only the sea-air choice. A significant market should exist for transport that could offer 5 to 10 day service, even if the cost is double or triple container shipping rates.

Figure 2: Value-Density Cargo Shipping Pyramid



A third component of the cargo that would move by transport airship is that which could be newly generated by the opportunity of a faster, low cost shipping method. No attempt is made to draw the value-density pyramids according to scale, but it is reasonable to expect that transport airships would induce larger volumes of some trade goods, and open entirely new markets for others. For example, the types and volumes of perishable food products that move between Southeast Asia, Europe and North America are very limited. Similarly, fully assembled upholstered furniture and large pieces of molded plastic are seldom moved long distances. These and other goods could become as widely traded intercontinentally, as they are continently traded.

As an indication of market size, we examine the air freight market of Hong Kong next in section 3. Hong Kong could become a representative air cargo market in the Asia Pacific regions for the following reasons (Hong Kong International Airport, 2014):

- Free port policy
- Strategic geographic location
- Excellent connectivity and accessibility
- Extensive IT application
- High safety and security
- Sufficient cargo capacity
- Efficient cargo operations
- Competitive costs

3. Hong Kong Air Cargo Market: A Case Study

Hong Kong has been a gateway to China[3] since the First Opium War (1839-1842) and a growing air cargo market hub for Southeast Asia. The Hong Kong International Airport is located at the heart of the Asia Pacific region where the aircraft can move towards over half of the world's population within 5 flying hours. Apart from its geographical advantages, Hong Kong has well-established financial, institutional and legislative settings, as well as, skilled labor and an entrepreneurial culture. Hong Kong could be significantly transformed from a regional relay hub into a world-class cargo center (Wang, 1998).

Before 1978, China adopted a closed door policy that adversely affected the major economic linkage between China and the Western world for almost 30 years. The centrally planned and self-sufficient economy induced in a small volume of trade via Hong Kong. The economic turning point emerged when Deng Xiaoping introduced the Open Door Policy in 1978 (Tang et al., 2014). The economic reform towards a 'socialist market economy with Chinese characteristics' resulted in an upward growth trend in air cargo (Wang, 1998; Tang et al., 2004). To implement such policies, China established special economic zones in Shenzhen, Zhuhai, Shantou, Xiamen and Hainan in 1980. Hong Kong's manufacturing sector moved northwards to China and then spread to the entire Pearl River Delta (PRD) region. In 1984, China further opened 14 coastal cities including Dalian, Qinhuangdao, Tainjin, Yantai, Qingdao, Lianyungang, Nantong, Shanghai, Ningbo, Wenzhou, Fuzhou, Guangzhou, Zhanjiang and Beihai. Hence, Hong Kong could absorb large amount of air cargoes from a vast hinterland, notably the PRD provinces.

In the Asia Pacific trading area, Hong Kong serves as a regional relay aviation hub for domestic and re-export trading activities. In the volume of re-export trade, Asian countries have occupied for 67%, North America and Western Europe have contributed to 10% respectively (Wang, 1998). In order to cater demand for a consolidated air cargo service in Hong Kong's manufacturing economy, Hong Kong Air Cargo Terminals Limited (HACTL) commenced its terminal operations at Kai Tak International Airport in 1976 (HACTL, 2015).

HACTL established a wholly-owned subsidiary (Hacis) to provide on airport operations support and delivery in Hong Kong and intermodal connection to Southern China regions. The extension enlarged HACTL's capacity from 350,000 to 680,000 tonnes per year. Subsequently, HACTL built a second air cargo terminal. The annual air cargo throughput reached 1.7 million tonnes by 1997 (HACTL, 2015).

The air cargo market has experienced an explosive growth in the Asian regions in the 2000s. The airport relocation marked a turn point in Hong Kong's historical development. HACTL invested US$1 billion in SuperTerminal 1 in 1998. The cargo handling capacity has increased significantly. Asia Airfreight Terminal (AAT) owns 2 air cargo terminals with 1.5 million tonnes of handling capacity (AAT, 2015). In 2013, Cathay Pacific Services Limited (CPSL) operated the third independent air cargo terminals with a designed annual throughput of 2.6 million tonnes (CPSL, 2015).

Hong Kong is recognized as one of the world's leading international airports, handling about 4.13 million tonnes of cargo in 2013. By weight, air cargo represents around 1.3% of Hong Kong's total cargo throughput. However, it contributes 37% of its total external trade value of HK$2,853 million in 2013. In the coming years, the cargo volumes would be increased by 2.7% per year (source: Hong Kong International Airport, 2014).

The HKSAR government has recognized that the air transport logistics industry is one of the four pillars in Hong Kong economy. Also, Hong Kong has joined PRD Airports Cooperation Forum with Guangzhou Baiyun International Airport, Macau International Airport, Shenzhen Baoan International Airport and Zhuhai Airport to increase air networks coverage within PRD area. Figure 3 illustrates the air cargo throughput at HKIA since 1998. While the rapid growth faltered during the international banking crisis of 2008-2009, the lost traffic was quickly recovered. However, the rate of air freight growth has stagnated during the worldwide recession that followed.

[3]Beginning with the First Opium War (1839-1842), the excellent natural harbour made Hong Kong the gateway and anchorage for southern China.

Figure 3: The air cargo throughput at HKIA

Year	Tonnage ('000 tons)
1998	1,629
1999	1,974
2000	2,241
2001	2,074
2002	2,479
2003	2,642
2004	3,090
2005	3,402
2006	3,579
2007	3,742
2008	3,627
2009	3,347
2010	4,128
2011	3,938
2012	4,025
2013	4,127

Source: Hong Kong International Airport, 2014

Hong Kong is the cargo hub for aviation logistics business among Southern China regions because of its excellent geographical location and comprehensive intermodal transportation system. Hence, the aviation logistics firms can shorten shipment time via Hong Kong (Lau, 2009). Compared with Manila, the required flight time is 10% shorter; Compared with Taiwan, the required flight time is 6% shorter; Compared with Singapore, the required flight time is 36 % shorter. The total fuel cost that could be saved is HKD 40 million per year (Schwieterman, 1993). Further details on the locational advantage on Hong Kong as an air transport hub are presented in Appendix A.

Transport airships could be seen as either a threat or an opportunity to the Hong Kong International Airport. On the one hand, transport airships could replace many cargo airplanes, or worse the airships could fly beyond Hong Kong and land closer to the ultimate markets. On the other hand, if this technology is coming anyway, then a wise manager would develop a strategy to maximize its use.

It would appear that Hong Kong has more to gain than potentially lose. First, as an established hub, Hong Kong has many feeder routes and businesses involved in logistics. Like all transport hubs, the long distance between major centres will be served by very large transport airships, while the feeder routes use smaller vehicles. The hubs are consolidation and sorting centres that make most efficient use of the larger vehicles and reduce the cost of shipping from smaller centres. There is no reason why Hong Kong could not evolve to be the largest transport airship hub in Southeast Asia.

Second, effective hubs are those that offer transshipment opportunities. With the availability of ocean container, land routes and air transport, Hong Kong is well-positioned to offer transshipment services via large airships. It might be that goods delivered across the ocean in a transport airship could be delivered in the belly freight of a flight to Nimbo, or other smaller Chinese second tier of cities.

Finally, Hong Kong has time to prepare itself for the opportunities that transport airships provide. Although airships are very large, they can operate from the shore as easily as from an airport. However, they need many services that airports offer, from security to re-fuelling. This is a new industry that is likely to create many more jobs than it eliminates. Those locations that take a proactive stance can be expected to benefit the most from the first-mover advantage that new technology offers.

4. Conclusions

Our paper identifies a new research agenda in the development of transportation and the aviation industry. Transport airships are soon to become a reality and trans-oceanic trade routes are extremely attractive for their use because of the limited options open to shippers: slow and cheap marine, or fast and very expensive aircraft. The new technology of transport airships will definitely influence the future of aviation industry (Wells and Wensveen, 2004). Transport airships could take at least half of the existing "dedicated cargo aircraft" capacity. Obviously, belly freight on passenger air liners would not be affected because it is a byproduct of the passenger service. An estimate of the space available in cargo airplanes, multiplied by the daily ton-miles for each aircraft would provide a target for the future transport airship demand.

Density and value have an impact on modal choice. Whatever the size of the sea-air market, just below its current density-value cut off is a much larger airship transport market of products that currently move in ocean containers. Higher value-low density ocean container freight could migrate to transport airships. In addition, some products go by sea because of their bulkiness and shape. The exact volume of traffic that would migrate from ocean containers to transport airships is open to conjecture. One factor that might influence this volume is port congestion and labour disputes. Transport airships do not need to stop at the coast, or at established airports for that matter. They could continue inland to new locations that are developed expressly to transfer goods from transport airships to trucks for final delivery.

Another potential market for transport airships is the demand created by the stimulation of trade. For example, buyers who can only purchase products for special occasions or seasonally, e.g. strawberries, want to buy more because the improvement of transportation has lowered its price and they can be sourced from more locations year-round. Similarly, the sellers benefit from the lower cost of transport because they get paid more for what they produce. Consequently, the double stimulus of supply and demand, yield a large market increase for the new mode of transport.

The double stimulus of trade is not a zero-sum game in which the gains to the airship are losses from airplanes or ocean containers. Although the magnitude is unpredictable, entirely new demands can be anticipated that do not even exist today. A case might be made for bulky, labour-intensive manufactured products that are now sold only on a local basis, such as upholstered sofas.

Both technical and economic reasons lie behind the 75-year old delay in the commercialization of large freight carrying airships, but in the 21st century no obvious technological barriers remain. The race is on to create this new transportation mode and the first-movers will have an advantage. Ultimately, it is our prognostication that the transport airship industry will be as large as the current commercial airline industry.

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Appendix A

From the geographical perspective, Hong Kong is located at an optimal location in Asia Pacific region for air transport. Air logistics firms can deliver cargo to over half of the world's population within 5 flying hours. The shorter flight hours allow the air logistics firms to achieve the greatest cost advantage by using HKIA. The airport is also located with 12 to 15 hours flight time to all the major financial and commercial centres of the world. To explain this in detail, the flight hours between Asian hubs and intercontinental hubs and the flight hours between regional hubs are presented in Table A1 and Table A2, respectively.

According to the Hong Kong International Airport (2014), the HKIA is connected to over 180 locations in over 50 countries. Thus, HKIA can attract more than 100 airlines (including 19 freighters) operated in HKIA. Aircraft land on and off the airport around 1,000 times per day. In order to achieve sustainable competitive advantage, the Airport Authority Hong Kong invested HKD4.5 billions to enlarge its apron for new large aircraft A380 and the Low Cost Carrier. 10 additional Cargo Stands have been built in 2007. In addition, the third runway is planned for launch in 2023. HKIA anticipates that the cargo volumes will average 6% growth per year in the coming 20 years (Hong Kong International Airport, 2007).

Table A1: Flight hours between Asian hubs and intercontinental hubs

	Hong Kong	Shanghai	Guangzhou	Singapore	Seoul	Taipei	Bangkok	Tokyo	Osaka	Dubai
Paris	13h40m	11h55m	12h50m	13h10m	11h45m	X	12h	12h30m	12h25m	7h50m
Frankfurt	12h50m	11h10m	12h15m	12h40m	11h20m	13h40m	11h15m	11h40m	12h10m	6h45m
Los Angeles	13h15m	14h45m	12h50m	18h05m	11h	11h35m	15h30m	9h55m	10h25m	X
New York	15h45m	17h30m	X	23h	13h40m	17h50m	17h10m	12h30m	X	10h10m
Chicago	14h32m	13h25m	X	20h30m	12h50m	X	X	12h20m	12h2m	X
Amsterdam	12h40m	10h45m	14h35m	13h25m	X	X	11h45m	12h	9h55m	7h10m
London	12h45m	12h00m	X	13h35m	11h35m	11h40m	12h05m	12h35m	12h30m	7h35m

Sources: Cathay Pacific Airways Limited (2006)

Table A2: Flight hours between regional hubs

	Hong Kong	Shanghai	Guangzhou	Singapore	Seoul	Taipei	Bangkok	Tokyo	Osaka	Dubai
Hong Kong	X	2h20m	45m	3h45m	3h20m	1h40m	2h40m	4h05m	3h45m	7h50m
Shanghai	2h20m	X	2h	5h15m	1h45m	X	5h30m	2h50m	3h20m	X
Guangzhou	45m	2h	X	3h55m	3h10m	X	3h	4h20m	3h20m	7h55m
Singapore	3h45m	5h15m	3h55m	X	7h20m	6h30m	2h25m	8h10m	7h30m	9h15m
Seoul	3h20m	1h45m	3h10m	7h20m	X	2h30m	6h20m	7h55m	1h40m	12h15m
Taipei	1h40m	X	X	6h30m	2h30m	X	4h10m	3h15m	7h03m	9h50m
Bangkok	2h40m	4h20m	3h	2h25m	6h20m	4h10m	X	6h10m	6h30m	6h50m
Tokyo	4h05m	2h50m	4h20m	8h10m	7h55m	3h15m	6h10m	X	1hr05m	12h45m
Osaka	3h45m	2h05m	3h20m	7h30m	1h40m	2h35m	6h30m	1h05m	X	12h
Dubai	7h50m	X	7h55m	9h15m	12h15m	9h50m	6h50m	12h45m	12h	x
Total	28h10m	30h5m	30h5m	54h05m	46h15m	33h35m	43h35m	50h35m	46h13m	90h

Sources: Cathay Pacific Airways Limited (2006)

The tangible cost between Hong Kong International Airport, Guangzhou Baiyun International Airport and Shenzhen Baoan International Airport, according to GHK (Hong Kong) Ltd (2006), is compared in Table A3. The air logistics firms could obtain the greatest cost advantage if they consider in selecting HKIA. Hong Kong air cargo business benefited from the first mover advantage over their neighbouring competitors.

Table A3: Comparison of Tangible Cost between Hong Kong International Airport, Guangzhou Baiyun International Airport and Shenzhen Baoan International Airport

Airport / Destination	Hong Kong International Airport	Guangzhou Baiyun International Airport	Shenzhen Baoan International Airport
Los Angeles	HK$19,750	HK$24,900	HK$27,000
Frankfurt	HK$27,150	HK$28,400	HK$29,300
Tokyo	HK$18,800	HK$18,900	HK$19,300

Sources: GHK (Hong Kong) Ltd (2006)

Risk Assessment of Dangerous Goods in Airfreights

Wen-Jui Tseng[1], Show-Hui Huang[2], Mei-Zhi Zheng[1] and Wen-Kai Hsu[1]*

[1]Department Shipping &Transportation Management, National Kaohsiung Marine University, Taiwan, R.O.C.
[2]Department of International Business & Trade, Shu-Te University, Taiwan. R.O.C.

Abstract

The purpose of this study is to assess the risk of dangerous goods in air cargo transportation. Based on the relevant literature, the risk factors (RFs) of dangerous goods in airfreight operations were first investigated. A revised risk matrix based on a fuzzy AHP model was then proposed to assess those RFs. Finally, to validate the research model, the airfreight operations of dangerous goods in Taiwan was empirically investigated. The results can provide practical information for the airfreight operators to improve the safety performance of dangerous good airfreights. Further, the revised risk matrix can provide methodological reference for risk assessment research.

Keywords: airfreight, risk matrix, dangerous good, fuzzy AHP

1. Introduction

Recently, with the rapid progress in technology, new electronic products have been continuously developing. This increase the styles and types of dangerous goods (DGs) in international trades, which leads to threaten the airfreight safety. For example, on July 28, 2013, a Boing 747-48EF cargo aircraft of Asiana Airline's 991flight from Seoul to Shanghai crashed in the sea 107 km west of Jeju Island. The investigation report of air accident indicated that cargos on fire is the main reason causing the crash. The report also pointed out that the cargo aircraft was carrying a total of 58tons of newly developed electronic products, including a large number of mobile phones, lithium batteries, semiconductors, light-emitting diodes and LCD monitors (Zheng, 2014). In the regulations of IATA (International Air Transport Association), all of those cargos are classified as DGs.

Generally, an air accident may result in an expensive loss. Not only the aircraft and cargo damages, the lives of passengers and crews could also be endangered. Further, a aircraft crash may cause severe destructions to the ground, including buildings, facilities and even the lives of a large number of residents. Since the losses from a air accident can be enormous, many air authorities in the world have paid attention to reducing the incidence of air accidents. Specifically, after 911 terror attacks, more and more global governments emphasis on the issues of risk assessment and safety management in air transports.

In the relevant literature about DG airfreights, most studies focus on the determinates of air safety or the investigation of air accidents. Few articles discuss about risk assessment and prevention issues. In practice, risk assessment is the initial step of preventions and is also the most important step (Chang, 2013). For risk assessment, risk matrix is one of the most popular assessment tools. A risk matrix displays the basic properties, "consequence" and "likelihood" of an adverse risk factor (RF) and the aggregate notion of risk by means of a graph (Duijm, 2015). In traditional risk matrix, both the consequence and likelihood are measured by category scale such as negligible = 1, serious = 2, catastrophic = 3 for consequence measurements, and almost impossible = 1, probable = 2, often = 3 for likelihood measurements. In practice, such a discrete scale measurement may limit its applications, such as the consistency between the risk matrix and quantitative measures (Cox, 2008; Levine, 2012), the subjective classification of consequence and likelihood (Cox, 2008; Smith et al., 2009), etc. Thus, for improving the performance of risk management, a risk matrix with a continuous scale for the measurements of consequence and likelihood should be considered (Duijm, 2015).

The purpose of this paper is to discuss the risk assessment of dangerous goods in airfreights. Specifically, this paper proposes a revised risk matrix with a continuous scale to assess the risk of DG airfreights. In this paper, based on the relevant literature, the risk factors (RFs) of DGs in airfreight operations were first investigated. A fuzzy AHP model is then conducted to assess those RFs, by which the revised risk assessment model is proposed. Finally, to validate the research model, the airfreight operations of DGs in Taiwan was empirically investigated. The rest of this paper is organized as follows. Section 2 describes the literature reviews. Section 3 explains the research method. The results are then discussed in Section 4. Finally, some general conclusions and limitations for further research are given.

2. Literature Reviews

2.1. Risk Metric

Risk is often expressed in terms of a combination of the *consequences* of an event together with the associated *likelihood* of its occurrence (ISO, 2009). Risk consequence is regarded as an loss or severity of an organization if a risk event occurs (NPSA, 2008). Traditionally, consequence is generally described by a category scale and rated, such as "negligible, minor, moderate, serious, and critical" (Waters, 2007; NPSA, 2008), "very low, low, medium, high, and very high" (Tzannatos, 2003) and "insignificant, minor, moderate, major, and catastrophic" (Chang et al, 2014). While, risk likelihood is defined as the probability of a risk event occurrence (Elky, 2006) and also conventional described by a category scale. For example, some studies categorize the likelihood by "rare, unlikely, possible, likely, and almost certain" (NPSA, 2008; Chang et al, 2014).

For risk assessment, risk matrix is one of the most popular tools. A risk matrix facilitates assigning a discrete risk category to each combination of consequence and likelihood, i.e. it provides a mapping of consequence and likelihood to risks (Duijm, 2015). In a traditional risk matrix, each pair of the consequence category and likelihood category can be assigned a different risk attribute. If there are m consequence categories and n likelihood categories, one can discriminate $m \times n$ different, discrete risk categories. Further, it is normal to divide the cell of the risk matrix in areas with fewer categories, often by using colors, such as green, yellow and red, to represent low risk (L), medium risk (M) and high risk (H), or by deriving a risk score based on the ordinal values of consequence and likelihood, such as the multiplication of the ordinal numbers of the likelihood and consequence category. For example, Figure 1 is a 4×4 risk matrix with 16 risk categories which are classified three types of risk scales by their risk scores. The risk score for each category are showed in the parentheses. The risk categories with risk score 1~ 2 is identified as low risk scale (L); 3~ 9 as medium risk scale (M); 12~16 as high risk scale (H).

Likelihood					
	4	M (4)	M (8)	H (12)	H (16)
	3	M (3)	M (6)	M (9)	H (12)
	2	L (2)	M (4)	M (6)	M (8)
	1	L (1)	L (2)	M (3)	M (4)
		1	**2**	**3**	**4**
		Consequences			

Figure 1: A traditional 4×4 risk matrix

2.2. The limitations of traditional risk matrix

Although risk matrix has been applied widely in risk assessment, there are some limitations to its practical applications. Duijm (2015) reviewed relevant studies and proposed six limitations about risk matrix in practical applications, in which most studies focus on discussing the following three issues:

(1) Consistency between the risk matrix and quantitative measures, and, as a consequence, the appropriateness of decisions based on risk matrices (Cox, 2008; Levine, 2012).

(2) The subjective classification of consequence and probability (Cox, 2008; Smith et al., 2009).

(3) The definition of risk scores and its relation to the scaling of the categories (linear or logarithmic) (Levine, 2012; Ni et al., 2010; Franks and Maddison, 2006).

For improve the above limitations, some revised risk matrices based on a continuous probability consequence map was thus proposed (e.g. Chang et al., 2014; Ale et al., 2015; Duijm, 2015). Differ from the discrete risk scales in traditional risk matrices, these revised risk matrices proposed continues risk scales to identify risk factors (RFs). Most of the revised risk matrices address risk maps displaying risk factors depicted by pairs of frequency and consequence, and several nonlinear lines based on the product of the risk likelihood and the risk consequence (Tzannatos, 2003; Woodruff, 2005; Zou et al., 2007; Chang et al., 2014) are employed to divide the risk scale, into three type of risks, generally, including low risk, medium risk and high risk. Those revised risk matrices based on a continuous probability consequence map indeed improve some limitations of traditional risk matrices. However, they could not resolve one of the main limitations: the subjective classification of consequence and probability (Duijm, 2015)

2.3. The risk factors of dangerous goods in airfreights

In practice, the main members in airfreights include shippers, airfreight forwarders and air carriers. Further, if the air safety is taken into account, the related public units for security checks (such as customs) can also be regarded as one of the main members in airfreights. Since the purpose of this paper is to discuss the DG airfreights, the risk factors (RFs) in the units of security checks is considered. In practice, the safety factors can be identified based on the operations of the four main members in airfreights. For example, a investigation of Federal Aviation Administration (FAA) in 2012 for 5,454 air accidents indicated that 40% air accidents results from the regulation violations of airfreight members. The most popular regulation violations includes shippers know the DG specifications unclearly, violating package specification etc. Further, the implementation of check procedures from airfreight forwarders and air carriers is also one of the determinants of DG airfreight safety (Zheng, 2014).

The relevant studies regarding risk factors of DGs depend on the model of transports, including aviation, ship transport, and land transport. For example, Chang et al. (2006) prioritizing the management issues of moving DGs by air transport. The article proposed 17 RFs grouped into 6 management constructs (functional areas), and each associated with the responsibility area of a corresponding government organization or industry sector. The six constructs includes: (1) Policies and regulations (Ministry of Transportation and Communications), (2) Security oversight audit (Civil Aeronautics Administration), (3) Loading and stowage (Airline operators), (4) Freight handling (Airfreight forwarders), (5) Surveillance and inspection (Aviation Police Bureau) and (6) Shipper awareness (shippers). The result concluded that the safety factor "insufficiency in detection of hidden or undeclared dangerous goods" has the highest overall priority. Further, the sector Taiwan’s Ministry of Transportation and Communications should take the highest priority to provide sufficient safety structures and regulations for managing other sectors in the DG transportation chain.

Ellis, J. (2011) investigated the accidents and incidents occurring during transport of packaged dangerous goods by sea. The proposed safety factors in the article includes the preparation of the goods for transport, packaging, stuffing containers, and loading the ship. The result indicated that 66% of failure causes could be categorized as deficiencies with packaging and containment, such as loose closures, corrosion, malfunctioning valves, overfilling, etc. A further 25% were caused by failures occurring during loading of cargo transport units, including inadequate blocking or bracing.

Batarlienė and Jarašūnienė (2014) explored the accidents and incidents occurring during the transportation of dangerous goods by railway transport. The article proposed five safety factors to the safety of DGs by rail transportations, including impact of hazardous substances while loading and unloading, risk of fire and explosion, speed of transportation and driver's competence, natural conditions and conformance of containers and vans with the requirement regulations. The result suggests that the first three factors should be given special attentions.

3. Research Method

The research framework of this paper is shown in Figure 2. The risk factors (RFs) of dangerous goods in airfreights are first identified. A fuzzy AHP is then constructed to assess both weights of the RFs' consequence and likelihood. Based on those two weights, a revised risk matrix is finally proposed, by which airfreight managers may make policies to improve the performance or risk management.

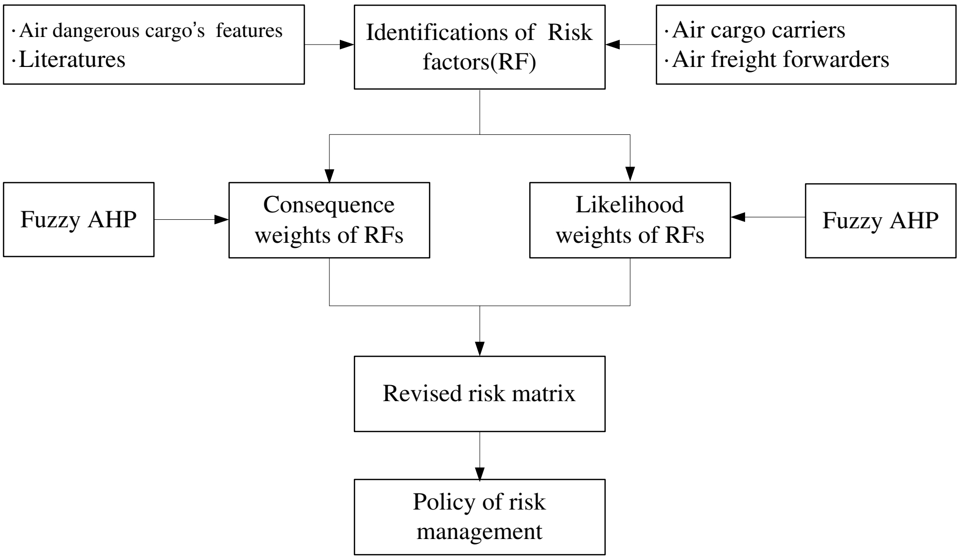

Figure 2: Research framework

3.1. Identification of risk factors

Since the main members in the DG airfreights includes: shippers, forwarders, customers and carriers, this paper first examined their operational features. Further, based on those features and relevant literature (Chang, 2006; Ellis, 2011; Batarlienė and Jarašūnienė, 2014), four RF constructs by the members' operations were finally identified as follows.

(1) Shipper operations (SO): This construct includes four SFs: DG trucking, staffs' DG knowledge, packing operations and DG declarations.

(2) Forward operations (FO): This construct includes four SFs: unfamiliarity partners' operations, labeling and marking of DG information, DG check procedure and controlling the consolidation operations.

(3) Customs operations (CO):This construct includes four SFs: equipments, inspectors' qualification and experience andupdate of new DG timely

(4) Air carrier operations (AO): This construct includes four SFs: Unfamiliarity of DG procedures, container packing operation and cabin stowage operation.

Based on the above identifications, a two-layer of hierarchy structure of RFs for DG airfreights was constructed. To improve the practical validity of the RFs, two practical senior airfreight operators (one airfreight forwarder and one carriers) were invited to revise those RFs and check if any important RFs were missed. Further, they also checked the independences among all of the RFs. After several rounds of discussions and revisions, including deleting one item, combining two items and adding one new item, the final hierarchy structure of the RFs, shown in Table 1, contains four dimensions of SFs for the first layer and 14 RFs for the second layer.

Table 1: The safety factors (SFs) of dangerous goods in airfreights

Layer1: construct	Layer 2: safety factors (SFs)	
Shipper operations (SO)	SO1	Insufficient packaging.

	SO2	Insufficient knowledge of dangerous goods
	SO3	Inappropriate trucking.
	SO4	Not really declaring dangerous goods.
Forwarder operations (FO)	FO1	Unfamiliarity of partners' (shipper, customs & carrier) operations.
	FO2	Inadequate labeling and marking of DG information.
	FO3	Failing to regulatory checks
	FO4	Failing to control the consolidation operations.
Customs police operations (CO)	CO1	Insufficient or inadequate equipments
	CO2	Lack of qualified and experienced inspectors.
	CO3	Failing to update new DG products timely.
Air carriers operations (AO)	AO1	Failing to regulatory container packing.
	AO2	Failing to regulatory cabin stowage.
	AO3	Unfamiliarity of regulatory procedures of DGs.

3.3. Questionnaire design

In this paper, an AHP questionnaire (Saaty, 1980) with a nine point rating scale was designed to measure the subject's perceived consequence and likelihoodon each RF respectively. Based on the hierarchical structure of RFs in Table 1, an AHP questionnaire with five criteria and 14 sub-criteria was created. To validate the scale, the questionnaire was then pre-tested by the two previous airfreight operators to check if the statements were understandable.

3.4. Research sample

Since the airfreight of dangerous goods is a highly professional problem, the subjects were qualified on two criteria: (1) having a licence of dangerous goods in airfreights, and (2) having practical experience in airfreights of dangerous goods. Further, to enhance the validity of the survey, an assistant was dispatched to help the respondents fill out the questionnaire. In Taiwan, the members of both Taipei and Kaohsiung airfreight forwarder associations contain over 90% airfreight forwarders. Based on their assistants, 30 senior forwarder stuffs with DG licences and experiences were interviewed to answer the AHP survey.

For each of the 30 samples, the Consistency Index (CI) was first employed to test the consistency of its pairwise comparison matrix. The results indicated five samples with CI > 0.1 were highly inconsistent (Saaty, 1980). Thus, those five respondents were then asked to revise their answered survey. This step was performed repeatedly until all of the 5 surveys were consistent. The profiles of the validated 30 respondents' characteristics are shown in Table 2. It shows all of the subjects have at least 6 years of work experience with over 90% respondents having at least one year of DG experience. Further, all of the respondents have DG licences. Note the remarkable qualifications of the respondents endorse the reliability of the survey findings.

3.5. The weights of risk factors.

In is paper, 30 pairwise comparison matrices are obtained for each comparison of RFs in each layer. In the past, most of relevant studies employed arithmetic mean or geometric mean to present multiple subjects' opinions. However, those two means are sensitive to extreme values. Thus, a fuzzy number is considered to integrate the 30 subjects' perceptions in this paper. Firstly, the geometric mean was employed to represent the consensus of respondents (Satty 1980; Buckley 1985). A triangular fuzzy number characterized with minimum, geometric mean and maximum of the measuring scores was then used to integrate the 30 pairwise comparison matrices into a fuzzy positive reciprocal matrix. Then, based on this matrix, a fuzzy AHP approach (Hsu, et. al., 2015) was employed to weight the RFs for both of the measurements of respondents' perceived "likelihood" and "consequence".

Table 2: Profile of the respondents

Features	Range	Frequency	%
Company scale (million NT$)	Under 50	20	66.67
	51~100	8	26.67
	Above 100	2	6.67
Job title	President level	2	6.67
	Manager level	16	53.33
	Senior sales	12	40.00
Educational Level	College	8	26.67
	University	20	66.67
	Master and Above	2	6.67
Age (Years)	31-40	14	46.67
	41-50	12	40.00
	51-60	2	6.67
	Above 60	2	6.67
Experience for Airfreights (years)	Under 5	0	0.00
	6-10	18	60.00
	Above 10	12	40.00
Experience for dangerous goods (years)	1-5	22	73.33
	6-10	6	20.00
	Above 10	2	6.67
Dangerous good license	Yes	30	100.00
	No	0	0.00

The results of the RFs' weights for likelihood measurement are shown in Table 3, in which the global weights of the RFs in the first layer are shown in the second field, and those of the RFs in the second layer are shown in the last field. The results indicate, for the first layer of RF constructs, SO (33.79%) has the highest consequence weight and followed by AO (28.26%), FO (19.75%) and CO (18.21%). While, for the second layer of RFs, the RFs with higher consequence weight are: SO2 (10.99%), AO3 (10.89%) and SO4 (10.18%). Likewise, the results of the RFs' weights for consequence measurement are shown in Table 4. The results indicate, for the first layer of RF constructs, the RFs with highest weight is SO (38.27%), and followed by FO (29.34%), CO (16.52%) and AO (15.87%). While, for the second layer of RFs, the RFs with higher consequence weight are: SO4 (10.84%), SO1 (10.51%) and SO2 (9.78%).

Table 3: The likelihood weights of risk factors (RFs)

Layer 1 RFs	The global weights of Layer 1	Layer 2 RFs	The local weights of Layer 2	The global weights of Layer 2
SO	**33.79**	SO1	17.10	5.78
		SO2	32.54	**10.99**
		SO3	20.23	6.83
		SO4	30.14	**10.18**
FO	19.75	FO1	24.29	4.80
		FO2	20.27	4.00
		FO3	28.03	5.54
		FO4	27.40	5.41
CO	18.21	CO1	31.18	5.68
		CO2	33.20	6.05
		CO3	35.62	6.49
AO	**28.26**	AO1	29.89	8.45
		AO2	31.56	8.92
		AO3	38.55	**10.89**

Note: The boldfaced numbers present the RFs with higher weights.

Table 4: The consequence weights of risk factors (RFs)

Layer 1 RFs	The global weights of Layer 1	Layer 2 RFs	The local weights of Layer 2	The global weights of Layer 2
SO	**38.27**	SO1	27.47	**10.51**
		SO2	25.55	**9.78**
		SO3	18.66	7.14
		SO4	28.32	**10.84**
FO	**29.34**	FO1	26.98	7.92
		FO2	19.05	5.59
		FO3	28.25	8.29
		FO4	25.72	7.55
CO	16.52	CO1	31.13	5.14
		CO2	35.16	5.81
		CO3	33.71	5.57
AO	15.87	AO1	27.36	4.34
		AO2	34.29	5.44
		AO3	38.35	6.09

Note: The boldfaced numbers present the RFs with higher weights.

3.6. The revised risk matrix

Obviously, an risk factor (RF) with higher likelihood weight and consequence weight should be a RF with higher risk. Based on this concept, a Risk Index (RI) is thus constructed by the product of consequence weight and likelihood weight (Cox, 2008, Levin, 2012). Let LW_i and FW_i be the consequence weight and likelihood weight of *i*th RF respectively. Then, the Risk Index of *i*th RF is defined as

$$RI_i = LW_i * FW_i,\quad i = 1,2,...,n \tag{10}$$

Finally, the RI can be normalized as:

$$RI_i = \frac{LW_i * FW_i}{\sum_{i=1}^{n}(LW_i * FW_i)} \times 100\%,\quad i = 1,2,...,n \tag{11}$$

Based on Equation (11), and the RFs' likelihood and consequence weights in Table 3 and Table 4, the RIs for each RF can be found as the fourth field of Table 5. The result indicates that the RF with the highest risk is SO4 (15.19%), and followed by SO2 (14.79%), AO3 (9.13%) and SO1 (8.36%).

Table 5: The classification of risk factors (RFs)

RFs	Likelihood weights (%)	Consequence weights (%)	Risk Index (%)	Risk class
SO4	**10.18**	**10.84**	**15.19**	**E**
SO2	**10.99**	**9.78**	**14.79**	
AO3	**10.89**	6.09	**9.13**	**H**
SO1	5.78	**10.51**	**8.36**	
SO3	6.83	7.14	6.71	**M**
AO2	8.92	5.44	6.68	
FO3	5.54	8.29	6.32	
FO4	5.41	7.55	5.62	
FO1	4.80	7.92	5.23	**L**
AO1	8.45	4.34	5.05	
CO3	6.49	5.57	4.98	

CO2	6.05	5.81	4.84	
CO1	5.68	5.14	4.02	
FO2	4.00	5.59	3.08	

According to the RIs, a two-dimensional of revised risk matrix is constructed to assess the RFs' classes. The matrix is shown in Figure 3, in which the consequence weight is depicted on the x-axis and the likelihood weight on the y-axis. Further, based on the mathematic function of Equation (11), three decreasing curves with different RI means divides the matrix into four quadrants. The first curve with mean RI = 7.14%, found by averaging all of the 14 risk factors' RIs, divides all of the RIs into two groups. Group one contains 4 RFs' RIs (SO4, SO2, AO3 and SO1), by which the second curve's mean RI =11.87% is obtained by averaging their RFs' RIs. Likewise, averaging the rest of 10 RFs' RIs in the other group, we have the third curve' mean RI = 5.25%.

The results, shown in Figure 3, indicate that two RFs (SO4 and SO2) classified as E (extreme risk), two RFs (AO3 and SO1) as H (high risk), four RFs (SO3, AO2, FO3 and FO4) as M (medium risk), and six RFs as L (low risk). For the first two classes of RFs (i.e. SO4, SO2, AO3 and SO1), the airfreight operators should pay more attention to improve their safety.

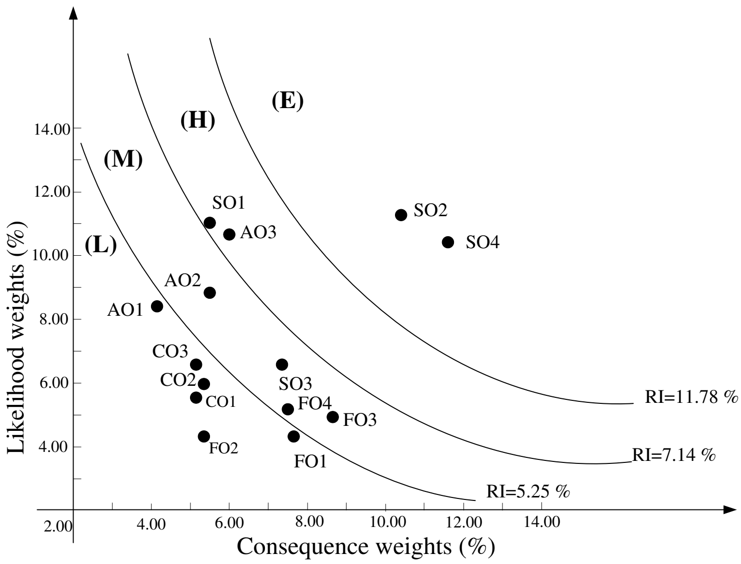

Figure 3: The revised risk matrix

4. Discussions

In traditional risk matrix, both the consequence and likelihood are measured by category scale and subjects need to score each RF directly by their perceptions. In practice, it may be difficult for subject to score a RF precisely in such a directly scoring measurement. While, a relatively comparable scoring may be more feasible for evaluating a RF's consequence and likelihood degrees. For example, a respondent could be easily to compare which RF occurs more likely for two RFs rather than to score each of the two RF's likelihood directly. This paper adopted a fuzzy AHP approach, which is a relatively comparable scoring, to assess the RFs can raise the measurement validity of subjects, leading to improve the performance of risk matrix.

Furthermore, the relevant literature indicated that the traditional risk matrix with a discrete scale measurement may limit its applications, such as the consistency between the risk matrix and quantitative measures (Cox, 2008; Levine, 2012), the subjective classification of consequence and likelihood (Cox, 2008; Smith et al., 2009), etc. Thus, most of risk matrixes colour the cells in the matrix to classify RFs. In this paper, based on the fuzzy AHP approach, the RFs are weighted with continuous scores, by which a revised risk matrix with a continuous scale was then proposed to assess the RFs' classes. The revised risk matrix can solve the limitations of traditional risk matrix and improve its practical applications.

The empirical result shows that two RFs are classified as extreme risk: SO4 (Not really declaring dangerous goods) and SO2 (Insufficient knowledge of DGs); and two RFs are classified as high risk: AO3 (Unfamiliarity of regulatory procedures of DGs) and SO1 (Insufficient packaging). This result implicates that shipper's operations, which contains three E-H risk class of RFs (SO4, SO2 and SO1), is the RF construct with the highest risk. Furthermore, two E-H risk class of RFs (SO2 and AO3) are related to DG knowledge. Based on the result, this paper further conducted a post-interviews with three senior airfreight forwarders, and proposes suggestions for improving the safety of DG airfreights as follows.

a) Shipper regulations

Currently, the relevant regulations clearly define the airfreight forwarders and carriers are required to have a DG license for operating DG transports. However these regulations are not available for DG shippers. In DG airfreight process, shippers is the starting operators. Thus, any of the shippers' miss would affect the following operators' operations. For example, if shippers fail to declare DGs or declare the DGs inaccurately, the airfreight forwarders and carriers may thus violate the DG rules unknowingly. For improving the safety of shippers' operations, we have the following suggestions:

i. Increasing penalty

In USA, according to the rule of Sec 2614 of Toxic Substances Control Act of 1976, for an inaccurate declaration of commercial chemicals, shippers will be fined US$ 25000. However, in Taiwan, the fine is less than 5000 US$. Generally, a light punishment may not discipline shippers' behavior effectively. Thus, a heavier penalty could be consider to regulate shippers' operations for safety.

ii. License policy

Regulating the shippers' staffs in import and export departments must have DG Licenses in performing the tasks of DG airfreights.

iii. AEO policy

Including DG licenses in the qualifications when shippers apply to be a AEO (Authorized Economic Operator) member. This may ensure each of AEO shipper members have the ability to transport dangerous goods.

b) Improving the DG knowledge of airfreight operators

In practice, trainings is one of the most popular ways to improve employees' professional knowledge. According to Civil Aviation Regulations in Taiwan, the airfreight operators, including shippers, carriers, airfreight forwarders, airport service, air cargo terminal and aviation polices, should establish a training program and assessment system for their employees work for DG airfreights. Further, this program and system should be performed per two years regularly. This paper suggests that customs authorities may include this program and system as a assessment item in the AEO certification that pushes airfreight operators to improve their employees' DG knowledge.

5. Conclusion

In the relevant literature about DG airfreights, most studies focus on the investigations of air accidents. Few articles discuss the preventions of hazards. In practice, risk assessment is the initial step of the hazardous preventions. The purpose of this article is to assess the risks of DGs in airfreights. The result constructs 14 risk factors (RFs) for DG airfreights, which can provide information for relevant studies abut DGs transports. Further, based on a fuzzy AHP approach, a revised risk matrix with a continuous scale was proposed to assess the RFs' classes. The revised risk matrix may provides theoretical references for methodological research in risk assessments.

Furthermore, for validating the practical applications of the proposed revised risk matrix, the airfreight operations of DGs in Taiwan was empirically investigated. The result identifies four E-H risk factors (RFs), in which the shipper's operations contains three RFs, and two RFs are related to DG knowledge. Based on this result, some management implications and suggestions are proposed. The results may provide practical information for airfreight operators to make policies in improving the performance of safety in DG airfreights.

In this paper, 30 airfreight forwarders in Taiwan were empirically surveyed to validate the proposed model. For enhancing the validity of the questionnaire investigation, this paper adopted an interview survey instead of a mailed survey. Thus, the validity and reliability of the findings in this paper could be endorsed. However, for better confirmation of the empirical results, more representative samples may be necessary in future research.

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Lotka-Volterra Model for Competition Dynamics among Airports: An Empirical Analysis

Yi-Xin Yang, Xin Yun, Gang Xie and Shou-Yang Wang

Institute of Systems Science, Academy of Mathematics and Systems Science, CAS, Beijing, China

Abstract

As a critical factor to promote the economic development of regions and even nations, air transport is a valuable and interesting topic in the research community. Meanwhile, the analysis of competition relationship among airports is of the great significance in this field. In this paper, the three-species Lotka-Volterra competition system which includes the dynamics of competition mechanism into a diffusion process is applied for characterizing the dynamic competition relationship among three main airports in Greater Pearl River Delta of China, Hong Kong International Airport (HKIA), Guangzhou Baiyun International Airport (GBIA) and Shenzhen Bao'an International Airport (SBIA). Through analyzing time series of (from Jan. 2006 to Mar. 2015) monthly air passenger throughput, the empirical results show that the complex competitive relationships among the airports are changing during different periods. We find that HKIA has a strongly promoting effect on the development of nearby airports to a large extent, and the potential uptrend of passenger throughput in GBIA is obvious and grounded in reality. However, in many cases the airports have shown the density-dependent feature. In order to prevent the possible reduction, the expansion and modernization of the airport infrastructure deserve much attention of the airports and government. Besides, equilibrium analysis of the passenger throughput is completed by investigating the equilibrium point and its stability. Our analysis shows that the equilibrium point has not yet been reached in the current circumstances, but the passenger throughput will converge the equilibrium point. The evolution analysis of competitive relationship and equilibrium solutions in this paper can support the decision-making of policy makers on the development and construction of airports.

Keywords: Competition relationship, Airports, Lotka-Volterra model, Equilibrium Analysis

1. Introduction

As the development of airports is an important issue in air transport industry, much attention has been paid to the competition analysis between various airports due to the fact that the airport is not an individual that can operate independently. Deregulation of air transport and the growth of low-cost carriers (LCCs) has resulted in intensified competition and lower prices. In order to objectively analyse the present situation of an airport, one must take the external environment and the competitors into consideration. Besides lower air fares of one airport due to the increasingly intensified competition, the improved road infrastructure has also made a contribution to higher levels of traffic leakage from the geographical catchment areas of an airport to nearby airports. Here, the geographical catchment areas mean the area closer to the one airport under consideration than any other airport. Traffic leakage occurs when travellers avoid using the local airport in their regions, and use other (out-of-region) airports to take advantage of lower fares and more convenient airline services" (Fuellhart, 2007). This tendency has been found in many areas such as the Europe and United States (Lian and Rønnevik, 2011). This paper will focus on the considerable issue of competing relationship among multiple airports in Greater Pearl River Delta of China from the passenger throughput aspect.

As a matter of fact, passenger throughput of an airport rely on various factors, and the airport-choice issue in metropolitan areas with multiple airports has been discussed in a variety of studies, which are mainly aimed at investigating the primary determinants of airport-choice decisions from the microcosmic point of view, including airport access time, traffic condition, flight frequency, differences in air fare, provision of services to airlines, type of aircraft, purpose of travel (Harvey, 1987; Başar and Bhat, 2004; Hess and Polak, 2005; Ishii et al., 2009). In contrast, this paper will analyse the competition dynamic among multiple airports through considering the whole network starting from the final performance, which effectively avoids the subjectivity and imperfection of the analysis on various determinant factors.

Meanwhile, there have been a few related works on airport competition analysis from different perspective (Starkie, 2002; Bush and Starkie, 2014; Adler and Liebert, 2014). Pels et al. (2000; 2003) proposed a nested logit model to investigate the airport competition and airline competition and applied the model in a case study for the San Francisco. Pels et al. (2009) have followed the methodology of Pels et al. and analysed the issue of the competition between full-service airports and serving adjacent airports with low-cost airlines in the Greater London using econometric estimation of demand structure. Barbot (2009) has developed a model of airport and airline competition and make a full use in three-stage game to analysis incentives for vertical collusion between airports and airlines. Kroes et al. (2005) have derived the Airport Network and Catchment area Competition Model (ACCM) to forecasts of future air passenger volumes not only based on generic passenger demand growth but also explicitly taking account of choices of air passengers among competing airports in Europe. In fact, some case studies about competitive relationship analysis have also been accomplished. Lian and Rønnevik (2011) discuss the airport competition based on the case study and aimed to identify the true reasons that regional airports in Norway are losing market shares to nearby main airports on flights to the national capital, Oslo, and on international travel via Oslo. There are still lots of researches focus on the effect of competition between airports or airlines (Chi-Lok and Zhang 2009). As we can see, a large proportion of related works are mainly qualitative analysis and lack of an effective model or method to characterize the competition state.

The analysis clue in this paper is based on the rationale that the relationships of three airports could be well understood by viewing them as species competing for resources due to the logical hypothesis that the uptrend of passenger throughput may follow the Logistic curve if there is no other airports as competitors. It is reasonable because the flow of travellers is more and more frequent with the increasing globalization and rapid economic development. Meanwhile, as many researchers pointed out that the limited resources can choose among different airports not only based on vicinity but also a wide range of other airport level-of-service (LOS) attributes in different parts of the world including China (Bradley, 1998; Loo, 2008), we can reasonably assert that airports in a multi-airport region may occur traffic leakage and have potential competition relationship with each other for limited passengers. On this basis, Lotka-Volterra equation that explains the growth of cells or species in ecology system can incorporate the dynamics of competition mechanism between species into the diffusion process and analyse the competition state effectively. The relationship of competing species is classified by natural selection, survival of the fittest and predator-prey interaction under restricted space and resources. In fact, Lotka-Volterra model has gained recognition in research community due to its capacity to model the interaction between the competing species and has been applied to analyse the competition relationship in some fields besides for ecology. Lee et al. (2005) studied the dynamic relationship between two competing markets at the Korean stock market, the Korean Stock Exchange and Korean Securities Dealers Automated Quotation, using daily empirical index data in different years. Kim et al. (2006) empirically clarified the dynamic competitive relationship between the cellular and PCS services using the Lotka-Volterra model through considering cellular service and PCS service as two competing species under the single environment. However, as far as we know, almost all of the related empirical studies make use of the two-species Lotka-Volterra model. And we will extend it to three-species situation innovatively in this paper and apply it to the competition analysis of airports. One point should be illustrated that although there are altogether five airports in Greater Pearl River Delta Economic Area of China, we merely analyse the competing relationship among HKIA, GBIA and SBIA considering that the Macau International Airport and Zhuhai Jinwan International Airport has obviously lower throughputs than the other three main airports and may generate relatively insignificant impacts on others.

The purpose of this paper is to analyse the evolution of the competitive relationship between three main airports in the Greater Pearl River Delta and find out the equilibrium solution of the airports' competitive relationship, which may make benefit of the government decision making and the airport's own development ambition design. In this paper, we creatively apply three-species Lotka-Volterra system for modelling the interaction between competing species and making an analysis of the competition process of airports which compete with each other. We also concern whether there is an equilibrium point of airports’ competition state and whether the equilibrium point has been reached comparing with the current situation. The remainder of this paper is organized as follows. Section 2 will introduce the basic methodology we use to analysis the competitive relationship. We will represent a brief description of the data in Section 3. And Section 4 will show the empirical results of competition and equilibrium analysis. In Section 5, we conclude this paper and give some policy implications.

2. Methodology

2.1. The Lotka-Volterra Model

Many species competing for limited food or source is an interesting phenomenon not only in nature but also in society. As a model of population dynamics analysis, Lotka-Volterra competition system has received much attention and been studied extensively due to its theoretical and practical significance. Lotka-Volterra proposed by Lotka and Volterra can characterize the dynamic relationship between populations in ecology (Dublin and Lotka, 1925; Volterra, 1926; Pielou, 1969) and have a full application in various field (Lee et al., 2005; Du and Sam, 2006; Kim et al., 2006). Based on the ecological theory, the population of a certain group will increase according to the Logistic growth curve when this group is alone in an ecosystem. When the two or multiple competing populations exist simultaneously, the growth of one group will be influenced by another's existence, and the growth rule will follow the Lotka-Volterra competition system. Of course, every real world system is complicated so that it is hardly explained exactly by a mathematical model. Nevertheless, the Lotka-Volterra model can effectively capture the main characteristics in this competing system.

In this paper, we use the three-species Lotka-Volterra model to analysis the competition relationship among Hong Kong International Airport, Guangzhou Baiyun International Airport and Shenzhen Bao'an International Airport. The three-species Lotka-Volterra competition system can be described by the following differential equations.

$$\begin{cases} \dfrac{dX_1}{dt} = X_1(r_1 - c_{11}X_1 - c_{12}X_2 - c_{13}X_3) \\ \dfrac{dX_2}{dt} = X_2(r_2 - c_{21}X_1 - c_{22}X_2 - c_{23}X_3) \\ \dfrac{dX_3}{dt} = X_3(r_3 - c_{31}X_1 - c_{32}X_2 - c_{33}X_3) \end{cases} \tag{1}$$

The parameters in the Lotka-Volterra model represent different meanings and the dependence of the growth rates between all species. The intrinsic growth rate $r_i (i = 1,2,3)$ is the logistic parameter for the species *i* when it is living alone. $c_{ii} (i = 1,2,3)$ is the rate of intra-specific competition related to the size for the species *i*, and $c_{ii} > 0 (i = 1,2,3)$ represents that the population of species *i* is density-dependent. $c_{ij} (i \neq j)$, is the rate of inter-specific competition. There are several different types of competition relationship between two species. According to the signals of $c_{ij} (i \neq j)$, the corresponding type of competitive roles are shown in Table 1.

Table 1: The three types of competitive relationship.

c_{ij}	c_{ji}	Types	Explanations
+	+	pure competition	both species suffer from each other's existence
+	0	amensalism	One that cannot receive any benefits
			inflicts harm to the other
-	-	mutualism	populations derive a mutual benefit
-	0	commensalism	one benefits from the other who is neither
			benefited nor harmed
0	0	neutralism	no interaction among populations

In order to analysis the competition dynamics among the airports, it is necessary to convert the Lotka-Volterra competition system, which is a continuous time differential equation, into discrete time version. Based on the work by Leslie (1958), the discrete time Lotka-Volterra model can be written as follows.

$$\begin{cases} X_1(t+1) = \dfrac{\alpha_1 X_1}{1+\beta_1 X_1+\gamma_1 X_2+\delta_1 X_3} \\ X_2(t+1) = \dfrac{\alpha_2 X_2}{1+\beta_2 X_1+\gamma_2 X_2+\delta_2 X_3} \\ X_3(t+1) = \dfrac{\alpha_3 X_3}{1+\beta_3 X_1+\gamma_3 X_2+\delta_3 X_3} \end{cases} \tag{2}$$

According to the Leslie's derivation, the parameters α is the logistics parameters for the single species *i* when it is living alone. The other parameters represent the effect of each species on the rate of another. The specific correspondences between coefficients of continuous time equation and those of discrete time version are as follows.

$$\begin{array}{l} r_i = \ln \alpha_i, i = 1,2,3 \\ c_{11} = \dfrac{\beta_1 \ln \alpha_1}{\alpha_1 - 1}, c_{12} = \dfrac{\gamma_1 \ln \alpha_1}{\alpha_1 - 1}, c_{13} = \dfrac{\delta_1 \ln \alpha_1}{\alpha_1 - 1} \\ c_{21} = \dfrac{\beta_2 \ln \alpha_2}{\alpha_2 - 1}, c_{22} = \dfrac{\gamma_2 \ln \alpha_2}{\alpha_2 - 1}, c_{23} = \dfrac{\delta_2 \ln \alpha_2}{\alpha_2 - 1} \\ c_{31} = \dfrac{\beta_3 \ln \alpha_3}{\alpha_3 - 1}, c_{32} = \dfrac{\gamma_3 \ln \alpha_3}{\alpha_3 - 1}, c_{33} = \dfrac{\delta_3 \ln \alpha_3}{\alpha_3 - 1} \end{array} \tag{3}$$

2.2. Estimation

Consider the non-linear form of the discrete Lotka-Volterra model, the non-linear least-square method is applied to estimate the parameters of the model in this paper by Eviews software. The numeric Marquardt algorithm related to the non-linear least-square method is an iterative procedure, which controlled by choosing the proper convergence criterion and the maximum number of iterations (Amemiya, 1983). In our paper, the convergence criterion value and the maximum number of iterations are set to 0.0001 and 500 respectively, which imply the iteration stops if the maximum of the percentage changes in the coefficients is smaller than 0.01% or the number of iteration exceeds 500. (Press et al., 1996).

2.3. Equilibrium Analysis

The analysis of competitive relationship by the Lotka-Volterra model can provide information as regards what the equilibrium state is and how the trajectory changes over time. Additionally, the stability of the equilibrium can be identified.

In equilibrium, the rate of X_i change must be zero because there are no simultaneous changes over time for each competitor. Thus, condition holds for any *i=1,2,3*, as follows:

$$\frac{dX_i}{dt} = 0. \tag{4}$$

Then the following system of equations is obtained:

$$\begin{cases} X_1(r_1 - c_{11}X_1 - c_{12}X_2 - c_{13}X_3) = 0 \\ X_2(r_2 - c_{21}X_1 - c_{22}X_2 - c_{23}X_3) = 0 \\ X_3(r_3 - c_{31}X_1 - c_{32}X_2 - c_{33}X_3) = 0 \end{cases} \tag{5}$$

The necessary conditions that there exists an equilibrium point are $dX_1/dt = 0, dX_2/dt = 0, dX_3/dt = 0$, that is

$$\begin{cases} r_1 - c_{11}X_1 - c_{12}X_2 - c_{13}X_3 = 0 \\ r_2 - c_{21}X_1 - c_{22}X_2 - c_{23}X_3 = 0 \\ r_3 - c_{31}X_1 - c_{32}X_2 - c_{33}X_3 = 0 \end{cases} \tag{6}$$

We denote the solution of the above equations as X_1^*, X_2^*, X_3^*. If $dX_i/dt < 0$ when $X_i > X_i^*$, which means the population of X_i will decrease and converge to X_i^*, and in the meantime, $dX_i/dt > 0$ when $X_i < X_i^*$, which means the population of X_i will increase and converge to X^*_i, it can be said that this competition system has an equilibrium point.

The equilibrium level and stability of the equilibrium can be identified if the equilibrium equation is solvable. Of course, the equilibrium state does not always exist in practice, which means that we should make some extra analysis based on the actual situation.

3. Data

Hong Kong International Airport, Guangzhou Baiyun International Airport and Shenzhen Bao'an International Airport is seen as three species competing at the air transportation market in Greater Pearl River Delta Economic Area of China in this paper. And we assume that the competitive situations of the airports correspond to the conditions of the Lotka-Volterra competition system. Data on monthly passenger throughput, of the three airports are obtained from the database of Wind Information. The sample period is from January 2006 to March 2015, which is the latest data we can get.

Considering the fact that amount of social and economic phenomena including the passenger throughput of airports have seasonal cycles and these seasonal patterns about airports that barely stem from competition factors may produce adverse effects on our competition analysis, it is necessary to adjust this component to capture what underlying trends are in the data. Therefore, we first handle the sample data with X-12-ARIMA method based on the moving average method and choose the natural logarithm of the seasonal adjustment term as the sample data in order to analyze the competition relationship clearly. The trend charts of the passenger throughput of each airport and corresponding seasonal adjustment terms are shown in Figure 1. In general, rising tendency all steadily appear in passenger throughput of three airports.

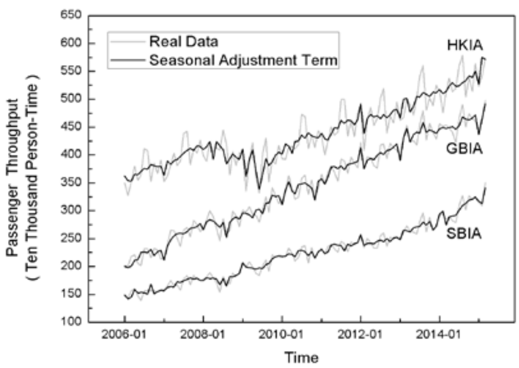

Figure 1: Passenger Throughput of HKIA, GBIA and SBIA from Jan. 2006 to Mar. 2015

Then the ADF unit root test is conducted to establish the stationary properties of the sample data and the results in table 2 show the hypothesis that the level sequences have a unit root is accepted, but the hypothesis that the 1st difference series have a unit root is rejected for various time period and indicators, which means all 1st difference series are stationary. Though the error correction model that has been used in previous studies (Yap and Lam, 2006) can capture the relationship of airports in part, there are still some limitations considering the individual nonstationary series. In the meanwhile, the error correction model cannot simultaneously combine all sample features to derive the competition relationship between different populations. The Lotka-Volterra model which characterizes the whole relationship shows satisfactory applicability and effectiveness.

Table 2: Results of ADF Test

	Time Period	HKIA	GBIA	SBIA
Passenger	Jan. 2006- Dec. 2008	0.8761(0.8938)	2.0291(0.9882)	1.8335(0.9819)
	Jan. 2009- Dec. 2011	1.2408(0.9423)	2.6655(0.9975)	1.8700(0.9834)
	Jan. 2012- Mar. 2015	3.8468(0.9999)	2.3589(0.9947)	2.8953(0.9987)
Passenger (1st difference)	Jan. 2006- Dec. 2008	-9.1380(0.0000	-7.6322(0.0000)	-10.4950(0.0000)
	Jan. 2009- Dec. 2011	-7.8024(0.0000)	-7.4957(0.0000)	-7.6331(0.0000)
	Jan. 2012- Mar. 2015	-8.0311(0.0000)	-7.9703(0.0000)	-7.7651 (0.0000)

4. Empirical Results

The Pearl River Delta (PRD) in Guangdong province, China, which located in the low-lying area surrounding the Pearl River estuary, is one of the most densely populated regions in the world and is known with Yangtze River Delta (YRD) as the main hubs of China's economic growth, including Guangzhou, Shenzhen, Zhuhai, etc. As a megalopolis, the population of Pearl River Delta reaches 40 million until 2014. In 1990s, as the cooperation with Hong Kong and Macau is gradually enhanced, the new concept of Greater Pearl River Delta (GPRD), including the Pearl River Delta, Hong Kong and Macau, is derived to promote the benign competition between economic areas. Meanwhile, the convenient transportation network of an economic area that the government want to establish can improve the connection of the metropolis and accelerate the economic circulation within Greater Pearl River Delta economic region, which may eventually put the economic development of the whole area in motion. The Greater Pearl River Delta is metropolitan area covered by 5 main civilian airports, including Guangzhou Baiyun International Airport, Shenzhen Bao'an International Airport, Hong Kong International Airport, Macau International Airport and Zhuhai Jinwan International Airport. As a matter of fact, there are three international airports (Guangzhou Baiyun International Airport, Shenzhen Bao'an International Airport and Hong Kong International Airport) occupying the vital position of GPRD's transportation network. Under the brief methodology we present in Section 2, Lotka-Volterra model is applied for capturing the competition system as well as analyzing the competition relationship among HKIA, GBIA and SBIA in detail.

4.1. The Analysis of Competition Relationship

In this part, we first assume that the competitive situations of the airports correspond to the conditions of the Lotka-Volterra competition system. Specifically, there are three competing species, Hong Kong International Airport, Guangzhou Baiyun International Airport and Shenzhen Bao'an International Airport. Then the competing environment is the air transportation market and the limited recourse is the passengers. Through observing Figure 1, there may be a structure change point in early 2009 from the most intuitive point of view, which is mostly ascribed to the great shock of the Sub-prime Mortgage Credit Crisis. Further, the results of Chow breakpoint test show that there exist a breakpoint in January, 2009 in most sample data sets. In order to analyze the competition dynamics among HKIA, GBIA and SBIA during different periods and take the absence of the breakpoint in January, 2009 into consideration, we divide the sample data into three parts almost equally: the first period is from January, 2006 to December, 2008, the second is from January, 2009 to December, 2011, and the third is from January, 2012 to March, 2015.

Then we will describe the competition dynamics during the three periods respectively. The nonlinear least square method is used to estimate the coefficients of the Lotka-Volterra model by the software tool Eviews. However, the some t-statistics indicate the effects of one airport on the development of another one are not statistically significant. It is reasonable to isolate the non-significant factors from the equation, and the estimation results are presented in Table 3. According to the corresponding equations between coefficients of continuous time Lotka-Volterra model and those of discrete time version, the estimation of the parameters of the discrete model can be derived and shown in Table 4. From the estimation results, we can find the competition relationship vary from different time periods with a great extent. On the whole, with the rapid growth of air transport resources, three major airports in Greater Pearl River Delta of China have not be faced with severe competition. Specifically, every airport could benefit from the growth of resources and achieve robust growth in passenger throughput.

In order to make the analysis of competition dynamics among HKIA, GBIA and SBIA more clearly and intuitively, the graphic method is applied in this paper. We use different arrows and symbols to represent different competition relationship between two airports and Figure 3 provides the specific explanations. The relationship graphs of the passenger throughput within the different period are shown respectively as Figure 2.

Table 3: Estimation of the Lotka-Volterra Model of Passenger Throughput

		α	β	γ	δ
Jan. 2006 to Dec. 2008	HKIA	1.4403[0.2095]	0.1304[0.0601]	-	-0.0662[0.0355]
	GBIA	-	-	-	-
	SBIA	-0.0662[0.0355]	-	-0.1797[0.0836]	0.3229[0.1453]
Jan. 2009 to Dec. 2011	HKIA	1.2285[0.1334]	0.1129[0.0416]	-0.0780[0.0285]	-
	GBIA	1.0046[0.0828]	-0.0409[0.0228]	0.0430[0.0198]	-
	SBIA	1.3158[0.1285]	-	-0.1205[0.0501]	0.1884[0.0720]
Jan.2012 to Mar. 2015	HKIA	1.6717[0.3332]	0.2162[0.1023]	-	-0.1201[0.0571]
	GBIA	1.4769[0.2367]	-	0.1560[0.0732]	-0.0840[0.0419]
	SBIA	0.7994[0.0966]	-0.0715[0.0291]	-	0.0432[0.0191]

Table 4: Estimation of the Discrete Lotka-Volterra Model of Passenger Throughput

		r_i	c_{i1}	c_{i2}	c_{i3}
Jan. 2006 to Dec. 2008	HKIA	0.3649	0.1081	-	-0.0549
	GBIA	-	-	-	-
	SBIA	0.5085	-	-0.1379	0.2478
Jan. 2009 to Dec. 2011	HKIA	0.2058	0.1017	-0.0702	-
	GBIA	0.0046	-0.0408	0.0429	-
	SBIA	0.2745	-	-0.1047	0.1637
Jan.2012 to Mar. 2015	HKIA	0.5138	0.1654	-	-0.0919
	GBIA	0.3900	-	0.1276	-0.0687
	SBIA	-0.2239	-0.0798	-	0.0483

According to Figure 2, competition dynamics among HKIA, GBIA and SBIA is described specifically as follow. Firstly, we will consider the competition relationships from the passenger throughput aspect. During the first sample period (from Jan. 2006 to Dec. 2008), there is seldom correlation and influence between HKIA and GBIA. However commensalism relationship is shown between HKIA and SBIA as well as GBIA and SBIA. Specifically, the increase of the passenger throughput in GBIA (SBIA) had a positive effect on SBIA (HKIA) respectively. The intrinsic growth rates of HKIA and SBIA were positive, which represents that they could attract extra passenger transportation resources into the competition system. At the same time, however, these two airports were density-dependent, that means the increase of passenger numbers would be largely limited due to their own conditions and capacity. As time goes by, the mutualism relationship between HKIA and GBIA appeared during the second sample period (from Jan. 2009 to Dec. 2011), which suggested that each airport has grown much more due to the close collaboration between HKIA and GBIA in these years. GBIA still had a positive impact on SBIA, but there is no competing relationship between HKIA and SBIA. Meanwhile, HKIA, GBIA and SBIA all had a positive growth rate and the density-dependent nature were clearly represented. As the third relationship graph in Figure 2 shows, we can find that competitiveness of GBIA gradually increase on account of the positive growth rate and the beneficial influence from SBIA, perhaps because SBIA had a relatively fast expansion during these years and had some influences on the other airports, but the mutual promotion of HKIA and GBIA was no longer significant from Jan. 2012 to Mar. 2015. However, HKIA and SBIA enhanced the cooperation relationship and showed the mutualism relationship during this period. At the same time, all three airports are density-dependent, so the growth of their throughput will be hampered by themselves. There may be various reasons leading to this phenomenon, such as the saturation of airport capacity and shoddy infrastructure.

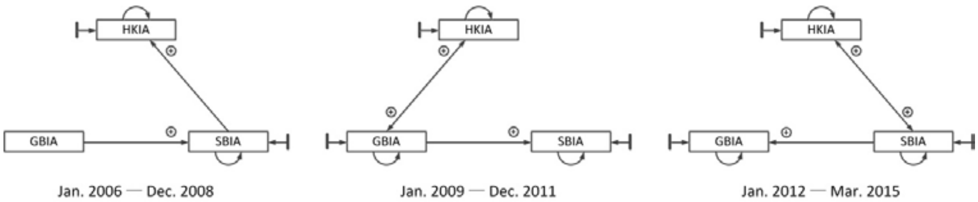

Figure 2: Competing Relationship of Passenger Throughput among HKIA, GBIA and SBIA

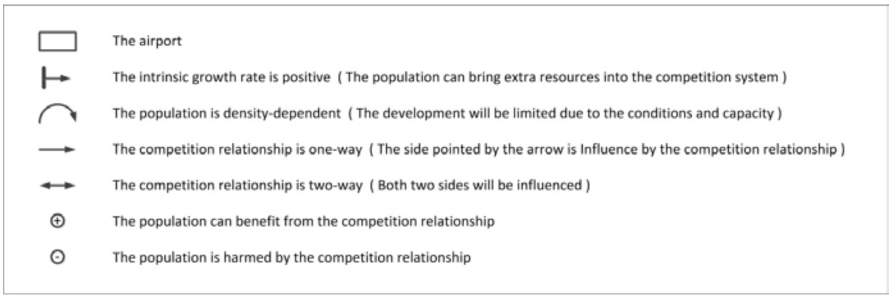

Figure 3: Explanation of Symbols

The presented analysis stated that the competitive relationships among HKIA, GBIA and SBIA are changing during different periods. Although the competition interaction is complex, but some conclusions can also be derived from our analysis above. Overall, as one of the world's largest and busiest airport in Greater Pearl River Delta, HKIA has a strongly promoting effect on the development of nearby airports in a way. And the potential development trend of GBIA in passenger throughput is obvious and grounded in reality. However, in addition to considering the competition influences among airports, the necessity of the expansion and modernization of the airport infrastructure deserves much attention of airports and even the government, which can be captured and concluded from the fact that in most instances the airports are density-dependent.

4.2. *Equilibrium Analysis*

The analysis of competitive relationship by the Lotka-Volterra model can provide information about what the equilibrium state is and how the trajectory changes over time. Specific equilibrium conditions are presented in section 2.3. If we can find X_1^*, X_2^*, X_3^* satisfying $dX_1/dt = 0, dX_2/dt = 0, dX_3/dt = 0$ and X_i can converge to X_i^* when X_i deviates from X_i^*, it implies that there exists an equilibrium point. In this paper, we take the competing relationship of HKIA, GBIA and SBIA into consideration and analyse whether the equilibrium state really exists. Additionally, the equilibrium level and stability of the equilibrium point can be identified if the equilibrium equation is solvable.

Considering the empirical results in Section 4.1, the equilibrium point about passenger throughput of three airports exists during the latest period (from Jan. 2012 to Mar. 2015). X_1, X_2, X_3 satisfy the following equation system:

$$\begin{cases} \dfrac{dX_1}{dt} = X_1(0.5138 - 0.1654X_1 + 0.0919X_3) \\ \dfrac{dX_2}{dt} = X_2(0.3900 - 0.1276X_2 + 0.0687X_3) \\ \dfrac{dX_3}{dt} = X_3(-0.2239 + 0.0798X_1 - 0.0483X_3) \end{cases} \tag{7}$$

Judging from the empirical result, the equilibrium point of passenger throughput from Jan. 2012 to Mar. 2015 really exists and is presented at Table 5. Specifically, if $X_1 < X_1^*$, that is $r_1 - c_{11}X_1 - c_{12}X_2 - c_{13}X_3 > 0$ and

$dX_1/dt > 0$, which implies that the passenger throughput of HKIA would increase. Conversely, if $X_1 > X_1^*$, that is $r_1 - c_{11}X_1 - c_{12}X_2 - c_{13}X_3 < 0$ and $dX_1/dt < 0$, and the passenger throughput of HKIA would decrease. Similarly, the passenger throughput of GBIA and SBIA can also be analysed by following the method above.

Table 5: Equilibrium point of passenger throughput

	HKIA	GBIA	SKIA
Equilibrium Point (ten thousand person-time)	646.45	554.02	426.84

The stability of the equilibrium point is to identify the situation that, if $X_i (i = 1,2,3)$ has an overall deviation from the equilibrium point, whether or not the passenger throughput will gradually return to the original equilibrium point. From Eq. (7), it is obvious that the rates of change in X_1 and X_3 are based on themselves and not dependent on X_2. For simplicity, the stability analysis of the passenger throughput will begin with X_1 and X_3.

By substituting the estimates of parameters for Eq. (6), two linear equations for equilibrium analysis of X_1 and X_3 are obtained, and Figure 4 shows graphically the relation of these two linear equations. Figure 6 shows an equilibrium point, that is the cross point of lines $dX_1/dt = 0$ and $dX_3/dt = 0$. According to the deviating direction X_1 and X_3 from the equilibrium level and the situations of the lines $dX_1/dt = 0$ and $dX_3/dt = 0$, we can divide the plane into some parts. In the area which is marked as (D), $dX_1/dt < 0$ and $dX_3/dt > 0$, $X_1 > X_1^*$ and $X_3 < X_3^*$ simultaneously , which means X_1 and X_3 can steadily approach the equilibrium state when X_1 has a positive deviation from X_1^* and X_3 has a negative deviation from X_3^*. Correspondingly, the negative feedback happens in the area (H), in which $dX_1/dt > 0$, $dX_3/dt < 0$, and $X_1 < X_1^*$, $X_3 > X_3^*$. Similar analysis can be accomplished when X_1 and X_3 are in area (B) and (F). The facts that $dX_1/dt < 0$, $dX_3/dt < 0$ and $X_1 > X_1^*$, $X_3 > X_3^*$ in area (B), as well as $dX_1/dt > 0$, $dX_3/dt > 0$ and $X_1 < X_1^*$, $X_3 < X_3^*$ in area (F) show that X_1 and X_3 will gradually converge to original equilibrium point X_1^* and X_3^* respectively. But the situations are rather more complicated in the rest areas. If X_1 and X_3 are located in area (A), that is $dX_1/dt > 0$, $dX_3/dt < 0$ as well as $X_1 > X_1^*$, $X_3 > X_3^*$, the direction of following change is right and downward, and X_1 and X_3 will approach and eventually enter into area (B), then it will converge to the equilibrium point after entering area (B). Similarly, X_1 and X_3 will change constantly and go back to X_1^* and X_3^* eventually in area (C), (E) or (G). Overall, no matter in what circumstance, as long as external conditions don't change, X_1 and X_3 will converge to the equilibrium point as time goes by. Now the analysis of X_2 becomes simple based on the discussion above. Since X_3 is certain to converge regardless of X_2, we only need to consider the state that X_3 has reached the equilibrium level. It is natural to show that X_2 will decrease if $X_2 > X_2^*$ because $dX_2/dt < 0$, and X_2 will increase if $X_2 < X_2^*$ because $dX_2/dt > 0$ under this condition. Therefore, the stability of equilibrium point for the passenger throughput during the latest period is confirmed.

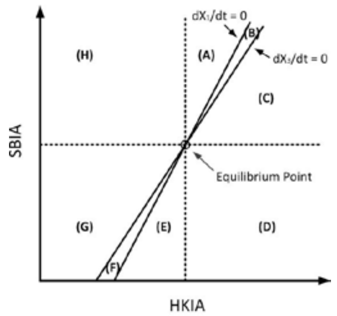

Figure 4: Equilibrium Point of HKIA and SBIA

On the basis of the corresponding analysis, we can take the current situations into consideration. Since the passenger throughput of three airports are 573.60, 498.19 and 350.71 ten thousands person-time in March 2015, which all have a negative bias from the equilibrium point, we have $dX_1/dt>0, dX_2/dt>0$ and $dX_3/dt>0$ by computation according to the estimation results from Jan. 2012 to Mar. 2015. The present state of HKIA and SBIA is located in area (G), which means the passenger throughput of HKIA will increase but the passenger throughput of SBIA is faced with the downward pressure in the short run. But in the long term, as the state of HKIA and SBIA gradually turns into area (F), the passenger throughput of all three airports will exhibit a rising trend under the current benign competition relationship. However, whenever the equilibrium condition is satisfied, the increasing of the passenger throughput will reach a plateau if there is lack of the serious attention of airport regulators. So in order to keep the steady growth of all three airports, the effective expansion or modernization of the airport infrastructure is extremely necessary. Of course, the reality is changeable and complex, and the competition relationship will constantly vary in accordance with national policies and economic environment. Presumably as in the past, the competition relationship among HKIA, GBIA and SBIA will be a dynamic process and deserve more attention in the future.

5. Conclusion

It is universally acknowledged that air transportation analysis is a valuable and interesting issue that should be paid much attention in order to promote the economic development of regions and even nations. In particular, the analysis of competition relationship among airports is of the great significance in this field. Hong Kong International Airport (HKIA), Guangzhou Baiyun International Airport (GBIA) and Shenzhen Bao'an International Airport (SBIA) are three main traffic hubs in Greater Pearl River Delta of China. With taking a deep look of the air transport industry in China, it is believed to be largely in need to study on the evolution of their competition relationship.

In this paper, Lotka-Volterra model is applied to investigate the competition dynamics of the airports. And the empirical results show the complex competitive relationships among HKIA, GBIA and SBIA, which are changing during different periods. HKIA has a strongly promoting effect on the development of nearby airports in a way. And the potential development trend of GBIA in passenger throughput is obvious and grounded in reality. However, the passenger throughput of three airports all suffer from density-dependent issue from January 2012 to March 2015. Therefore, the necessity of the expansion and modernization of the airport infrastructure deserves much attention of airport regulators as well as the government.

Meanwhile, as the equilibrium analysis shows, the equilibrium point has not been reached up to now, and the stability of equilibrium point is proved. We can see that, based on the latest data, the passenger throughput of HKIA, GBIA and SBIA will eventually reach the equilibrium point although passenger throughput of SBIA has a faint downtrend in the short term. Therefore, the effective expansion or modernization of the airport infrastructure is extremely necessary as the development of the airports may reach a plateau whenever the equilibrium condition is satisfied. As a matter of fact, the competition relationship among HKIA, GBIA and SBIA will be a dynamic process and the equilibrium state will also change through time. So it still deserve more attention in the future. All in all, airports and government still need to take steps to prevent the possible cut-throat competition relationship of three airports due to inappropriate decision-making and keep the steady growth of all three airports.

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Can Google Search Data Help Nowcasting Air Passenger Volume? A Study of Hong Kong International Airport

Mengchen Ji, Gang Xie[*] and Shouyang Wang

Academy of Mathematics and Systems Science, Chinese Academy of Sciences, Beijing 100190, China
[*]*Tel. +86-10-82541368, Fax: +86-10-62541823. E-mail address: gxie@amss.ac.cn*

[*]*Corresponding author*

Abstract

Nowcasting air passenger volume is important and helpful for decision-making in air transportation industry and related industries, since official air passenger volume data is often released with a delay of nearly one month. With the fast development of Internet, people tend to search for airport information on Internet when they have flights to take. Thus, air passenger volume may be reflected and explained by the Internet search data. Using air passenger volume in Hong Kong as an example, this paper conducts an empirical study combining Seasonal-ARIMAX (SARIMAX) model and the Google search intensity, and demonstrates that Google search index about airport parking and transportation has a significant explanatory power on air passenger volume. Out-of-sample nowcast is performed and results show that this hybrid model can achieve a better performance than the benchmark model. This research is the first application of Internet search data in air passenger volume analysis and nowcast. And it proves that Google search intensity can help nowcasting air passenger throughput, and therefore be useful for decision-makers.

Keywords: Air passenger volume, Google Insights, Nowcast, SARIMAX

1. Introduction

1.1. Air Passenger Volume Nowcast

Air passenger volume estimation is the most important area in the air transportation industry. Past researches mainly focus on the forecasting air passenger volume in order to improve the management and operational planning for airports, see Kim and Ngo (2001), Samagaio and Wolters (2010), Xie at al.(2014) and Tsui et al. (2014). To the best of our knowledge, there has been little consideration about nowcasting air passenger volume. Reliable and accurate air passenger volume nowcast is of great significance to decision-making in air transportation industry and other related industry. As we know, data of many macroeconomic indicators are only available with a delay of one or two months. For air passenger throughput, the lag time of the official data release is nearly one month. Decision-makers in air transportation industry or related industries would like to know the current air passenger volume in a certain geographic region (for example, in a city, a state, or in the whole country). However, the air passenger volume data of the current month is unavailable to them. Such a delay makes decision-makers hard to accurately access current air traffic conditions. Thus, it deteriorates their management and ability to adjust future development plans based on current situations. For example, decision-makers are likely to enhance the sales campaigns, if they find the air passenger volume of the current month is relatively low. But it is difficult for them to find this, due to the unavailability of current data. Thus, nowcasting, which means the prediction of the present, is very valuable and important. Nowcasting estimation can provide a good substitute of the actual data, and can help decision-makers observe trend before official data releases, and make better decisions.

The authors believe that the blank of nowcasting air passenger volume is due to the lack of proper tools. In the researches of air passenger volume forecast, some past researches have used exogenous macroeconomic variables to build multivariate forecast models. But those macroeconomic variables are useless in nowcast since they all have release delays. However, the fast development of Internet search engines has provided us with valuable data that can be used in air traffic nowcast. Further discussions on nowcast can be seen in Giannone, Reichlin, and Small (2008), and Kuzin, Marcellino, and Schumacher (2011).

1.2. Application of Google Search Data

With the rapid development of the Internet, the linkage between Internet and people's daily lives have become much stronger nowadays. Such close connection suggests that useful information can be extracted from Internet to analyze and nowcast activities in real life, especially in economic, financial and medical fields. As Google being the Internet search engine with the largest market share, Google's search index is an important source of Internet data that can reflect people’s attention, demand and sentiment.

Research of nowcast based on Internet search data is a new topic, and is developing rapidly since Choi and Varian (2009) firstly used Internet search data to nowcast economic indicators. They demonstrated that basic nowcasting models for unemployment claims in the USA could be improved by incorporating Internet search intensity. Della Penna and Huang (2009) employed search data for retail goods to nowcast private consumption in USA. Vosen and Schmidt (2011) performed similar research by constructing a new indicator for private consumption based on Google search query time series. Carrière−Swallow and Labbé (2014) introduced an index of online interest in automobile purchases in Chile using data on Google search queries, and found it to be useful for improving the fit and efficiency of nowcasting models for automobile sales.

1.3. Connection between Air Passenger Volume and Google Search Data

As more and more people tend to search for information on Internet when they are about to take a flight, it naturally occurs to the authors that there should be some linkage between the air passenger volume and the Google search data. We hypothesize that when search intensity for airport information goes up, the air passenger volume increases. Thus, we expect that Google search indicators can be useful for explaining and nowcasting air passenger volume. Moreover, Google provides the search intensity index within a specific geographic region (a city, a state, or a country). We expect that the air passenger volume in a certain region can be reflected and explained by the search index in this region.

Study on the relationship between Internet data and air passenger volume has been a blank. Our research is aimed at filling this blank by proposing a hybrid approach combining Box-Jenkins Seasonal-ARIMAX (SARIMAX) models and Google search index, and using this approach to examine whether Google search intensity improves the performance of air passenger throughput nowcast. Our research is believed to be the first application of Google search data in air passenger volume nowcast. Using air passenger volume in Hong Kong, we find that Google search indicators are significant to explaining air passenger volume, and SARIMAX models incorporating Google search data can outperform benchmark models in out-of-sample nowcast.

The remainder of this paper is organized as follows: Section 2 provides the source of the data, including air passenger volume data and Google search data, and the methodology in our research. Moreover, empirical analysis is implemented and the performances of different nowcasting models are compared and evaluated in Section 3. Section 4 draws the conclusions and suggests some directions for future investigation.

2. Data and Methodology

2.1. Data

2.1.1. Air Passenger Volume Data

In this paper, we will use air passenger volume data in Hong Kong to conduct our research. Hong Kong International Airport (HKIA) is the only airport in Hong Kong. The time series data of air passenger volume in HKIA is obtained from CEIC Database (http://www.ceicdata.com). The data of HKIA from CEIC Database is monthly data starts from January 1999. But because most of the web search data related to air passenger volume is not available until June 2004, we choose the sample period from June 2004 to March 2015, with a total of 130 observations. To eliminate the effect of scales, we subtract the average monthly volume from raw data and divide the difference by the average volume.

2.1.2. Google Search Data

Google Insights provides an index of the Google queries by geographic location (http://www.google.com/insights/search). Google Insights data, which is aggregated over the millions of users of the Google search engine, does not report the raw level of queries for a given search term. Instead, the raw volume is normalized by dividing the total search volume for a particular keyword in a given geographic region by the overall total number of searches in that region during a particular time period.

People who have flights to attend may have the intention to search for information about this airport, such as airport transportation, airport parking, surrounding services, and so on. So their demand may be reflected in the data of Google queries. Google provides a composite index for category "Airport Parking and Transportation" which is a subcategory of "Air Travel" which is a subcategory of "Travel". This is a comprehensive index integrating search volume for many keywords related to airport parking and transportation, including "Shuttle", "Airport bus", "Parking", "Hong Kong airport" and so on, in different languages (because there are three languages that are frequently used in Hong Kong: English, Mandarin, and Cantonese). In Google Insights, we select the geographic location as Hong Kong. Note that Google search series are all weekly data, so we convert them into monthly data by taking the mean value of each month.

2.2. Models and Methodology

Following Chen and Wang (2007), the Box-Jenkins ARIMA model is adopted as a foundation of our research. ARIMA means autoregressive, integrated, and moving average combined method. Box-Jenkins Seasonal-ARIMA (SARIMA model), the combination of the non-seasonal stationary ARIMA(p,d,q) model and the seasonal stationary ARIMA(P,D,Q)s model, is the most popular linear model for analyzing seasonal time series. SARIMA (p,d,q)(P,D,Q)s model can be written as follows, see Equation(1):

$$\phi_p(B)\Phi_p(B^s)(1-B^s)^D Z_t = \theta_q(B)\Theta_q(B^s)\varepsilon_t, \tag{1}$$

where Z_t is the observed value at time t, t = 1, 2, ..., k. ε_t is the estimated residual at time t. s is the seasonal pattern in the time series, and p, d, q, P, D, Q are integers.

$$\varphi_p(B) = 1 - \varphi_1 B - \varphi_2 B^2 - \cdots - \varphi_p B^p, \tag{2}$$

$$\Phi_p(B^s) = 1 - \Phi_s B^s - \Phi_{2s} B^{2s} - \cdots - \Phi_{Ps} B^{Ps}, \tag{3}$$

$$\theta_q(B) = 1 - \theta_1 B - \theta_2 B^2 - \cdots - \theta_q B^q \text{ and} \tag{4}$$

$$\Theta_Q(B^s) = 1 - \Theta_s B^s - \Theta_{2s} B^{2s} - \cdots - \Theta_{Qs} B^{Qs} \tag{5}$$

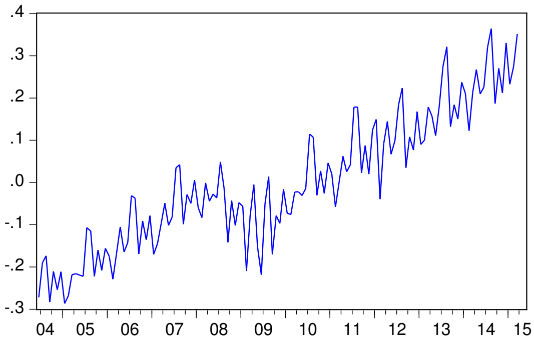
are polynomials in B of degree p, d, P and Q. B denotes the backward shift operator. d is the number of regular differences, D is the number of seasonal differences.

In this paper, we will apply SARIMA model in conjunction with exogenous explanatory variable, which is the composite Google search index in our research. Combining SARIMA model and the exogenous explanatory indicator makes the SARIMAX model. And we will compare the explanatory and nowcasting power of these different models.

3. Empirical Study

3.1. SARIMA Model

In the following subsections, we will use different models to analyze air passenger volume of HKIA. According to ADF test, this air passenger volume time series is not stationary (p=0.9758). And both the ACF and PACF tests indicate that the time series has a strong seasonal pattern. Its trend and seasonal pattern can also been seen clearly in Fig 1. Thus, we take its first-order difference and then take the year-on-year difference. This means we have to sacrifice the first thirteen (1+12) observations, leaving us with 117 observations (from July 2005 to March 2015). See Figure 1. We denote this seasonal differenced series as HKAV(t).



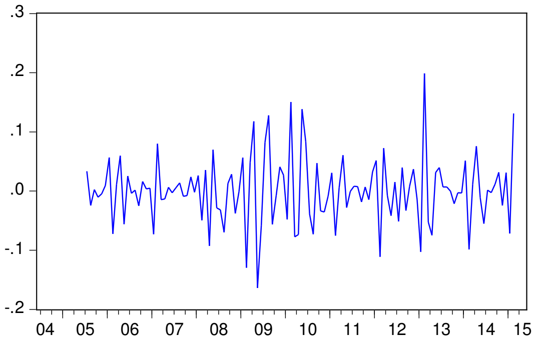


Figure 1: Air Passenger Volume in HKIA and the Seasonal Differenced Series HKAV

Table 1: Statistic Results of AR(1), SARIMA, and SARIMAX Empirical Models (During the Whole Sample Period)

	AR(1)	SARIMA (0,1,1)(1,1,1)12	SARIMAX (HKAPT)
HKAPT	—— ——	—— ——	0.0907 0.0117
AR(1)	-0.3691 0.0001	—— ——	—— ——
AR(12)	—— ——	-0.2708 0.0094	-0.2915 0.0043
MA(1)	—— ——	-0.5907 0.0000	-0.6010 0.0000
SMA(12)	—— ——	-0.8763 0.0000	-0.8957 0.0000
C	0.0004 0.9183	0.0005 0.2328	0.0004 0.2707
R^2 Adjusted R^2 AIC	0.1304 0.1227 -2.9886	0.6834 0.6739 -3.9016	0.7022 0.6902 -3.9437

Note: For every variable, the upper value is the coefficient, and the lower value is the p-value.

In this paper, we will use the simple AR(1) model as the benchmark model. First, we build a SARIMA model for air passenger throughput in Hong Kong. For SARIMA model, the lag orders are selected based on Akaike Info Criterion (AIC). We find that SARIMA $(0,1,1)(1,1,1)_{12}$ is the best SARIMA model. The results of AR(1) model and SARIMA $(0,1,1)(1,1,1)_{12}$ model is presented in the second and third columns of Table 1 in Subsection 4.2.2. From Table 1, we can find that SARIMA $(0,1,1)(1,1,1)_{12}$ model has a much better result than the benchmark AR(1) model. The R^2 of SARIMA $(0,1,1)(1,1,1)_{12}$ is 0.6834, which is significantly higher than the R^2 of benchmark AR(1) model, 0.1304. The adjust R^2 of SARIMA $(0,1,1)(1,1,1)_{12}$ is also higher than AR(1) model. Moreover, the AIC of SARIMA $(0,1,1)(1,1,1)_{12}$ model is -3.9016, which is much better than the AIC of AR(1) model, -2.9886.

3.2. SARIMAX Model with Google Search Index

Based on SARIMA $(0,1,1)(1,1,1)_{12}$ model, we will combine this SARIMA model with the Google search indicator. The composed index of "Airport Parking and Transportation" in Hong Kong in Google Insights is employed in our research. Similar as the air passenger volume time series, this composite index also has trend and seasonal cycles. So we will also take its first-order difference and its year-on-year difference. The index series after difference is denoted as HKAPT(t). Figure 2 displays graphs of HKAV and HKAPT.

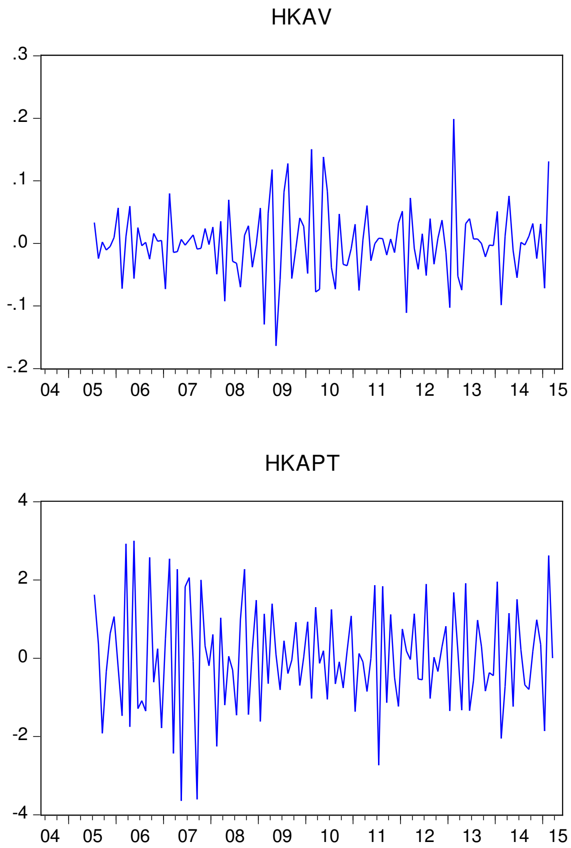


Figure 2: Graphs of HKAV and HKAPT

By adding HKAPT into SARIMA $(0,1,1)(1,1,1)_{12}$ model, we find that HKAPT has a significant explanatory power on HKAV. According to the fourth column in Table 1, the coefficient of HKAPT is 0.0907 with the p-value of 0.0117. This implies that search intensity of airport parking and transportation information has a significant positive correlation with air passenger volume in HKIA. When people are searching information about airport transportation or parking in Hong Kong, they are probably going to take a flight in HKIA. Consequently, the increase of search intensity of the "Airport Parking and Transportation" index in Hong Kong probably results in the increase of air passenger volume in HKIA. Empirical results show that the SARIMAX-(HKAPT) model is the best model of all three models, with the highest R^2, adjusted R^2, and lowest AIC (R^2=0.7022, adjusted R^2=0.6902, AIC= -3.9437).

3.3. Out-of-sample Nowcasting Results of Different Models

In this part, we will perform out-of-sample dynamic nowcast, using nine years of data as training set (From July 2005 to June 2014), and the rest nine months (From July 2014 to March 2015) as testing set. In order to compare nowcasting performances of different models, we employ MAPE, MAE, and RMSE as the criteria of nowcasting accuracy measurement. Calculation of MAPE, MAE, and RMSE is shown as follows:

$$RMSE = \sqrt{\left[\sum_{t=1}^{n}(y_t - \hat{y}_t)^2\right] \Big/ n}, \tag{6}$$

$$MAE = \sum_{t=1}^{n}\left|y_t - \hat{y}_t\right| \Big/ n, \tag{7}$$

$$MAPE = \left(100\sum_{t=1}^{n}\left|1 - \hat{y}_t / y_t\right|\right) \Big/ n, \tag{8}$$

where y_t is the actual value of the observation in the t^{th} month, and $\hat{y}_t$ is the corresponding nowcasting value. n is the sample size.

Modeling results of the training set (From July 2005 to June 2014) is presented in Table 2. The results are very similar from Table 1, indicating that the composite Google search index HKAPT has significant explanatory powers on air passenger volume in Hong Kong during the training period.

Table 2: Statistic Results of AR(1), SARIMA, and SARIMAX Models
(During Training Period: from July 2005 to June 2014)

	AR(1)	SARIMA $(0,1,1)(1,1,1)_{12}$	SARIMAX-(HKAPT)
HKAPT	—— ——	—— ——	0.0697 0.0613
AR(1)	-0.3437 0.0001	—— ——	—— ——
AR(12)	—— ——	-0.2529 0.0119	-0.2614 0.0085
MA(1)	—— ——	-0.5935 0.0000	-0.6059 0.0000
SMA(12)	—— ——	-0.9159 0.0000	-0.9256 0.0000
C	-0.0002 0.9688	0.0004 0.3342	0.0003 0.4820
R^2 Adjusted R^2 AIC	0.1175 0.1091 -2.9733	0.7010 0.6913 -3.9500	0.7121 0.6995 -3.9670

Note: For every variable, the upper value is the coefficient, and the lower value is the p-value.

Next, we will use these models to nowcast the air passenger volume in Hong Kong during the testing period, from July 2014 to March 2015. The actual values, nowcasting values, and nowcasting errors are provided in Table 3.

Nowcasting results show that the SARIMAX model combining Google search intensity can achieve better nowcasting performance than SARIMA model. And their performances are far better than the benchmark AR(1) model. The out-of-sample nowcasting results support our hypothesis that Google search intensity is useful for improving the nowcasting accuracy on air passenger volume. Therefore, our research can be employed to improve the management of airports and airlines.

Table 3: Nowcasting performance comparison of AR(1), SARIMA and SARIMAX models

Period	Actual	AR(1)		SARIMA		SARIMAX -(HKAPT)	
		nowcast	error	nowcast	error	nowcast	error
Jul-2014	5602	5674	-1.29%	5665	-1.12%	5662	-1.08%
Aug-2014	5789	5844	-0.95%	5712	1.33%	5722	1.15%
Sep-2014	5037	5052	-0.30%	5078	-0.81%	5034	0.06%
Oct-2014	5390	5267	2.28%	5397	-0.12%	5336	1.00%
Nov-2014	5144	5124	0.38%	5228	-1.64%	5189	-0.88%
Dec-2014	5645	5492	2.70%	5547	1.73%	5532	1.99%
Jan-2015	5231	5381	-2.87%	5381	-2.86%	5309	-1.49%
Feb-2015	5410	5004	7.50%	5154	4.73%	5159	4.63%
Mar-2015	5736	5388	6.07%	5506	4.01%	5498	4.15%
MAPE		2.70		2.04		1.83	
MAE		149.04		111.63		100.93	
RMSE		198.82		137.07		129.60	

4. Conclusion

This paper explores the relationship between Google search intensity and air passenger volume in Hong Kong, by building a SARIMAX model incorporating Google search data for airport transportation and parking information. We demonstate that Google search index has significant explanatory power in analyzing air passenger volume. We conduct out-of-sample nowcast with different models and find that SARIMAX model with the Google search index has the best performance.

Air passenger throughput nowcast is of significance for air transport industry. Air passenger volume for the current month cannot be obtained due to the one month delay of data release, which makes decision-makers hard to evaluate the current condition and respond quickly. The innovative nowcasting model proposed in this paper can stably and effectively nowcast the present air passenger volume, thus provide a quick and good estimation of the air passenger volume of the current month. It is important and helpful for decision-making in air transport industry.

Moreover, this research is the first attempt to analyze the relationship between air passenger volume and Internet search intensity. We have proved our hypothesis that that Internet search intensity does have a significant explanatory effect on air passenger throuput. Our work fills in the blank of application of Internet search data on air passenger volume nowcast. This successful application shows the huge potential of Internel search data, and hopefully can encourage more study on Internet search data. Internet search data is a quick and reliable reflection of users' requirement and sentiment. It has already been employed in nowcast and forecast in several field, including consuming, stock prices, automobile sales, real estate prices, and even movie ticket sales. We have reasons to believe it can achieve great nowcast and forecast performances in other fields that have not been explored yet. We hope our research can be an inspiration.

We must admit that there is a limitation of our research, that we did not investigate the Google search intensity for air ticket booking. Apart from the Google search index HKAPT, which is about airport parking and transportation, Google search data related to air ticket booking may be useful for air passenger volume nowcast as well. This issue can be addressed in further research.

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A Simulation Model of Safety Control System Functioning: A Case Study of the Wroclaw Airport Terminal

A. Kierzkowski and T. Kisiel

Department of Maintenance and Operation of Logistics, Transportation and Hydraulic Systems, Wroclaw University of Technology, Poland

Abstract

A security control system is the key element of an airport because each passenger must undergo a security check before boarding. The security check must be performed efficiently, but, on the other hand, a high level of security must be maintained. The article presents a security check model at the airport. A set of variable input data describing the model has been presented and data received by the user as a result of its use. The security check model was developed in Flexsim Software. It was based on the model of security check implementation, for which algorithms for the management of the security check point operation schedule were used. The article describes two basic patterns of implementing the security check process: one-stream and two-stream. The security check process has been divided into zones (queues). The developed model was implemented for the management of security check points at the Wroclaw Airport. For sample input data (system characteristics and the stream of passenger reports), measures of system efficiency were determined: the average duration of the passenger's stay in the security check system, the number of work hours of security check operators depending on the adopted management strategy. The developed model can be used in existing security control systems and it can also be used to evaluate the operation of a system being designed.

Keywords: Airports, Management, Simulation model, Safety

1. Introduction

The necessity to ensure a high security level of the air transport system is conditioned by the existence of a large number of international regulations, which define procedures related to the passenger flow and baggage control at airports. The main act responsible for keeping an appropriate air transport security level in Poland is JoL (2002), which refers to regulations EC (2008), EC (2009), EC (2010), defining detailed security control procedures, which the airport operator is obliged to execute. Passengers beginning their journey at the airport as well as transfer passengers, who move between areas with various access levels during the check-in process, have go-through security.

The security control is performed by the airport operator using the airport security services in accordance with regulation EU (2010) and annexes EC (2008), EC (2009). The airport operator demarcates boundaries between individual areas and marks them in an unambiguous manner using physical obstacles preventing unauthorised access. The restricted area can be accessed by access control at security control points. Before starting the control, passengers are obliged to prepare their cabin baggage for control and put their overcoats into special trays, which are placed in the appropriate area. Large electronic devices are removed from the cabin luggage as their density significantly affects the results obtained from the scanning device. Such equipment is inspected separately. Liquids are also removed for personal control as their transport is regulated by EU (2013). If the scanning device can control liquids together with other objects, they are inspected only inside the luggage. The next stage of the process involves simultaneous baggage and passenger control. The diagram of the security control process is presented in Figure 1.

Security control of passengers can be conducted using JoL (2002):
- a metal detector gate,
- a hand search,
- security scanners,

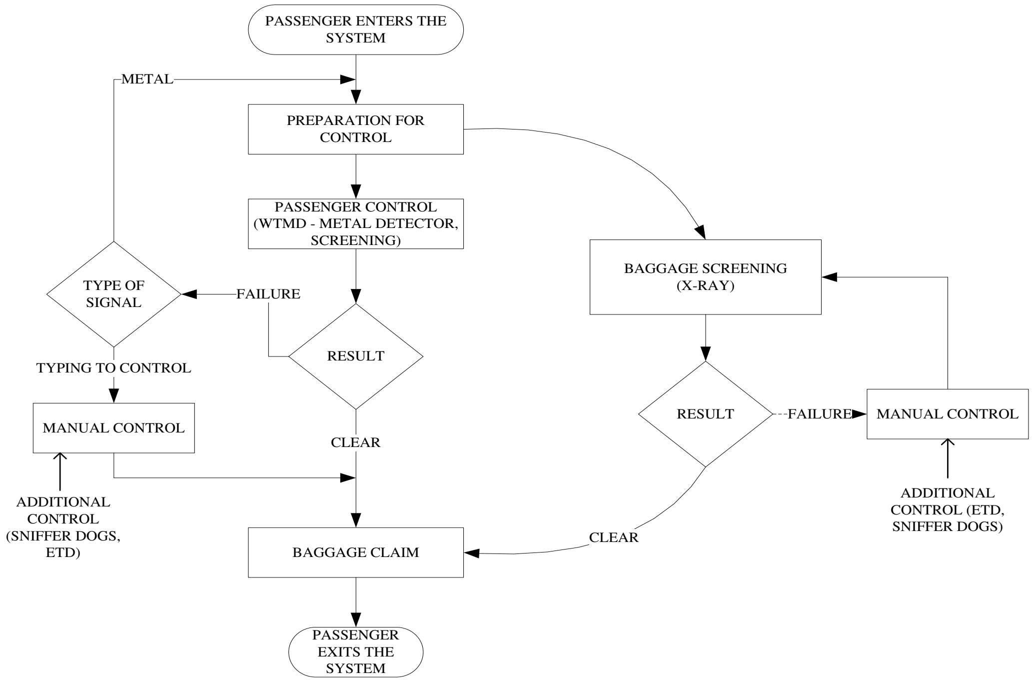

Figure 1: Diagram of security control process implementation
Source: Prepared by the author on the basis of EU (2013)

- devices for detecting trace amounts of explosives combined with a hand-held metal detector,
- dogs detecting explosives in combination with a hand search.

Security control of cabin baggage is conducted using (in accordance with JoL (2002)):
- an X-ray device,
- a hand search,
- systems for detection of explosives,
- dogs detecting explosives in combination with a hand search.

Dogs and devices for detecting trace amounts of explosives can be used only as additional security control measures. Both passenger and luggage control has a positive result only if the process operator can unambiguously decide that the requirements of the control process have been met. Each negative signal from control devices must be identified and eliminated. Otherwise, the passenger or the luggage goes through subsequent control or is refused admittance onto the aircraft.

After the end of the security process, passengers and their cabin luggage are protected against groundless intervention until take-off unless passenger or baggage occurs (contact with a passenger or luggage that has not been screened).

2. Overview of the State of Research

While analysing literature on the security control system operation, one can distinguish the following research areas:
- the importance of the security control system in airport operation,
- the capacity of the security control area,
- the issues related to the passenger's experience during the security check.

Preliminary issues connected with the use of terminal areas are presented in Hamzawi (1992), Stelmach et al. (2006), Skorupski and Stelmach (2008), Kierzkowski and Kisiel (2014). The need for solving problems connected with bottlenecks in passenger flows with the organisation of terminal operations. The possibility of minimising costs connected with the construction of the terminal and subsequent changes in the infrastructure resulting from variable intensity of passenger flows. There are many publications, which focus on methods of designing passenger terminals (McCullough and Roberts (1979), McKelvey (1989), Lemer (1992), Saffarzadeh and Braaksma (2000)). Examination of travel comfort is also particularly important Greghi et al. (2013). The model which, apart from the need to ensure security, also indicates the appropriateness of minimisation of inconveniences, which may have a negative influence on passenger service quality Gkritza et al. (2006). There exists a range of models which divide the system operation into a collection of individual queuing systems. A lot of models have been developed for these systems which are used to estimate basic indices and parameters of the system (Cooper R.B. (1981)). However, for complex processes, such as security control, where there exists a range of external factors forcing the operation of the system in a queuing system, it is necessary to develop a model which allow for taking these factors into account. Already initial considerations allowed for introducing a multi-criteria analysis for passenger flows at the passenger terminal Eilon and Mathewson (1973). The problem of queuing time minimisation with minimal use of resources have been brought up on numerous occasions (Bevilacqua and Ciarapica (2010), Manataki and Zografos (2010)). Also, several models for the selection of an appropriate number of technical resources to handle the assumed traffic flow (Roanes-Lozano E. et al. (2004), Solak et al. (2009)).

Wu and Mengersen (2013) presented an overview of the literature on the model of the comprehensive management of airport operation systems. Models were identified which include: capacity planning, operational planning and design, security policy and planning, airport performance. In their study, Manataki and Zografos (2010) presented a decision-making support model based on system dynamics. The developed model makes it possible to make effective strategic decisions to ensure the desired quality of services. The developed model makes it possible to determine the number of persons and the average passenger waiting time (in the time function) for check-in desks, passport control and boarding. The developed model was implemented at the Athens airport. Its further development was presented in Manataki et al. (2009). The model presented in the study, which has been implemented in the arrivals hall makes it possible to determine the number of passengers at the arrivals hall in the time function. Also, a detailed model of the security control process was presented. In Koray Kıyıldı and Karasahin (2008), the authors presented a model of determining the hourly capacity of the check-in desk system. The model is based on the fuzzy logic method. The developed model was verified and implemented for the Antalya airport. According to the results obtained from the capacity analysis model, a management strategy may be developed to prevent queues in short and long-time periods. The model of the check-in desk system was presented in Bevilacqua and Ciarapica (2010). The authors analysed the operation of the system during common check-in and dedicated check-in. Average passenger waiting times were recorded depending on the stream of reports and the number of open check-in desks. The results for queuing passengers were compared with the number of open desks. Tam (2011) drew attention to passenger orientation as one of significant factors affecting the terminal design. The presented model can be widely applied to practical situations for determining the appropriate locations for setting up way finding aids in enclosed environments including the airport terminals. Skorupski and Wierzbińska (2015) presented a model, which estimated the time needed to wait for a passenger, who is late for boarding. This model can be proposed as a procedure for gate operators.

Schultz and Fricke (2011) presented a model of the operation of a passenger airport terminal. In the article, the authors pay attention to the security control system as an element which, as a result from research, generates the greatest delay among elements of the terminal infrastructure. The study presents a model of the security control system operation and statistical data concerning the operation of this subsystem. Wilson et al. (2006) presented a two-line security checkpoint model in their study. The developed model together with models of check-in desks was implemented in a simulation environment. The developed application allowed an analysis of passenger flow and pinpoint bottlenecks. van Boekhold et al. (2014) presented a microscopic model of the security control system based on the control process diagram. Data, which concerned the implementation of the control process on individual devices (WTMD, ETD, etc.), was presented. Input data for the model (pre-screening, alarm rates, etc.) was presented together with results. The model made it possible to determine the passenger's waiting time for the security check, depending on the number of employees performing the manual search. Skorupski and Uchroński (2015) presented a fuzzy logic model aimed at assessing the effectiveness of the baggage-screening process at the airport. A significant aspect of the study took into consideration both technical and human factors. The developed model was used for the evaluation of the operation of the security check point system at the Wroclaw Airport. This study presents characteristics of the security control system operation. Kirschenbaum (2013) described the influence of passengers' behaviour on the security control process. According to the research conducted, the lack of delay in the security control system can be caused by extraordinary circumstances, i.e. drunk or violent passengers, but also by an increased frequency of conducting baggage control, passengers, etc. The total cost of the security control was determined after dividing passengers into three groups: Good Passengers, Problematic 1 minute, Problematic 5 minutes. The problem of security control costs was also considered by Oum and Fu (2007).

The issue of the passenger experience resulting from the method of implementing individual stages of the check-in at the airport is very important. The security control subsystem is especially the key element here. On the one hand, the security check must be accurate (the passenger must feel safe), but, on the other hand, it has to be efficient so that the passenger is not late for the flight. Additionally, the passenger's personal experience of the check should be positive. In this study by Correia et al. (2008b), the authors evaluated the "level of service" (LOS) for the airport passenger terminal. The necessity of research was indicated and the methodology of research was identified. It was based on determining relationships between LOS and quantities influencing its assessment (e.g. distances covered by passengers at the terminal). The developed methodology was used in research at the Sao Paulo airport. Analysis of the results obtained was presented. Next, in a study by Correia et al. (2008a), the authors presented LOS results for individual subsystems of the airport operation. A model of the airport LOS evaluation was presented as the weighted average of individual airport subsystems (the check-in, security check, etc.). In a study by Bezerra and Gomes (2015), the authors presented the results of their research at the Guarulhos Airport, which were aimed at showing the passengers' experience in various subsystems of the airport using Cronbach's alpha. Check-in desks, the security control system, etc., were analysed. In the security control system, attention was paid to: courtesy and helpfulness of security staff, thoroughness of security screening, wait – time at security check-points, feeling of being safe and secure. Research pertaining to passenger satisfaction from the quality of provided services is also conducted by various organizations, e.g. IATA.

An analysis of literature on the operation of the security check system shows that there is no model, which would take into account structural aspects of the security control system and the way of its management. From the point of view of the system structure, the security check point is treated as one process (e.g. with a preset time of implementation). This is actually a set of subsequent processes where the next activity is conditioned by an external factor (another passenger, security control employee, etc.). Some quantities, e.g. the capacity of the area before the WTMD gate and the area on the other side of the gate determine the throughput of the security check point, which was described in Kierzkowski and Kisiel (2015). An analysis of the security control system management makes sense if changes can be introduced into it and the results obtained can be observed. It results clearly from the literature overview that one of the key indices of the security control system assessment is the average wait time for the security check or the average time the passenger spends in the security control system, which is indirectly related to it.

The paper is organised as follows: Section 3 presents a simulation model of the security control system. Input data of the model is presented, which takes into account: the structure of the security control system, security control procedures, the flight schedule as a stream of reports. Next, a simulation model of the security check process and the algorithms for the management of the security check point operation were presented. Section 4 presents the application of the developed model for the security control at the Wroclaw airport. This section presents input data of the model of the security control system obtained as a result of research conducted at the Wroclaw airport. Figures obtained from various scenarios of the security control operation and a schedule of the security check point operation was determined, depending on the developed algorithms. The paper is closed with the conclusion contained in Section 5.

3. Simulation Model of the Security Control System Operation

This section presents a simulation model of the security control system operation, which was implemented into the Flexsim environment. This software allows for modelling and optimisation of discrete processes. Basic advantages of the software include: the possibility of importing CAD files and creating own libraries for subsequent use. The software also makes it possible to visualise 3D processes (Fig. 2).

Figure 2: Visualisation of a security check point prepared in the Flexsim software

The simulation model of the security control system is presented in Figure 3.

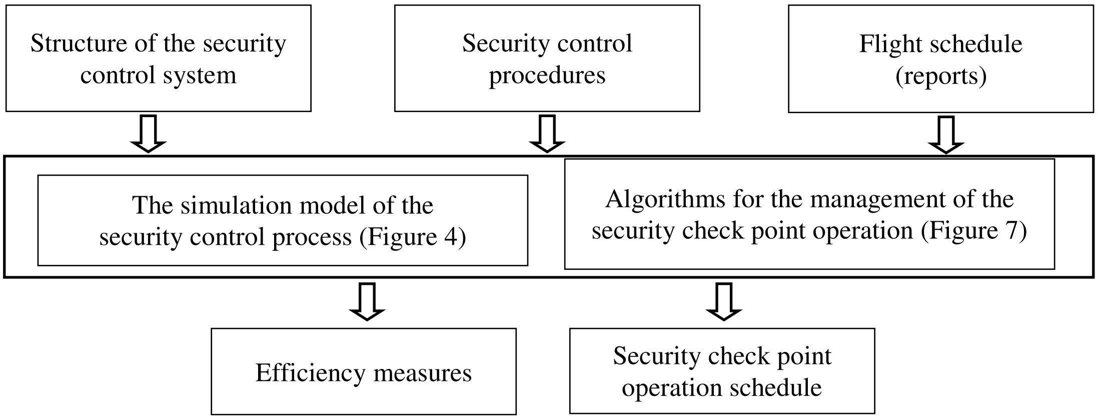

Figure 3: Security control system model

The input data for the security control system model includes:

- the structure of the security control system (distribution of the security check system, characteristics of the check points, etc.),
- the procedure of the implementation of the security check process (consequences of the triggering of the WTMD gate, etc.),
- flight schedule. On this basis, the stream of passenger reports to the security control system is determined.

On the basis of the introduced data, the security check process of the passenger safety is implemented in accordance with Figure 4. In the case of dynamic management of the security check point operation schedule, the algorithm presented in Figure 7 is used.

The developed simulation model allows for determining the following quantities:

- the average passenger wait time $\overline{t_{Q_E}}$ in a queue for the security check Q_E,
- the average time $\overline{t_{SC}}$ of stay in the security control system (from entry to the queue system Q_E to exist from the system),
- the throughput of the system depending on the capacity of the individual areas,
- the number of work hours of security control operators,
- the degree of using individual devices and operators depending on the number of open security check points,
- the schedule of operation of individual security check points depending on the preset maximum passenger wait time for the security check,
- the schedule of the operation of individual security check points depending on the maximum preset length of the queue Q_E.

For the purposes of the description of the security control process model, the following variables were adopted:

- i is the number of the next passenger reporting for the security check,$i = 1,2, \dots, n$,
- j is the number of open security check points is $j = 1,2, \dots, m$,
- the capacity of individual areas is described by $c_{UA}(j), c_{FU}(j), c_{BAA}(j), c_{BAB}(j), c_{LA}(j)$,
- the probability density functions of times for the performance of individual activities were described $f(t_{1stunl}), t(_{1finunl}),\ f(t_{\mathrm{mcont}}), f(t_{\mathrm{wfi}}), f(t_{\mathrm{load}})$.

The security control process was divided into components:

- the area of the passenger entry into the security control system E – in this area, the passenger is waiting in a queue Q_E. The capacity of this area is unlimited, while the number of passengers Q_E at a given time t has the value of $n_{Q_E}(t)$. The passenger's$i - th$ wait time at time t, in a queue Q_E has the value $t^i_{Q_E}(t)$,
- the area of passenger preliminary preparation for security control$UA(j)$ – in this area, the passenger prepares for security control on their own in accordance with their knowledge pertaining to limitations for hand baggage. The time for performing the activity by the passenger is described by the random variable (t_{1stunl}), , the capacity of this areaat the $j - th$ point is the value $c_{UA}(j)$, the queue in this area is marked as $Q_{UA(j)}$,
- the area of passenger final preparation for security control$FU(j)$ – in this area, the passenger prepares for security control in accordance with the assistance of a security control area employee. The fact of performing the activity by the passenger is described by the random variable (t_{finunl}), the capacity of this areaat the $j - th$ point is the value $c_{FU}(j)$, the queue in this area is marked as $Q_{FU(j)}$,
- the passenger's waiting time for the security check $BAA(j)$. The passenger's waiting time depends on the availability of a metal detector, the capacity of this area at the $j - th$ point has the value of $c_{BAA}(j)$, the queue in this area is marked as $Q_{BAA(j)}$,
- the metal detector area – it is an area where the passenger goes through the security screening process. If the passenger is indicated by the metal detector, he/she goes to the hand search area; otherwise, he/she goes to the baggage-waiting area,
- a hand search area $MC(j)$ – a hand search is performed in this area. The fact of performing the activity is described by the random variable $f(t_{\mathrm{mcont}})$, the capacity of this areaat the $j - th$ point is the value $c_{MC}(j)$, the queue in this area is marked as $Q_{MC(j)}$,
- baggage-waiting area $BAB(j)$ – in this area, the passenger waits for the baggage, which is being checked separately on an X-ray device. The time for performing the activity is described by the random variable $f(t_{\mathrm{wfi}})$, while the capacity of this area is the value $c_{BAB}(j)$, the queue in this area is marked as $Q_{BAB(j)}$,
- the baggage and coat collection area from conveyors after the security control. The time for performing this activity is the time $f(t_{\mathrm{load}})$, while the capacity of this area at the$j - tym$ point is determined by the value $c_{LA}(j)$, queue in the area marked $Q_{LA(j)}$.

The model of the security control process performed by the passenger at the airport is presented in Figure 4.

The first stage of the passenger service process at the security control point is performed by entering the input data. The stream of passenger reports is defined by entering the flight schedule. Next, the capacity of individual areas $c_{UA}(j), c_{FU}(j), c_{BAA}(j), c_{BAB}(j), c_{LA}(j)$, is determined depending on the point number. The number of employees (screeners) at the WTMD gate is defined. There are two modes of security control point operation: single (Fig. 5) and double (Fig. 6). Difference between the security point operation occur within the metal detector area and the manual control area.

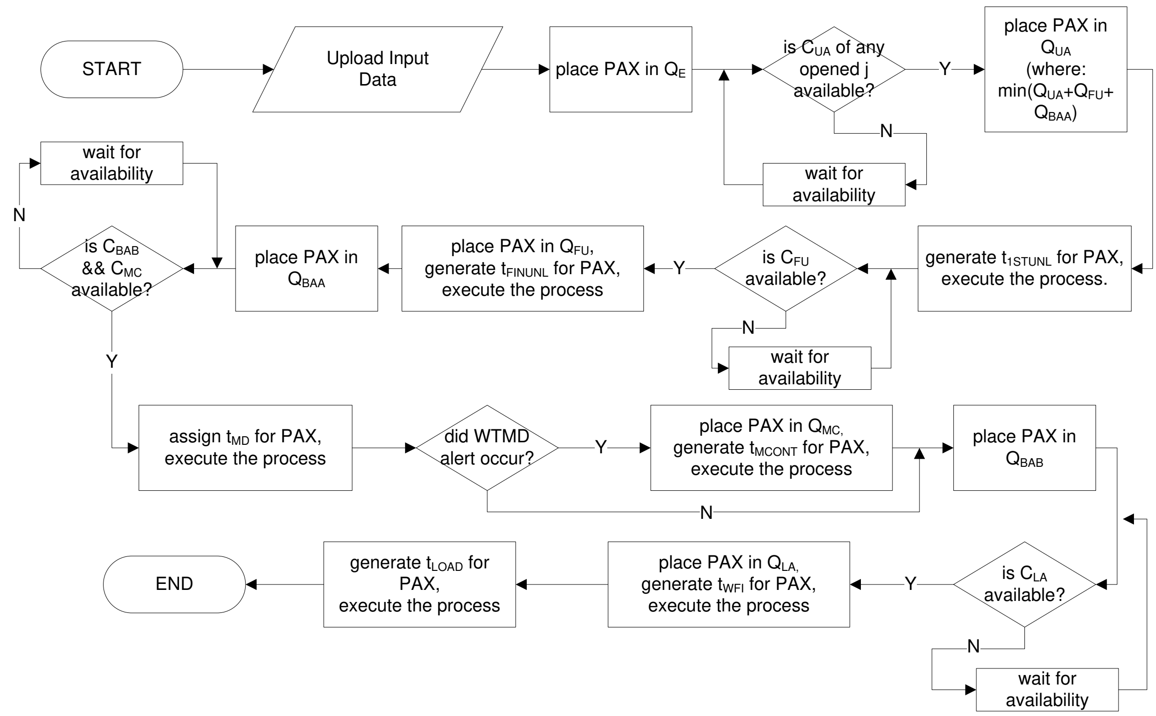

Figure 4: Model of the security control process

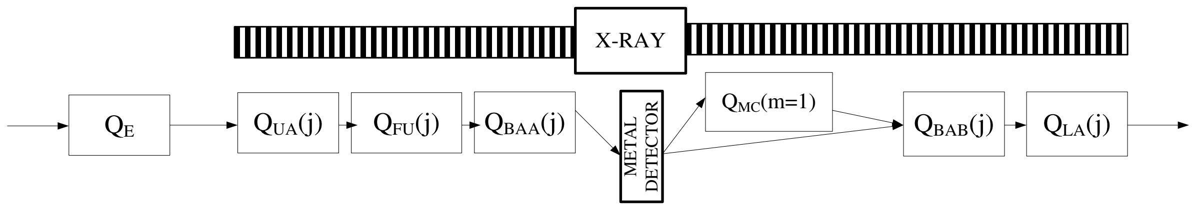

Figure 5: The diagram of security processes control implementation at a single point
Source: Kierzkowski and Kisiel (2015)

The security control process at a single point takes place in a serial manner. The passenger waiting in the queue Q_E checks the availability of the area c_{UA} and, if it is available, they start the process of preliminary independent preparation for the security check – the area automatically assigned to the queue Q_{UA}. Next, the process of the passenger's final preparation is implemented in the area c_{FU}, in accordance with the instructions from a security check point employee – the passenger is directed to the queue Q_{FU}. At the next stage (in area c_{BAA}, in the queue Q_{BAA}) , the passenger prepares for the metal detector control. What is important is that the operator's availability allows the passenger to pass through to the metal detector gate. If the detector did not indicate the necessity for a hand search, the passenger goes to the baggage waiting areac_{BAB} (queue Q_{BAB}). If the metal detector indicated the necessity for manual control, a hand search is performed in the area c_{MC}, in the queue Q_{MC}. The metal detector is not available for the next passengers until the hand search is completed by the operator. After the manual control, the passenger goes to the baggage waiting area and next to thec_{BAB}(queue Q_{BAB})and next to the baggage collection area c_{LA}(queue Q_{LA}).The security control process is implemented in a similar manner at a double point (Fig. 6).

The difference in the implementation of the security control process between a double and a single point occurs the moment the passenger walks through the metal detector gate. The availability of one of two operators allows for further implementation of the security control process (walking through the metal detector gate). The correctness of the check-point operation model was presented in Kierzkowski and Kisiel (2015).

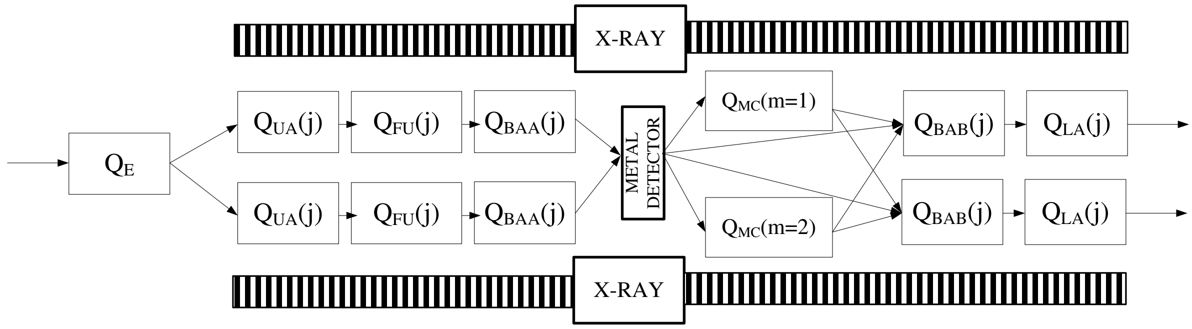

Figure 6: The diagram of security processes control implementation at a double point
Source: Kierzkowski and Kisiel (2015)

There are a range of methods for the management of security check-point operation, including static and dynamic ones. Static management of the security check-point operation schedule assumes the operation of a specific number of points within specific time limits, regardless of the passenger report stream. Dynamic management, on the other hand, involves the dependence of the security check-point operation schedule on the stream of reports. The following assumptions are usually made:

- the number of open security check points depends on the length of the queue,
- the number of open security check points depends on the time the passenger spends waiting in a queue,
- the number of open security check points depends on the length of the queue and the time the passenger spends waiting in a queue,
- the number of open security check points depends on the length of the queue or the time the passenger spends waiting in a queue.
- The scheduling algorithm of the security check point operation is presented in Figure 7.

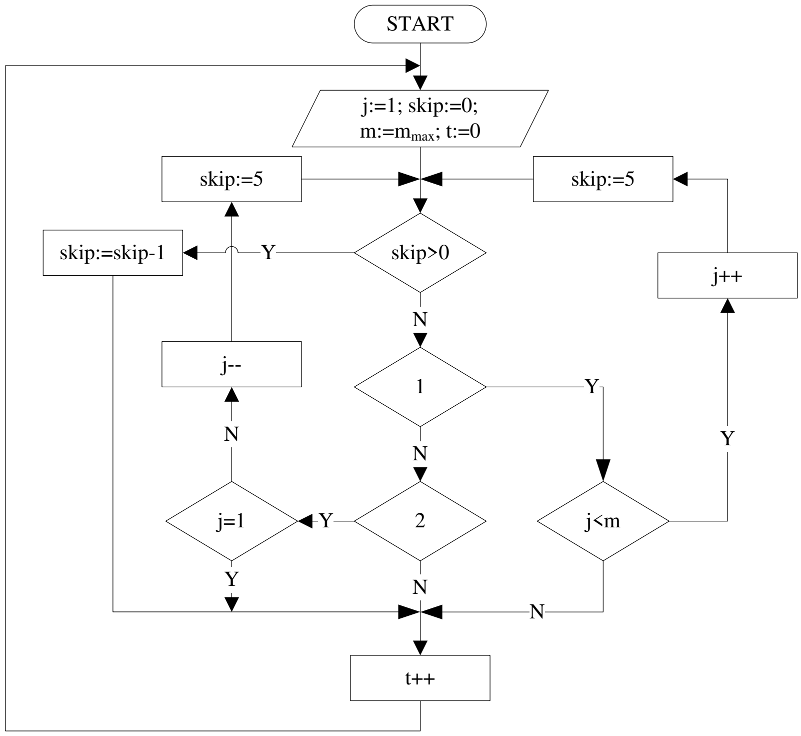

Figure 7: The algorithm for the management of the security check point operation

In accordance with the algorithm presented in Figure 7, input data are preset at the beginning:

- $j = 1$ – the number of open security check points is 1,

- $skip = 0$ – the length of the time for which changes in the system operation are observed, which are caused by closing (opening) a point,
- $m = m_{max}$ – the maximum possible number of operating security check points,
- $t = 0$ – simulation time,
- $t_{Q_E}^{waitmin}$- the minimum assumed passenger wait time in the queue Q_E,
- $t_{Q_E}^{waitmax}$- the maximum assumed passenger wait time in the queueQ_E,
- $n_{Q_E}^{min}$- the minimum assumed number of passengers waiting for the security check in the queue Q_E,
- $n_{Q_E}^{max}$- the maximum assumed number of passengers waiting for the security check in the queue Q_E,

In the next step, conditions pertaining to the operation of the system and next decisions are made on the opening, closing or leaving the number of points at the same level, depending on the system management method (formulas "1" and "2" as presented in Table 1). In each step of the algorithm execution (at time t), information about the passenger's wait time,$i - th\ Q_E$ (marked as $t_{Q_E}^{wait(i)}(t)$) and about the number of people waiting for the security check in a queue Q_E(marked as $n_{Q_E}(t)$). If a decision is made about opening or closing a security check point, the value of $skip = t_{res}$ is set. Until time $t + t_{res}$, no decisions about system operation are made.

Table 1: Criteria for the algorithm for the management of the security check point operation

	"1"	"2"
time in queue approach	$max\left\{t_{Q_E}^{wait(i)}(t): i \in Q_E(t)\right\} \geq t_{Q_E}^{waitmax}$	$max\left\{t_{Q_E}^{wait(i)}(t): i \in Q_E(t)\right\} \leq t_{Q_E}^{waitmin}$
queue size approach	$\sum_{s=t-5}^{t-1} n_{Q_E}(s) \geq n_{Q_E}^{max}$	$\sum_{s=t-5}^{t-1} n_{Q_E}(s) \leq n_{Q_E}^{min}$
time in queue or queue size approach	$max\left\{t_{Q_E}^{wait(i)}(t): i \in Q_E(t)\right\} \geq t_{Q_E}^{waitmax}$ OR $\sum_{s=t-5}^{t-1} n_{Q_E}(s) \geq n_{Q_E}^{max}$	$max\left\{t_{Q_E}^{wait(i)}(t): i \in Q_E(t)\right\} \leq t_{Q_E}^{waitmin}$ OR $\sum_{s=t-5}^{t-1} n_{Q_E}(s) \leq n_{Q_E}^{min}$
time in queue and queue size approach	$max\left\{t_{Q_E}^{wait(i)}(t): i \in Q_E(t)\right\} \geq t_{Q_E}^{waitmax}$ AND $\sum_{s=t-5}^{t-1} n_{Q_E}(s) \geq n_{Q_E}^{max}$	$max\left\{t_{Q_E}^{wait(i)}(t): i \in Q_E(t)\right\} \leq t_{Q_E}^{waitmin}$ AND $\sum_{s=t-5}^{t-1} n_{Q_E}(s) \leq n_{Q_E}^{min}$

4. Model Application: The Wroclaw Airport

The security control system is based on seven security check points, which can be single or double points. At point 1, passengers and baggage are checked as to who is entitled to using the fast track point. Due to the low intensity of passengers at the fast-track point and its complete isolation from the system, point 1 is taken into account in the simulation model. The diagram of the security control system is presented in Figure 8.

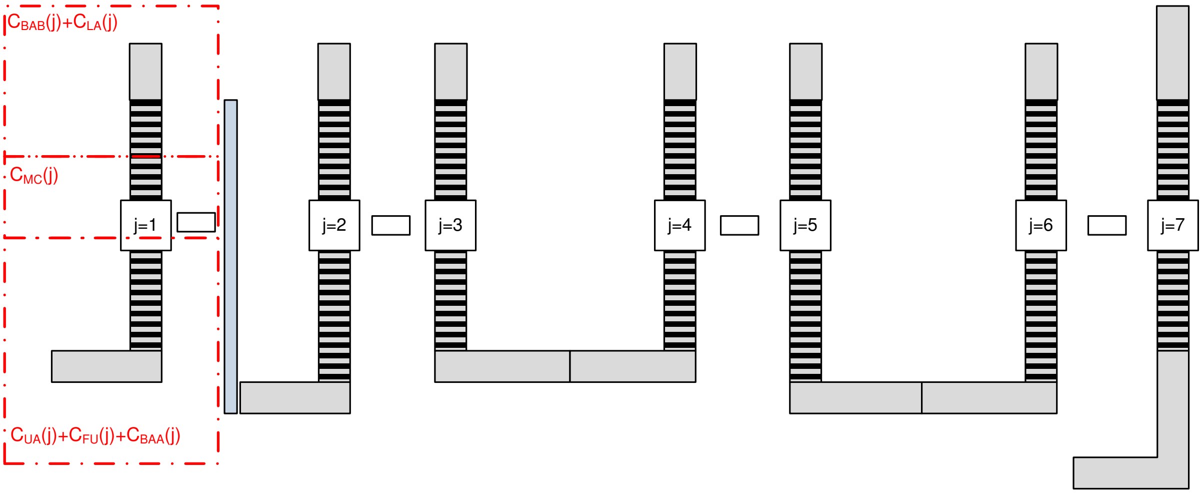

Figure 8: Diagram of the security control system at the Wroclaw Airport

All points have the same organisational characteristics. Five employees are assigned to each device. The capacity of the individual areas is described in Table 2.

Table 2: Capacity of areas in the security control system at the Wroclaw airport

	$j \in \{2,3,4\}$	$j \in \{5,6\}$	$j \in \{7\}$
$c_{UA}(j) + c_{FU}(j) + c_{BAA}(j)$	5	6	10
$c_{BAB}(j) + c_{LA}(j)$	5	5	6
$c_{MC}(j)$	2	2	2

The order of opening security check points is the following: point no. 7 is open first and next 6, 3, 2, 5 and, finally, 4. If only point 7 is open it is classified as single. If point 6 is open, the set of stands 6 and 7 operates as a double point. The specified order of opening (closing) results from the throughput of individual stands. The influence of the individual areas on the throughput of the point was described in Kierzkowski and Kisiel (2015). There are two airport security employees at the metal detector, who verify gate indications and conduct hand searches, if necessary. Another airport security employee is responsible for baggage control using an X-ray device while a third employee verifies images and performs manual control of the baggage, if necessary. Two employees inform the passenger about objects, which may not be carried in the hand baggage (the first in area c_{UA} - preliminary preparation and the other one in area c_{FU} - final preparation of the passenger). To determine the times of the performance of individual activities at the security check point (the time of the passenger's preliminary preparation for the security check, the time of manual control, etc.), research was conducted at the Wroclaw Airport. On the basis of these results, the distributions of probability densities of the times of implementation of individual activities are in security check areas. The results are presented in Table 3.

Table 3: The probability density functions of times for the performance of individual activities at the security check point

Action	Labelling	Probability density function	Test value λ
Preliminary preparation	t_{1stunl}	$f(t_{1stunl}) = \frac{t_{1stunl}{}^{3,42}}{13.74^{4,42} \cdot \Gamma(4.42)} e^{-\frac{t_{1stunl}}{13,74}}$	0.4711
Final preparation	t_{finunl}	$f(t_{finunl}) = \frac{e^{-\frac{23,62}{t_{finunl}-0,94}}}{23.62 \cdot \Gamma(2.02) \cdot \left(\frac{t_{finunl}-0.94}{23.62}\right)^{3,02}}$	0.5786
Hand search	t_{mcont}	$f(t_{mcont}) = \frac{(t_{mcont} - 16.95)^6}{2.13^7 \cdot \Gamma(7)} \cdot e^{-\frac{t_{mcont}-16.95}{2,13}}$	0.4041

Waiting time	t_{wfi}	$f(t_{wfi}) = \frac{1}{B(0.67; 2.56)} \cdot \frac{(t_{wfi} - 2.93)^{-0.33} \cdot (139.10 - t_{wfi})^{1.56}}{136.17^{2,23}}$	0.6551
Baggage, device and clothing collection time	t_{load}	$f(t_{load}) = \frac{2.01}{23.62} \cdot \left(\frac{t_{load} - 0.94}{23.62}\right)^{1,01} e^{-\left(\frac{t_{load}-0.94}{23.62}\right)^{2,01}}$	0.5768

Source: Kierzkowski and Kisiel (2015)

The consistence of empirical and theoretical distribuants was verified using theλ-Kolmogorov consistency test at a significance level of α = 0.05. All tests performed have shown that there were no grounds for rejecting the zero hypothesis (values lower than the limit value,$\lambda_{0.05} = 1.36$).

The intensity of passenger reports at 5-minute time intervals for the selected day of the week is presented in Figure 9. A distinct passenger accumulation of passengers can be noticed in the morning, around noon and in the afternoon.

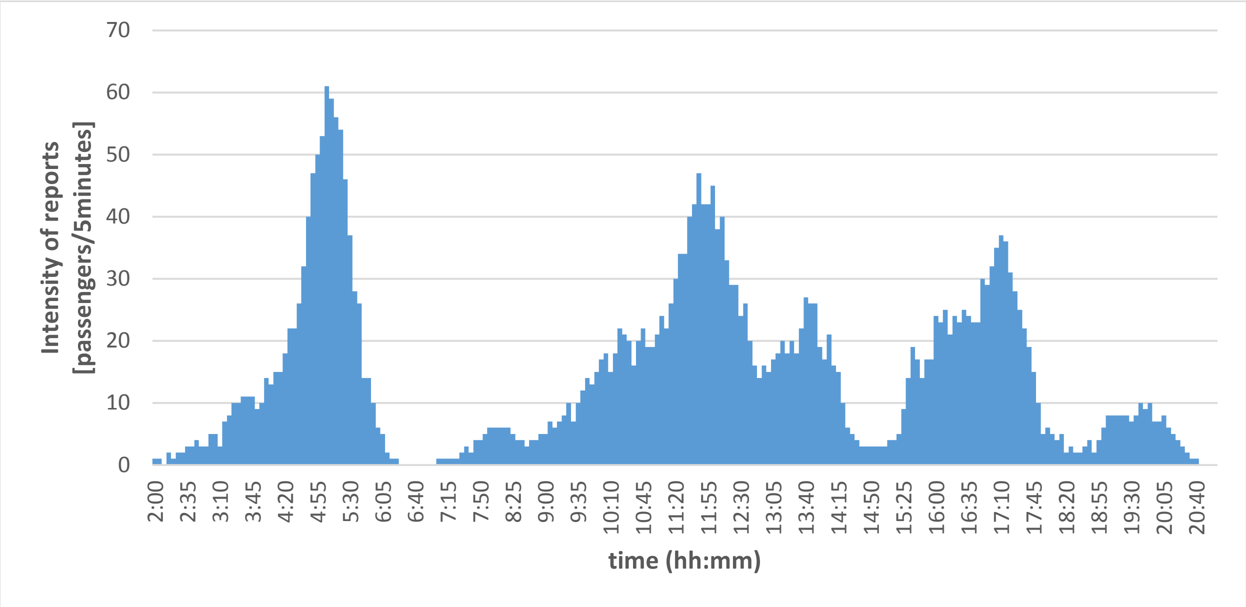

Figure 9: Intensity of passenger reports at 5-minute time intervals for a day of the week

The implementation of the developed model (together with the characteristics described in Tables 2, 3 and in Figure 9) and algorithms for the management of the security check point operation allowed for obtaining characteristics of the security control system operation, which are presented in Table 5. The following scenarios were assumed: one, two, three, four, five, six security check point(s) is/are opened. Additionally, fours scenarios were adopted, for which changes occur dynamically in accordance with the adopted algorithm (Table 4).

Table 4: Criteria for the algorithm for the management of the security check point operation at the Wroclaw airport

	"1"	"2"
time in queue approach	$max\left\{t_{Q_E}^{wait(i)}(t): i \in Q_E(t)\right\} \geq 5$	$max\left\{t_{Q_E}^{wait(i)}(t): i \in Q_E(t)\right\} \leq 1$
queue size approach	$\sum_{s=t-5}^{t-1} n_{Q_E}(s) \geq 30$	$\sum_{s=t-5}^{t-1} n_{Q_E}(s) \leq 5$

time in queue or queue size approach	$max\left\{t_{Q_E}^{wait(i)}(t): i \in Q_E(t)\right\} \geq 5$ OR $\sum_{s=t-5}^{t-1} n_{Q_E}(s) \geq 30$	$max\left\{t_{Q_E}^{wait(i)}(t): i \in Q_E(t)\right\} \leq 1$ OR $\sum_{s=t-5}^{t-1} n_{Q_E}(s) \leq 5$
time in queue and queue size approach	$max\left\{t_{Q_E}^{wait(i)}(t): i \in Q_E(t)\right\} \geq 5$ AND $\sum_{s=t-5}^{t-1} n_{Q_E}(s) \geq 30$	$max\left\{t_{Q_E}^{wait(i)}(t): i \in Q_E(t)\right\} \leq 1$ AND $\sum_{s=t-5}^{t-1} n_{Q_E}(s) \leq 5$

Table 5: Figures related to the security control system operation at the Wroclaw Airport

scenario	man-hours	time in system				
		mean time	lower 95%	upper 95%	minimum	maximum
	[h]	[min]				
1 lane	122.350	240.120	28.840	311.930	2.780	314.020
2 lanes	190.000	31.434	3.300	91.035	0.847	105.740
3 lanes	285.000	9.538	2.460	42.379	0.993	49.648
4 lanes	380.000	5.936	2.307	19.257	1.097	23.646
5 lanes	475.000	4.114	2.209	7.167	1.098	10.393
6 lanes	570.000	3.802	2.227	5.733	1.319	8.496
Time in queue approach	161.080	7.196	3.917	10.459	2.460	12.462
Queue size approach	162.500	7.139	3.537	11.219	2.667	12.095
Time in queue or queue size approach	162.670	6.945	3.320	10.972	2.440	11.936
Time in queue and queue size approach	162.916	7.287	3.377	10.755	2.280	12.843

Static management of the security control system operation provides results, which are hardly satisfactory. Assuming the operation of 3 security control lines, 285 work hours are used, while the average time of the passenger's stay in the security control system is $\overline{t_{SC}} = 9{,}538\ min$. Additionally, the minimum time of the passenger's stay in the system is 1 minute while the maximum time is nearly 50 minutes. The results which were obtained for the algorithms (Table 4). The average time of the passenger's stay in the system is approx. 7 minutes with the use of approx. 162 work hours. The minimum time of the passenger's stay in the system is 2.5 minute while the maximum time is approx. 12 minutes.

The dynamic schedule of the security check point operation depending on the adopted strategy (algorithm Table 4) is presented in Figure 10.

It should be noticed that during the morning rush hours, any strategy provides a similar solution (algorithm Table 4). In the subsequent periods, differences in the check point operation schedule can be seen. Time ranges, for which these differences occur, are very short though (max. 10 minutes). The selection of the management strategy (time in queue approach, queue size approach, time in queue or queue size approach, time in queue and queue size approach) depends only on the system's user (the airport). However, if the minimum average time of the passenger's stay in the security control system is the objective function, the system user chooses the “time in queue or queue size approach” and if it is the minimum number of work hours, the “time in queue approach” is chosen.

5. Conclusions

This article presents a simulation security control system operation model. The developed model allows for determining the average passenger wait time for the security check, the minimum average time of the passenger's stay in the security control system, the number of work hours of security control operators. The article describes algorithms for the management of the security check point operation depending on the adopted criteria (e.g. the maximum length of the queue to the security control system). The developed model, together with the algorithms, was used at the Wroclaw airport to determine the quantities described above for the security control system. On the basis of the results obtained, an assessment of the operation of the security control system was assessed, depending on the adopted scenarios (static and dynamic management of the security control point schedule). Schedules of the security check point operation were also determined, depending on the strategy: “time in queue or queue size approach”, “time in queue approach”, etc. The universality of the developed model makes it possible to use it at any airport. A significant direction for further research will be the possibility of implementing the human factor and the management algorithm to the developed model. Security check points will be treated as a socio-technical system. The reliability of proper operation of such a system will depend on the reliability of the device used for the passenger service process, the timely report service and proper passenger service.

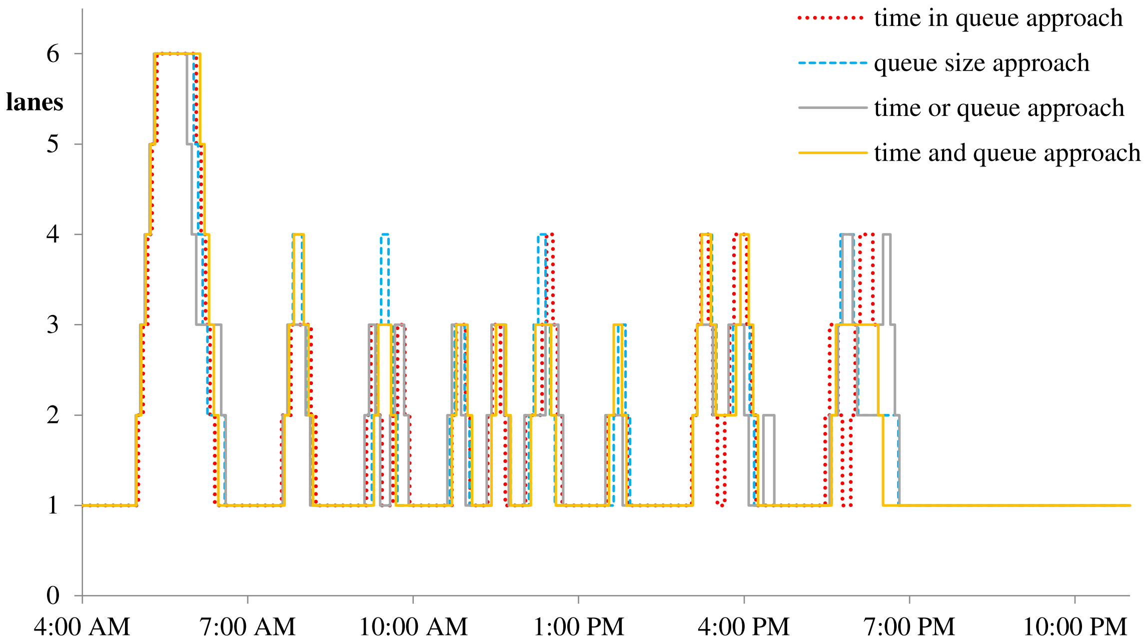

Figure 10: The dynamic schedule of the security check point operation depending on the adopted strategy

Owing to a model of security control, it was possible to develop a system configuration offering maximum efficiency while keeping the original surface of the system. The surface limitation resulted from minimisation of capital expenditures. The average efficiency of the original security control system (Kierzkowski and Kisiel (2014)) was 750PAX/h. Using the developed model, a new configuration of the system was proposed (Figure 8, Table 2). It was implemented in April 2014. Its average efficiency is 1025PAX/h. The developed algorithm of the security system management made it possible to limit the maximum length of the queue from 45 to 30 PAX. The average time of stay in the security control system (together with the waiting time) was reduced from 11 to 7 minutes. An additional economic benefit resulting from the developed model and security control system algorithm involves limitation of labour-consumption from 191 to 162 work-hours.

Further work will be performed to develop a simulation model for check-in desks. It will be possible to manage the security control system depending on the stream of reports forced by the operation of check-in desks. The influence of the check-in desk operation on the stream of passenger reports into the security control system will be analysed. In particular, it will be possible to implement the algorithm of the optimisation of the operation of two systems, for which the total number of employee work hours in the security control system and the check-in system will be minimal.

6. Acknowledgements

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Airlines Network Changes Influenced by Emission Charges

Baek-Jae Kim[1], Jinyoung Choi[2] and Youn-Chul Choi[3]

[1]Airport Services Manager, Qatar Airways, Incheon Airport, Korea
[2]Adv. LL.M., Air and Space Law, Leiden University, Netherland
[3]School of Aeronautical Engineering, Hanseo University, Korea

Abstract

Air travel has become an essential part of global society. External costs such as emission charges of airlines will be internalized by global standards such as the European Union-Emission Trading Scheme, which will result in changes of profit structures of airlines and network operations. Due to these changes, air ticket fares will increase and consequently, passenger demand will decrease. This study analyses the impact of emission charges on airlines network changes by application of global standards, EU-ETS in particular. A long-term, reliable estimation of the future price of carbon dioxide (CO_2) shall be presented.

Keywords: Emission charges, EU-ETS, Airlines Network

1. Introduction

In the last few decades, International civil aviation has reached the highest point compared to the average economic growth of other industry fields. This growth is still expected to continue but has had a negative effect on global climate changes due to greenhouse emissions. Airlines profit structures and network operations will also be influenced by the internalization of external costs like emission charges. This additional cost to fulfil the requirements for environmental protection will affect network and profit structures of airlines, according to demands. The research objective of this paper is to evaluate the influence of carbon charges on airline network behavior. The study conducts an empirical research on a very specific flight network change for the Incheon (ICN) – Frankfurt (FRA) route by the application of carbon charges under the European Union Emission Trading Scheme (EU-ETS), which was developed and applied by the European Union.

2. Research Method

2.1 Calculation of carbon emission by aircraft engine

Research data used in this study is based on the International Civil Aviation Organization (ICAO) Carbon Emissions Calculator Version 5, issued in June 2012. It is a general method employed to estimate the amount of carbon emissions generated by a passenger on a flight and to use in the carbon offsetting program. This Calculator is designed to provide information on the methodological approach and the detailed assumptions of the generic factors based on database constructed from several data sources. This flowchart below identifies information used as inputs to the calculator:

CO_2 per Passenger =

$$3.157 \times (\text{total fuel} \times \text{Passenger to Freight factor}) \div (\text{number of Y - seats} \times \text{Passenger load factor}) \quad (1)$$

Where:
Total fuel = A weighted average of the fuel used by all flights departed from the origin airport in order to reach the destination airport. The weighting factor is the ratio of number of departures for each equivalent aircraft type, to the total number of departures.

Passenger-to-Freight factor = Ratio calculated from ICAO statistical database based on the number of passengers and the tonnage of mail and freight, transported in a given route group.

Number of Y-seats = T total number of economy equivalent seats available on all flights serving the given city pair.

Passenger load factor = Ratio calculated from ICAO statistical database based on the number of passengers transported and the number of seats available in a given route group.

3.157 = constant representing the number of tonnes of CO_2 produced by burning a tonne of aviation fuel.

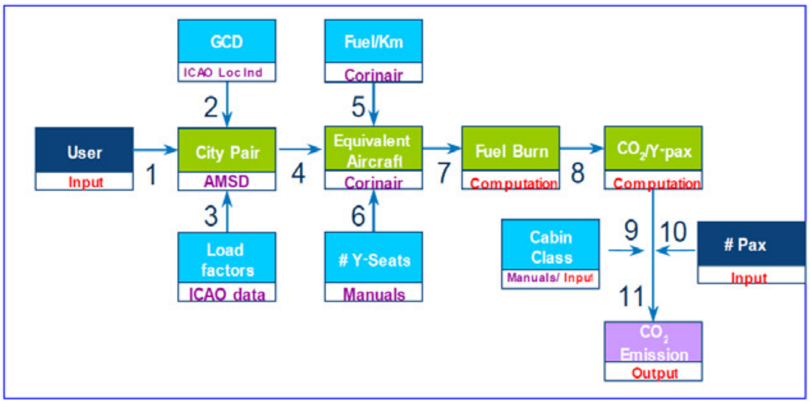

Figure 1: Recognition of emissions of ground and air transportation
Source: ICAO Carbon Emission Calculator (Version 5, June 2012)

There are various carbon calculation systems developed by States and carriers to evaluate emissions caused by air transport. Among these systems, the ICAO Carbon Emissions Calculator is the most general methodology providing an open source format facilitating air carriers that may wish to customize carbon emissions with their own data. The ICAO Calculator includes a general description of the method adopted by ICAO in order to estimate the CO_2 emissions, a demonstration of data coverage and sensitivity, and the steps a carrier needs to take in order to customize the calculator with its own data set. (ICAO, 2012)

2.2 Carbon charges' influence on airline costs and demand

Environmental cost is one of the direct operation costs. It has a direct influence on the profitability of airlines. This additional cost caused for the protection of the environment will affect airlines' networks and profit structures. Eventually, airlines will charge passengers this additional cost and this will be the burden of passengers, as fuel surcharges are. These calculations according to the negative demand effect are based on price elasticity. Oum et al. (1992) also carried out a research on empirically estimated demand functions and fare elasticity measures for air travel. Generally speaking, when other influences on demand remain unchanged, a higher price for a product results in lower quantity demand. Then the air passenger demand will decrease due to the increased carbon price. In this paper, -0.82 of price elasticity in the mixed air passengers category from the research of Oum et al. (1992) will be used for empirical research.

3. Route Selected for Empirical Study and Fuel Consumption

In this study, the impact of environmental charges are discussed when the EU-ETS applies to the aviation market. The Incheon International Airport (hereinafter 'ICN') to Frankfurt Main International Airport (hereinafter 'FRA') route and its network changes influenced by emission charges under the restriction of the EU-ETS has been selected for an empirical study because this route has the most frequent travel volume compared to the routes between ICN and other EU airports.

The EU-ETS is the first and the largest emissions trading scheme in the world, which launched in 2005 as a response to the rapid climate changes and the European Union's climate policy. As of 2015, 28 Member States in the EU and Iceland, Lichtenstein and Norway are participating in the scheme. This scheme applies to all carriers arriving in and departing from airports in the EU regardless of the carriers' nationalities and the total amount of the emission produced from flights within the routes is calculated. For the purpose of comparison on the cost and demand assessment, this study chose three different flight routes and airlines presented in the Table 1.

Table 1: Selected flight routes and airlines for cost and demand assessment

Flight routes			Airlines	Aircraft Type
Origin	Stopover	Destin.		
ICN		FRA	LH	A340
ICN	ZRH	FRA	KE / LH	B777 / A320
ICN	DXB	FRA	EK	A380 / B777

For the empirical analysis, individual routes are selected based on two criteria, which are typical flight patterns through, to and from Europe and the extant variance in the ETS-effects on different routings between origin and destination pairs. Any direct flight between ICN and FRA is covered by the EU-ETS, whereas with the two-segment flight via Zurich (ZRH) only the ZRH-FRA sector is subject to the scheme as ZRH is an ETS-evasion airport, even if the airport is located in the continent of Europe, because Switzerland is a non-EU country. Similarly, with the two-segment flight via Dubai (DXB), only the DXB-FRA sector is covered by the ETS. In this context, ZRH and DXB are potentially attractive ETS-evasion stopover airports. In particular, DXB airport located in the Middle-East attracts airlines flying from/to the ICN, South Korea as it has price competitiveness.

For a realistic appraisal and practical research, a German carrier Lufthansa (LH) and a flag carrier Korean Air (KE) of South Korea are selected for comparison. The LH provides a direct service route from ICN to FRA and the KE provides a service from ICN to ZRH. For the onward ZRH/FRA sector, passengers are forced to take flights of other foreign carriers as KE does not provide an onward connection service. In this case, the ticket price is higher than single carrier services to the final destination. Airport charges and other environmental costs such as noise charges and environmental tax imposed for the additional landing at the airport of ZRH may countervail the ETS-evasion stopover benefit of ZRH.

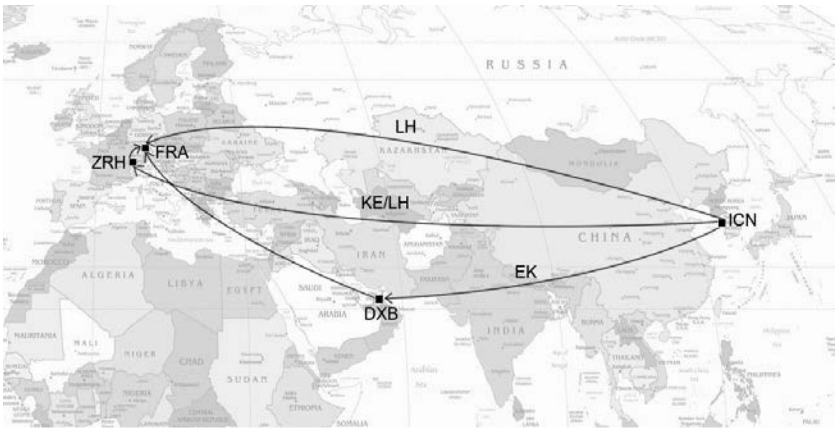

Figure 2: Selected flight routes and airlines for cost and demand assessment

On the other hand, Emirates (EK) transiting in DXB has an onward sector connection service out of DXB Hub and airport user charges are relatively lower. Also, environmental charges are currently not imposed on the carriers. In fact, the Dubai Hub of EK is quite far away to deviate significant traffic via its Hub due to the EU-ETS, especially from the Far-East airports. However, EK's network operations are an extreme model of Hub-and-Spoke. This means that their multitude of other advantages that are competitively more significant than this ET-ETS related cost advantage. (Scheelhaase, J. D., Grimme, W. G., 2007) EU-ETS cost of ZRH airport transit might be lower than the Middle-East airport transit, but the total cost of stopover in ZRH is not competitive due to other environmental costs that ZRH airport applies, such as noise charge. Landing charge is also higher than airports located in the Middle-East.

The distance and average fuel consumption data based on ICAO Carbon Emissions Calculator is as indicated in Table 2. It is applied to one-way economy class passenger basis for each sector.

Table 2: Distance and average fuel consumption

Flight routes			Distance (km)			Average fuel consumption(kg of fuel)		
Origin	Stopover	Destin.	1st leg	2nd leg	Total	1st leg	2nd leg	Total
ICN		FRA			8,534			89,084
ICN	ZRH	FRA	8,732	285	9,017	61,517	1,855	63,372
ICN	DXB	FRA	6,721	4,836	11,557	53,319	39,321	92,640

4. Estimation of Carbon Prices

It is not easy to forecast the precise level of carbon price in short-term, mid-term and long-term as it will be influenced by various factors such as economic growth, general income, relevant regulations and policy-makers' decisions. Despite this difficulty to provide accurate information on the average carbon offset credits price due to the price fluctuation, the current market price is assumed as ranging between €10/tonnes and €30/tonnes of CO_2 (Ernst & Young, 2007). The average EU Allowance (EUA) price in the third EU-ETS trading period between January 2013 and December 2020 will be €22/tonnes of CO_2 according to Thomson Reuters Point Carbon. EU-ETS prices are expected to increase more rapidly towards the end of the third period and estimated prices are expected to reach €28/tonnes in 2020.

The Committee on Climate Change of the United Kingdom suggested the price of £30 per tonne of carbon dioxide to be equivalent in 2020 and it will rise to £70 per tonne in 2030, £135 per tonne in 2040 and £70 per tonne in 2050. In light of recent research results, the price of carbon should rise steadily even if the rates of increase all differ. The rate should increase constantly close to the real rate of interest, which will be from 3% to 5% per year.

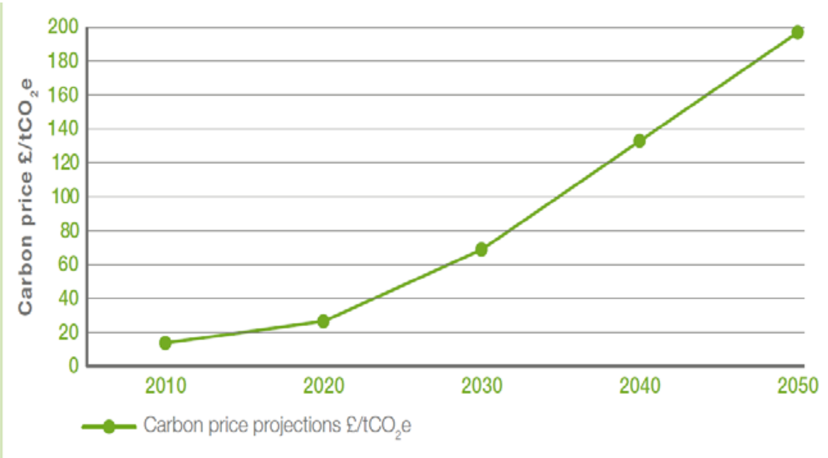

Figure 3: Carbon price projections (£/t CO_2e)
Source: DECC (2010), EC (2010), CCC calculations

A report from ICAO also supports this increasing trend for carbon charges in the long-term. (ICAO, 2012) In spite of various efforts in the aviation industry to reduce carbon emission through technical developments in manufacturing engines and airframes, high energy-density fuel options, aircraft operational options, policy and regulation options, it is still difficult to catch up with the quick increase of the amount of carbon emission. The expected steady growth of international civil aviation will have a negative impact on global climate change. Therefore, collective efforts are required in order to reduce the amount of emission and find out reasonable and sustainable solutions. These efforts include developing the best airline network model to cope with this change.

5. Influence of Emission Charges on Airfare and Demand

To access CO_2 emissions per flight, fuel consumption has to be combined with a specific CO2 emission factor. Flight distance and average fuel consumption data of flight route options based on ICAO Carbon Emissions Calculator are provided in Table 3.

Table 3: Result of CO_2 emission and the impact assessment of the EU-ETS

Flight routes			Average CO_2 emitted per passenger (kg of CO_2)			Additional cost per passenger (€22 / tons of CO_2)		
Origin	Stopover	Destin.	1st leg	2nd leg	Total	1st leg	2nd leg	Total
ICN		FRA			562.98			12.39
ICN	ZRH	FRA	566.13	53.05	53.05	0	1.17	1.17
ICN	DXB	FRA	452.84	333.54	333.54	0	7.34	7.34

Carbon dioxide emissions are produced in direct proportion to the combustion of the dominant jet fuel, kerosene: Per one kilogram (kg) of kerosene on combustion in the aircraft engine, 3.15 kg of CO_2 are emitted (IPCC, 2008). To access additional costs of each flight associated with the EU-ETS, an estimated quantity of CO_2 emission per flight is multiplied with the expected market price for the CO_2 emission allowances. To understand the actual impact of EU-ETS charges on existing flight routes, actual samples compared are provided in Table 4.

Table 4: Air ticket fare and CO_2 emission per passenger depend on flight routes

	Flight routes	Airlines	Net air ticket fare (KRW)	Taxes (KRW)	Ticket fare (KRW)	CO_2 emitted per pax
P2P	ICN/FRA	LH	2,090,000	656,900	2,746,900	1,125.96
H&S	ICN/ZRH/FRA	KE/LH	2,210,000	701,000	2,911,000	106.10
	ICN/DXB/FRA	EK	1,735,000	550,900	2,285,900	667.08

Note: Unit of air ticket fare: KRW (Korean Won) / Round Trip. CO_2 emitted per passenger: kg of CO_2

In relation to air ticket fares, it is difficult to compare fares per different flight routes and carriers because there are various kinds of discounted tickets that include promotion fares. For a fair comparison, one-year valid round-trip ticket fares plus taxes are used to cope with average CO_2 emissions of the ICAO Carbon Emission Calculator in this research.

Table 5: Additional ticket fare per passenger depend on flight routes

	Flight routes	Airlines	2020 30£/t CO_2 (KRW)	2030 70£/t CO_2 (KRW)	2040 135£/t CO_2 (KRW)	2050 195£/t CO_2 (KRW)
P2P	ICN/FRA	LH	58,160.00	135,706.67	261,720.00	378,040.00
H&S	ICN/ZRH/FRA	KE/LH	5,480.46	12,787.73	24,662.06	35,622.97
	ICN/DXB/FRA	EK	34,457.15	80,400.02	155,057.18	223,971.48

Note: Exchange rate: 1£ = KRW 1,721.79

According to the forecast for the increasing carbon price of the UK Committee on Climate Change provided earlier, ticket fares will increase due to the EU-ETS carbon price increase when other conditions remain the same.

Table 6: Air ticket fare reflected EU-ETS charges depend on flight routes

	Flight routes	Airlines	2020 30£/tCO_2 (KRW)	2030 70£/t CO_2 (KRW)	2040 135£/t CO_2 (KRW)	2050 195£/t CO_2 (KRW)
P2P	ICN/FRA	LH	2,805,060.00	2,882,606.67	3,008,620.00	3,124,940.00
H&S	ICN/ZRH/FRA	KE/LH	2,916,480.46	2,923,787.73	2,935,662.06	2,946,622.97
	ICN/DXB/FRA	EK	2,320,357.15	2,366,300.02	2,440,957.18	2,509,871.48

Note: Exchange rate: 1£ = KRW 1,721.79

Air ticket fares under EU-ETS charges per routes, which are direct flight and indirect flight via ZRH or via DXB are presented in the Table 6.

Table 7: Increase rate of ticket fare forecast (2020~2050)

	Flight Routes	Airlines	2020 30£/t CO_2 (KRW)	2030 70£/t CO_2 (KRW)	2040 135£/t CO_2 (KRW)	2050 195£/t CO_2 (KRW)
P2P	ICN/FRA	LH	2.12 %	4.94 %	9.53 %	13.76 %
H&S	ICN/ZRH/FRA	KE/LH	0.19 %	0.44 %	0.85 %	1.22 %
	ICN/DXB/FRA	EK	1.51 %	3.52 %	6.78 %	9.80 %

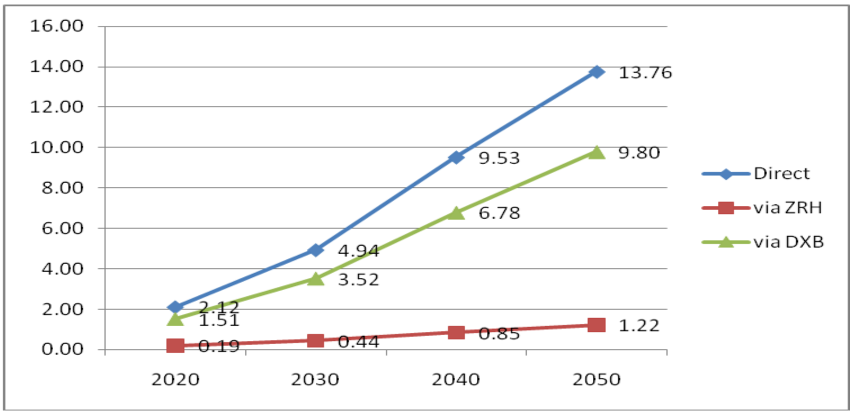

Figure 4: Increase rate of ticket fare forecast (2020~2050)

According to the forecast of carbon prices by the UK's Committee on Climate Change, these will rise steadily at a constant rate close to the real rate of interest. This forecast represents an assumption that ticket fares influenced by the EU-ETS charges will also increase. Moreover, the EU-ETS will apply higher rates on the carriers flying from ICN to FRA. In comparison, other flight routes via EU-ETS evasion airports, such as DXB or ZRH, will be charged less.

Table 8: Demand decrease forecast due to increase of carbon price (2020~2050)

	Flight Routes	Airlines	2020 30£/t CO_2 (KRW)	2030 70£/t CO_2 (KRW)	2040 135£/t CO_2 (KRW)	2050 195£/t CO_2 (KRW)
P2P	ICN/FRA	LH	-1.74	-4.05	-7.81	-11.29
H&S	ICN/ZRH/FRA	KE/LH	-0.15	-0.36	-0.69	-1.00
	ICN/DXB/FRA	EK	-1.24	-2.88	-5.56	-8.03

Note: Price elasticity: -0.82 (Oum et al.)

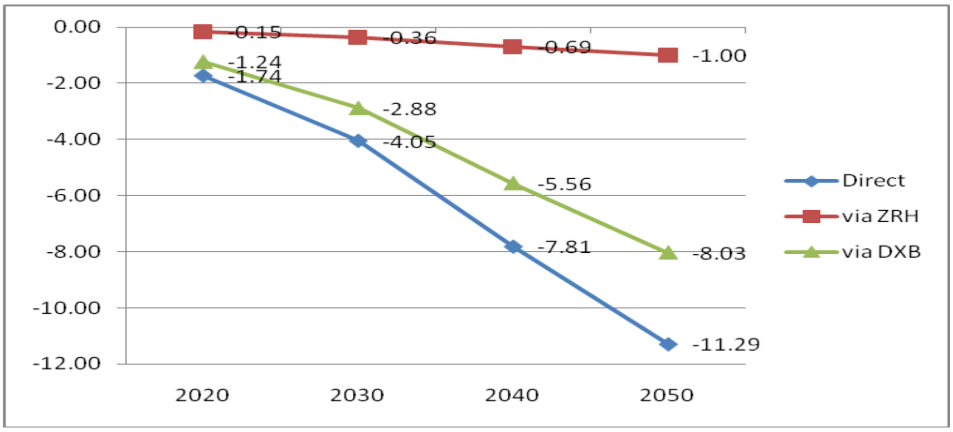

Figure 5: Demand decrease forecast due to increase of carbon price (2020~2050)

On the other hand, air passenger demand will decrease due to the increasing carbon price. In this paper, -0.82 of price elasticity in the mixed air passenger category from the research of Oum et al. (1992) has been used for empirical research. Price elasticity used in the research of Oum et al. (1992) is defined as the maximum value. As Figure 5 indicates, air passenger demand of direct flight routes will decrease more drastically compared to the demand of other transit flight routes.

Prices of the three different products given will be changeable according to the forecast of EU-ETS charge; to evaluate correlations, cross-price elasticity has been used. Cross-price elasticity is measured as the percentage change in demand for the first good that occurs in response to a percentage change in price of the second good.

$$e_d = \frac{\%\ \text{change in quantity demanded}}{\%\ \text{change in price}} = \frac{\Delta Q_d/Q_d}{\Delta P_d/P_d} \qquad (2)$$

Table 9: Cross-price elasticity of demand (2020~2050) of direct route (ICN/FRA) by LH

Flight Routes	Airlines	2020 30£/t CO_2 (KRW)	2030 70£/t CO_2 (KRW)	2040 135£/t CO_2 (KRW)	2050 195£/t CO_2 (KRW)
ICN/ZRH/FRA	KE/LH	9.15789	9.20455	9.18824	9.2541
ICN/DXB/FRA	EK	1.15232	1.15057	1.15192	1.15204

Table 10: Cross-price elasticity of demand (2020~2050) of transit route via ZRH by KE/LH

Flight Routes	Airlines	2020 30£/t CO_2 (KRW)	2030 70£/t CO_2 (KRW)	2040 135£/t CO_2 (KRW)	2050 195£/t CO_2 (KRW)
ICN/FRA	LH	0.07075	0.07287	0.0724	0.07267
ICN/DXB/FRA	EK	9.93377	10.2273	10.177	10.2041

Table 11: Cross-price elasticity of demand (2020~2050) of transit route via DXB by EK

Flight Routes	Airlines	2020 30£/t CO_2 (KRW)	2030 70£/t CO_2 (KRW)	2040 135£/t CO_2 (KRW)	2050 195£/t CO_2 (KRW)
ICN/FRA	LH	0.58491	0.583	0.58342	0.58358
ICN/ZRH/FRA	KE/LH	6.52632	6.54545	6.54118	6.58197

A negative cross elasticity denotes two complementary products, while a positive cross elasticity denotes two substitute products. As airline tickets are a substitute product, passengers will make decisions depending on fares and other ticket conditions. Lower airfare will be favored, if the other conditions are the same.

This result confirms that EU-ETS evasion airports outside of EU Member States will be used as transit airports if the EU-ETS is commercialized as planned. Also, EU-based carriers will be negatively influenced in the competitive commercial air travel market.

6. Airlines Network Behavior Influenced by Emission Charges

This study illustrates differences between the rise in the cost of direct flights and stopover flights via ZRH and DXB respectively due to the inclusion of aviation in the EU-ETS.

Lufthansa's direct flight routing leads to an additional cost of €13.45 per trip per passenger, whereas Korean Air and Emirates are partially affected as they have stopover airports within the EU. A Korean Air's flight from ICN via ZRH and connection to a Lufthansa flight to FRA results in an additional cost of €1.14 per trip per passenger only. The effects of rerouting via a non-European hub to avoid the ETS are visible: the routing via ZRH would save €12.31 in costs per trip per passenger. In reality, nevertheless, not only the costs out of ETS but also other external costs should be taken into account. An Emirates flight from ICN via DXB to FRA results in an additional cost of €7.59 per trip per passenger as EU-ETS will be applied to the DXB to FRA sector only.

The negative demand effects influenced by the internalization of external costs will be of significant importance for European Hub carriers; whereas cost increases due to the emission cap will affect non-EU carriers only on selected routes, the EU carriers networks will be subject to the ETS-evoked costs. As a result, EU-Hub carriers will lose more customers due to increasing airfares over the entire network than non-EU-Hub carriers with only certain routes to be influenced to and from EU airports. The most energetic and fast growing competitors against European and Asian carriers are Middle-East based carriers such as Emirates, Qatar Airways and Etihad Airways. These Middle-East carriers have been seen as major beneficiaries of the EU-ETS introduction in the aviation market (Scheelhaase, J. D., Grimme, W. G., 2007). An actual impact of the EU ETS on the aviation market is not yet significant because the price of carbon offset credits is not high enough to reallocate network operations of major carriers at this stage, but the price of carbon offset credits will gradually increase.

Another point is that unilateral emission control by a government or organization such as EU-ETS could lead to imputativeness of additional costs towards end-users, passengers in this case. A competitive advantage may also be conferred upon foreign carriers as the effects of increased aviation cost exert less of an adverse impact on foreign carriers than home carriers. Moreover, emission intensity increases depending on flight distance. This means that airlines are less likely to use a hub-and-spoke network than a point-to-point network, as hub-and-spoke networks usually have longer flying distances and more take-offs and landings which will lead to higher costs under strict emission control. (Andrew C.L. Yuen, Anming Zhang., 2011) Under the EU-ETS, carriers may add an intermediate stop outside the EU on long-haul flights. Then the ETS will apply only to the last short-haul sector for the intermediate stop to a final destination within the EU. (Albers, et al., 2009) Airline networks will be influenced also by the drastic development of manufacturing technology such as engine performance, light and strong airframe. This development will directly benefit airlines with aircrafts producing low emission and capable of shortening flight hours and fuel consumption. Thus, it will be important to estimate and prepare network operation strategies for each carrier. The current dominant airline network model, the Hub-and-spoke model, will be affected by increasing environmental charges including carbon charges more than the Point-to-point network model will be, due to slightly longer flight distances and more frequent landings and take-offs, which will lead to the rise of total operation costs for airlines. In the long term, carbon charges increasing the direct operating costs will have an impact on route networks of airlines.

7. Conclusion

The implementation of the EU-ETS will affect the Korean aviation market especially for flights to Europe. Since the EU-ETS adds extra costs to airlines on the basis of flight distance from a departing airport to any EU airport and fuel burned, the direct operating cost of long-haul route airlines to EU airports will be more affected than airlines offering medium-haul or short-haul route services. This implies a cost disadvantage for long-haul route direct flights. Therefore, between Far-East Asia and EU routes, transiting via the Middle East is more favorable than the direct operation. However, this cost difference from the EU-ETS is still acceptable for passenger behavior to choose an airline to travel with as the ticket price impact of the EU-ETS charge addition is not severe.

The environmental aspect does not receive enough attention in the Korean aviation market yet, so that there is not a compulsory environmental cost. However, various types of environmental costs will be imposed as more the attention will draw more attention.

There are certain limitations in this research because this study has been made based on the assumption of the EU-ETS application in aviation. As discussed in the 38th ICAO General Assembly in 2013, the global ETS will be developed and the MBM (Market-Based Measures) scheme will be applied to international aviation in the future. When global ETS is applied to aviation, transit through the nearest airports of EU flight routes will be no longer more beneficial than direct flights to EU airports. Also, continued research regarding this issue will be required as environmental bindings on global aviation will last.

The EU-ETS is limited to airports located in the EU region and there are some evasion air routes that are available. However, there is no exception in the scenario of the Global ETS. According to the consensus of the

38th ICAO general assembly in 2013, the Global ETS will be developed and applied in international aviation after 2018 at the earliest, regardless of the many expected and unexpected barriers. Thus, it is important to tackle the problem and to find a feasible network solution for the carriers.

Finally, there are so many other aspects to make a decision on airline network other than environmental cost increase. In this regard, further research is required on airlines network choices including various factors of the aviation business.

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A Dynamically Inter-dependent Business Model for Airline and Airport Coexistence

Nobuaki Minato[1] and Risako Morimoto[2]

[1]Graduate School of Technology Management, Ritsumeikan University, Kyoto, Japan
[2]School of Oriental and African Studies, University of London, London, United Kingdom

Abstract

We discuss a dynamically inter-dependent business model between an airline and an airport for coexistence. Governments provide various financial supports for sustaining unprofitable regional airways when such airways are essential to local life and the economy. However, providing inefficient subsidies are often criticised worldwide. The present paper examines a business model called load factor guarantee (LFG) in which an airline and an airport agree on the load factor of a flight and the either party compensates for any discrepancy between the actual and agreed upon load factor. System Dynamics is introduced to model the dynamic interactions of the two parties. We calibrated the mode using data from Noto Airport and All Nippon Airways (ANA) from 2003to 2014. The key to the success of the coexistence between an airline and an airport is an integral management of annual negotiation of a target load factor and monthly demand adjustment with subsidies. Although a subsidy means a temporary financial loss for an airport, it is an effective way of maintaining the long-term airline and airport coexistence. The model is applicable to unprofitable airways worldwide and contributes to their sustainable management.

Keywords: Airport, Airline, Coexistence, System Dynamics, Load Factor Guarantee

1. Introduction

Regional air transport generally has a thin air traffic demand with wide fluctuations; thus, its operational efficiency is lower than that of trunk routes (Suzuki et al., 1995). Critical factors in enhancing the profitability of regional air transport include fleet selection and daily frequency (Sato et al., 1990). However, at the micro level, forecasting future air traffic demand is imprecise (Lyneis, 2000), adding to an airline's difficulties when making decisions and developing a new regional airway.

To reduce the business risk associated with the entry of a new regional airway, governments provide financial support when air travel demand is expected to be slight and when air transport is important to local livelihoods and economies (Minato and Morimoto, 2011a). Measures such as profit loss compensation, landing fee reductions, and fuel tax reductions are then made available (Nomura and Kiritoshi, 2010). However, these measures do not essentially mitigate the problem. Furthermore, anticipated social changes such as population decline and tax revenue decline will prevent regional air transport system from relying solely on public financing.

We elaborate on a business model, the load factor guarantee (LFG), which attempts to share business risk between an airline and an airport (Figure 1). It may be able to manage the sustainability of airways based on market principles where each player acts for better pay-off in the commercial activities. LFG is an agreement by which an airline and an airport, usually owned by a local government in Japan, agree to the load factor of a regional flight beforehand. The airport and government then compensate for the discrepancy between the actual and the agreed-upon load factor. An airline may transfer a portion of its revenues to a local government when the actual load factor is higher than the guaranteed load factor (Noto Airport Promotion Council (NAPC), 2012). The LFG allows airlines to maintain load factors above the breakeven level and therefore encourages airlines to enter new regional air routes even when profitability is uncertain. In addition, the owner of the airport, local government, is encouraged to increase the number of local air passengers to enhance the load factor of a regional airway. Therefore, a symbiotic relation between an airline and an airport is established by the business model.

Few studies on LFG have been done; therefore, the validity of the business model must be appropriately studied. Hihara (2007) analyses the LFG agreement between Ishikawa Prefecture and All Nippon Airways (ANA) in Japan. His study attempts to forecast future load factor and pay-off considering the impact of the LFG agreement on both parties' decision-making, but the results are not significant due to data scarcity. Fukuyama et al. (2009) analyse the LFG agreement between Tottori Prefecture in Japan and Korea's Asiana Airlines. Their research considers LFG as a Nash bargaining competition between airlines and the local government and examines the rationality of the negotiations using multivariate regression analysis. The negotiation resulted in an approximate Nash bargaining solution in 2007. However, these studies analyse the LFG using mathematical modelling with static data input and do not consider the dynamic interactions between airline and airport, which could greatly affect the future state of the business model.

Therefore, we would like to examine the business model analysing the feedback effect of each party's decision-making on long-term airline and airport coexistence. The remainder of the present paper is organized as follows. The section 2 explains the methodology used for evaluation. The section3 illustrates overview of the model structure and describes the results of the model building. The section 4 presents the analysis and discussions based on the simulation results. The section 5 provides the conclusions and identifies the study's limitations.

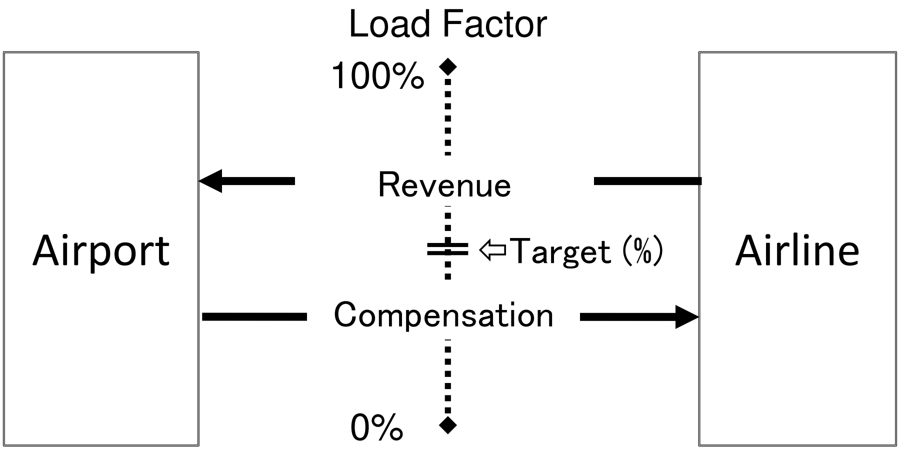

Figure 1: A dynamically inter-dependent business model between an airline and an airport

2. Methodology

We introduced Systems Dynamics (SD) for modelling since it enables to represent physical and information flows based on information feedback controls that are continuously converted into decisions and actions (Suryani, Chou, and Chen, 2010). It is a method of modelling the nonlinear dynamics of complex systems developed by Jay Forrester of MIT in the 1950s (Sterman, 2000). Stock and Flow Diagram (SFD) uses several graphical icons, such as stock, flow, valve, and cloud icons, to express a system structure (Figure 2). Stocks are integrated accumulations of inflows and outflows. Inflows are represented by pipes leading into a stock and outflows by pipes leading out. Valves in the middle of each pipe control the inflows and outflows. Clouds represent the sources, and sinks represent the flows (Sterman, pp. 192, 2000).

For mathematical modelling, System Dynamism uses both integral equation (Eq. 1) and differential equation (Eq. 2). Assume now that state of system is represented by Stock (t) and calculated by:

$$\text{Stock (t)} = \int_{t_0}^{t} [Inflow(s) - Outflow(s)]ds + Stock\ (t_0) \quad (1)$$

where t_0 is initial time, t is terminal time, inflow is a flow connected into to the Stock and outflow is a flow connected out from the Stock. Deferential of Stock at time t is then calculated by;

$$\frac{d(Stock)}{dt} = Inflow(t) - Outflow(t) \quad (2)$$

Figure 2: Stock and Flow Diagram (SFD)

3. Model Development

3.1. Model architecture

We developed the SD model to calibrate a general LFG management framework adopted by an airline and an airport. The model consists of four different subsystems: 1) a flight and passenger, 2) a demand adjustment, 3) a load factor adjustment, and 4) a load factor guarantee. Fig. 3 shows a subsystem diagram describing the overall architecture of the model.

An airline provides flights depending on its flight strategy, taking into account frequency and fleet. The strategy defines supply in terms of the number of seats, while the number of passengers is generated by market demand based on historical data. The flight and passenger subsystem generates the annual load factor as an input into the LFG subsystem. The airline and airport negotiate within the load factor adjustment subsystem and generate a target load factor as an input into the LFG subsystem. Payment is computed based on the discrepancy between the annual and target load factors. When a certain discrepancy exists between the two, an airport with financial support from the local government that owns it attempts to stimulate passenger demand by providing subsidies. An airline attempts to control passenger demand by changing the ticket price as well. Their reactions bring about demand changes as an input into the LFG subsystem. In this way, airline and airport coexistence is expected to be maintained through the dynamic interactions between the two parties.

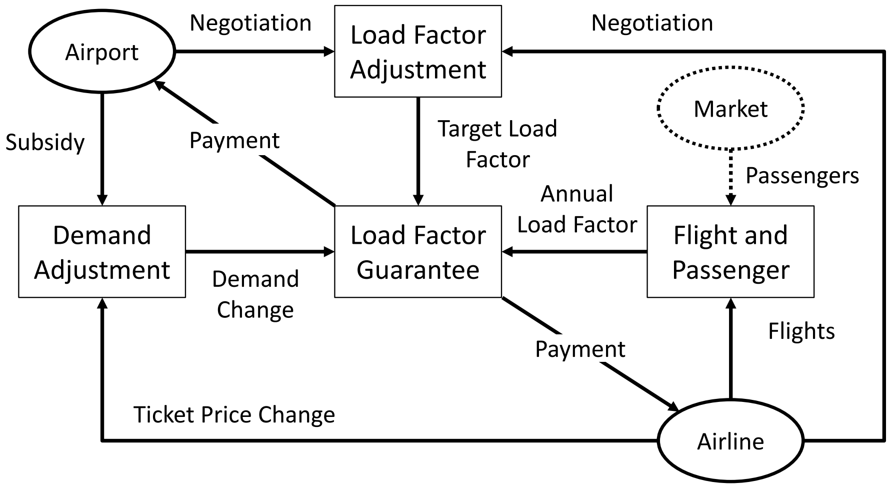

Figure 3: Model overview

3.2. Flight and passenger subsystem

Figure 4 shows the stock and flow diagram for a flight and passenger subsystem. There are two stocks in the model: 1) Accumulated Number of Seats Provided, which generates a supply to the system, and 2) Accumulated Number of Passengers, which generates a natural demand for the system. The Annual Load Factor is computed using these two stock variables. A stock and flow structure is used to compute the annual load factor at each month accumulating the monthly records.

An inflow to the stock, Monthly Number of Seats Provided, is computed as the multiple of four variables: Number of Days per Month, Number of Flights per Day, Number of Seats per Aircraft, and Operation Reliability. Each variable is set based on the historical data. The monthly supply is accumulated into the stock for 12 months and is repeatedly discarded at the end of a year by Clearance using the pulse train function of Vensim software.

The other inflow to the stock, Monthly Number of Passengers, is computed by summing the Monthly Passenger Demand, Subsidized Passenger Demand and Demand Change by Price. Monthly Passenger Demand is a natural demand that is set based on the historical data using the lookup function. Subsidized Passenger Demand and Demand Change by Price are computed using the Demand Adjustment Subsystem, which is explained later. Monthly demand is accumulated into the stock for 12 months and repeatedly discarded at the end of a year. This discard might not be realistic for air transport business operations in practice; however, we designed this model to simulate the game between the airline and the airport. At the end of each year, they compute the average load factor for the year to determine payments to the other, and the result does not influence next year's passenger demand.

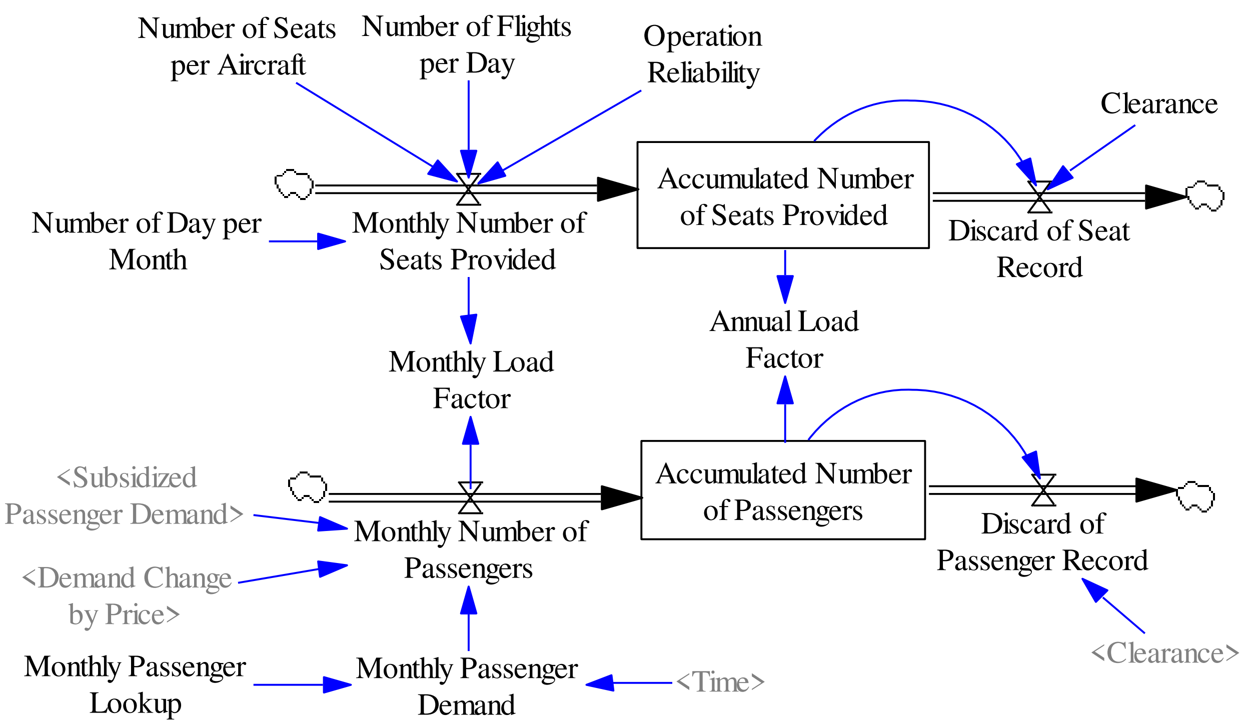

Figure 4: Flight and passenger subsystem

3.3. Load factor guarantee subsystem

Figure 5 shows the SFD for the LFG subsystem. Two main stocks are used in the model: 1) Financial Stock of Airline, calculated in Eq. 3, and 2) Financial Stock of Airport, calculated in Eq. 4. The term 'financial stock' means the latest cash position of an airline and an airport, enabling the evaluation of their financial states through a monitoring of these stock variables. Additional Passenger Revenues is calculated in Eq. 5 and Impact of Ticket Price Change is calculated in Eq. 6.

An airport pays the Guarantee Fee calculated in Eq. 7 when the Annual Load Factor is lower than the Target Load Factor. An airline pays the Cooperation Fee calculated in Eq. 8 when the Annual Load Factor is larger than the Target Load Factor. Each payment is calculated at the end of a year according to the Clearance.

$$\mathbf{FinancialStockofAirline} = \sum \text{Guarantee Fee} - \text{Cooperation Fee} + \text{Additional Passenger Revenues} - \text{Impact of Ticket Price Change} \tag{3}$$

$$\mathbf{AdditionalPassengerRevenue} = \text{Average Ticket Price} \times (\text{Subsidiezed Passenger Demand} + \text{Demand Change by Price}) \tag{5}$$

$$\mathbf{ImpactofTicketPriceChange} = \text{Price Adjustment} \times \text{Monthly Passenger Demand} \tag{6}$$

$$\mathbf{GuaranteeFee} = \mathbf{Ifthenelse}\ (\mathbf{TargetLoadFactor} > \boldsymbol{AnnualLoadFactor}, \boldsymbol{Accum}\mathbf{ulatedNumberofSeatsProvided} \times \mathbf{DiscrepancyofLoadFactor} \times \frac{1}{2} \times \mathbf{AirportUnitPayment} \times \mathbf{Clearance}, \mathbf{0}) \tag{7}$$

$$\mathbf{Cooperation\ Fee} = \mathbf{If\ then\ else}\ (\mathbf{Annual\ Load\ Factor} > \boldsymbol{TargetLoadFactor}, \boldsymbol{Accum}\mathbf{ulated\ Number\ of\ Seats\ Provided} \times \mathbf{Discrepancy\ of\ Load\ Factor} \times \frac{1}{2} \times \mathbf{Airl}\square\square\mathbf{e\ Unit\ Payment} \times \mathbf{Clearance}, \mathbf{0}) \tag{8}$$

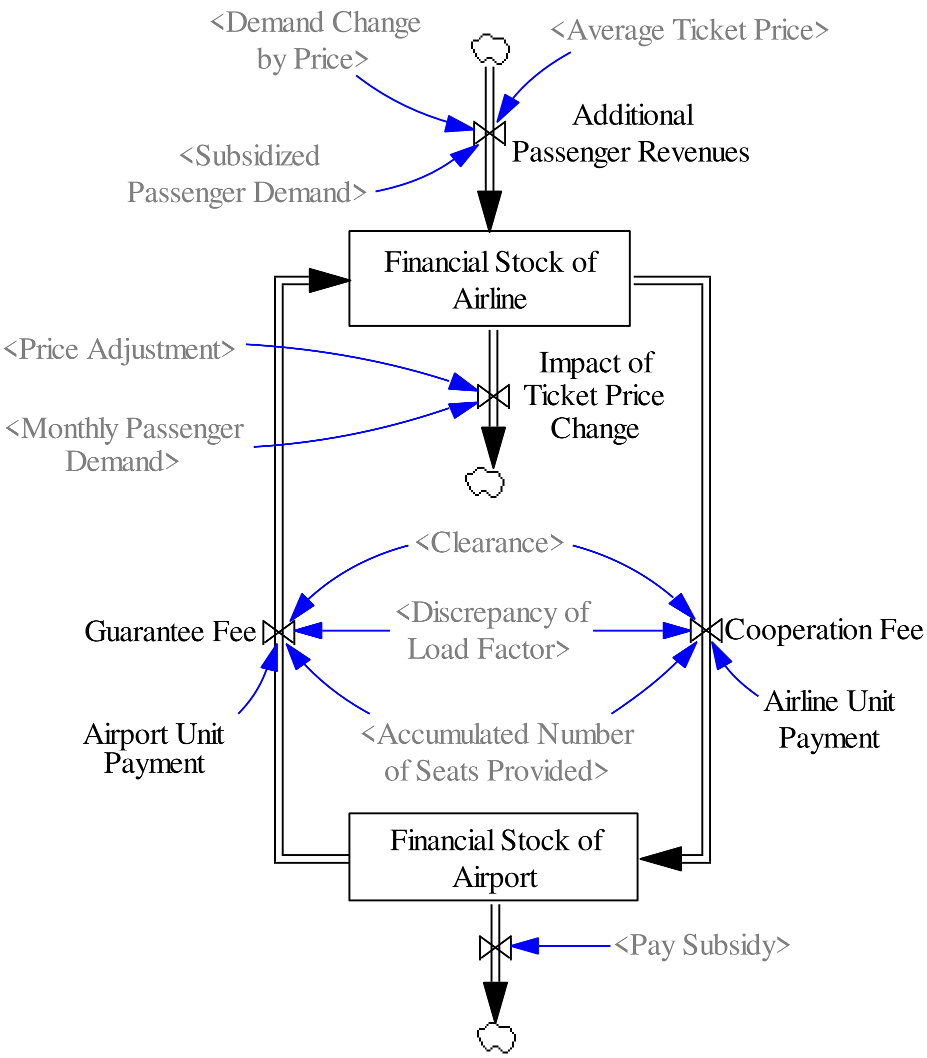

Figure 5: Load factor guarantee subsystem

3.4. *Load factor adjustment subsystem*

Figure6 shows the SFD for the Load Factor Adjustment Subsystem. The model contains one stock variable, Target Load Factor. Each stakeholder negotiates to adjust the Target Load Factor according to the Discrepancy of Load Factor. The Target Load Factor is increased when the Annual Load Factor is larger than the Target Load Factor of the previous year. In contrast, the Target Load Factor is decreased when the Annual Load Factor is lower than the Target Load Factor. The Load Factor Adjustment Rate defines the adjusted discrepancy which becomes Load Factor Adjustment.

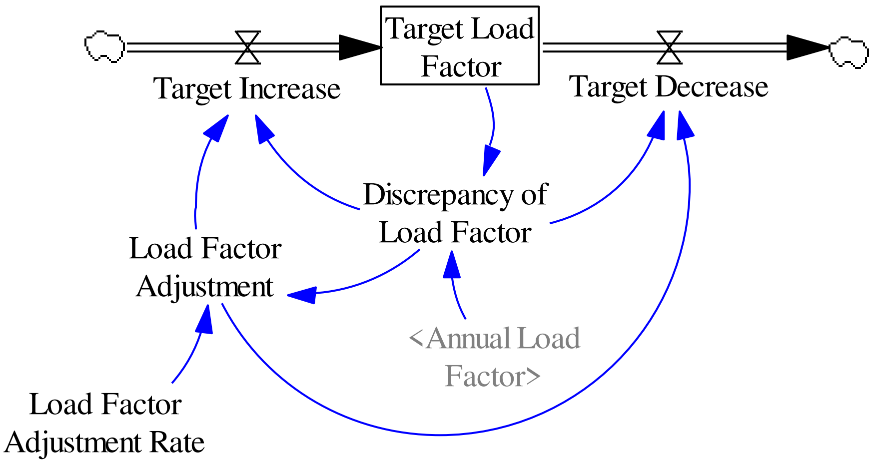

Figure 6: Load factor adjustment subsystem

3.5. *Demand adjustment subsystem*

Figure7 shows the SFD for the Demand Adjustment Subsystem. The demand is adjusted according to the discrepancy between the Target Load Factor and the Annual Load Factor of the previous year and the Demand Adjustment Rate. We assume that the demand adjustment is conducted by controlling the ticket price with two different measures, subsidy by airport and price change by airline. Ticket Price Elasticity of Demand is computed in Eq. 9 (Murakami et al., 2008, 59–64),

$$\mathbf{PriceElasticityofDemand}\ (e_t) = -\frac{(q_{t+1}-q_t)/q_t}{(p_{t+1}-p_t)/p_t} \tag{9}$$

where q is demand and p is price. We assume that Price Elasticity of Demand is fixed throughout the simulation and is set at −0.74 (Yamauchi 2000, 195–225) in the baseline simulation but conduct scenario study changing the value as well. Converting Eq. 9, the Required Decrease of Ticket Price is computed as in Eq. 10, which defines Subsidy per Ticket. The total amount of the subsidy is computed using the multiple of Subsidized Passenger Demand and Subsidy per Ticket. The subsidy payment is accumulated in the stock of Accumulated Amount of Subsidy. We evaluate how much an airport and a local government should spend by adjusting the Average Load Factor. On the other hand, we assume that an airline proactively changes the ticket price when the demand is not sufficient. Considering the Expected Ticket Price in Eq. 11, an airline attempts to fill the Price Gap between Average Ticket Price and Expected Ticket Price. Price Adjustment is computed in Eq. 12 and Demand Change by Price is computed in Eq. 13.

$$\mathbf{RequiredDecreaseofTicketPrice} = -\frac{(q_{t+1}-q_t)\times p_t}{q_t \times e_t} \tag{10}$$

$$\mathbf{ExpectedTicketPrice} = \mathbf{FixedTicketPrice} - \mathbf{RequiredDecreaseofTicket}\ \mathrm{Price} \tag{11}$$

$$\mathbf{PriceAdjustment} = \frac{\mathbf{PriceGap}}{\mathbf{PriceAdjustmentTime}} \tag{12}$$

$$\mathbf{DemandChangebyPrice} = -\frac{\mathbf{PriceAdjustment} \times \mathbf{q_t} \times \mathbf{e_t}}{\mathbf{p_t}} \tag{13}$$

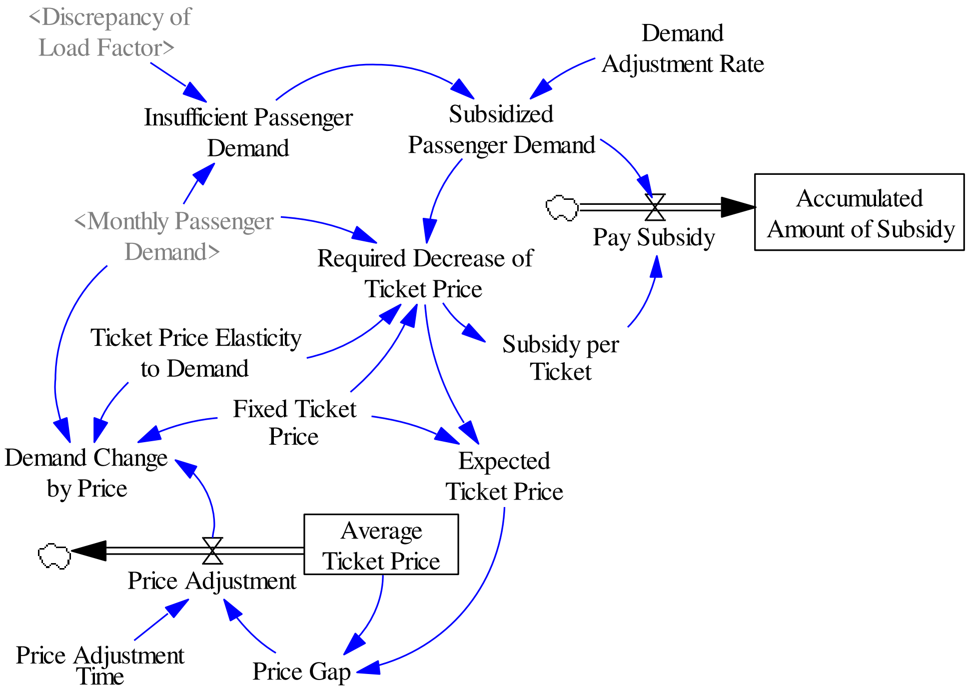

Figure 7: Demand adjustment subsystem

3.6. Data for model building

We used data for the Haneda–Noto flight in Japan, believing the case to be appropriate for a simulation for two key reasons. First, the Haneda–Noto route has operated from Noto Airport since it opened in 2003 and thus provides a complete stream of uninterrupted data. Second, the prefecture government owns and manages the airport and has supported ANA and passengers through a LFG. This particular LFG requires ANA to operate twice-daily flights between Haneda and Noto. Whenever annual load factors are below the guaranteed threshold, the prefectural government compensates ANA for the difference. It is called guarantee fee. When the load factor exceeds the guaranteed load factor, ANA transfers some revenues to the prefectural government. It is called cooperation fee. These agreements have sustained the twice-daily flights since the airport opened in 2003. The flight and passenger records are shown in Appendix (NAPC 2015).

For this particular LFG, both parties agreed on a maximum payment amount and ranges around the guaranteed load factor, making both parties exempt from payments since 2005 (Fukuyama et al., 2009; Minato and Morimoto, 2011b, Hihara, 2012). In 2005, for example, the target load factor was 64%. However, the government had to pay ANA only when the actual load factor was below 63%, and ANA had to pay the government only when the load factor exceeded 65% (NAPC, 2010). The present model excluded the maximum payment and the ranges around the guaranteed load factor in order to present a more generalised simulation model of a LFG.

3.7. Model Testing

We tested the model using the historical data of Haneda–Noto flight in 2003 and 2004 since the average load factors exceeded the guaranteed load factors in each year. ANA transferred some of its revenues to the prefectural government as Cooperation Fee. It means that we can examine the system behaviour according to the actual reactions of the both parties.

We compared the two data sets, Xd: historical data and Xm: model output, in terms of payment of Cooperation Fee and Guarantee Fee. We used two measures for examining the data fit: Mean Absolute Error

(MAE) and Mean Absolute Percentage Error (MAPE) for each item for the two years. Both MAE and MAPE provide a measure of the average error between the simulated and actual data sets (Sterman, p. 874, 2000) but MAPE is dimensionless.

Table 1 shows the model testing results. Regarding the Guarantee Fee, the simulation results are identical to the historical data both in 2003 and 2004. The model succeeded in reproducing exact behaviours occurred in the past. Regarding the Cooperation Fee, there were cash transfers from ANA to Ishikawa prefecture both in 2003 and 2004. The historical data in 2003 was 811,000 USD and the simulation result was 811,562 USD and the deviation was only 562 USD. In 2004, the historical data was 133,167 USD and the simulation result was 136,766 USD and the deviation was only 3,599 USD. The MAE is 2,081 USD and the MAPE is 1.4%. The test results show some deviation in Cooperation Fee payment to the historical data but we think the model can appropriately reproduce macroscopic system behaviors for further simulations.

Table 1: Model testing results

		2003	2004	MAE	MAPE
Cooperation Fee (USD)	Xd	811,000	133,167	2,081	1.4%
	Xm	811,562	136,766		
Guarantee Fee (USD)	Xd	0	0	0	0.0%
	Xm	0	0		

4. Results and Discussions

Weexamine four different scenarios: 1) baseline, 2) load factor adjustment, 3) demand adjustment and 4) combination. The baseline scenario does not include any measure of the impact on the system. The load factor adjustment scenario includes adjustment to the rate of the guaranteed load factor. The demand adjustment scenario includes a demand adjustment using ticket subsidies and the price change. The combination scenario includes both of the load factor adjustment and the demand adjustment. For each scenario, we run the simulation for 120months (ten years).The period of simulation is identical to the period the flight operation from 2005 to 2014 in which we are able to acquire the time-series monthly demand data (shown in Appendix).

4.1. Baseline scenario

We set a baseline scenario assuming no load factor adjustment or demand adjustment. Figure 8 shows the financial stock of the airline and the airport. The movements of each financial stock are horizontally symmetrical to the even level because neither party took any adjustment action. The difference can be explained by the payment results of the guarantee fee and the cooperation fee (Figure 9). Initially, the airline continuously pays cooperation fee for the airport as there is adequate air passenger demand. The amount of the payments gradually lessons overtime due to the decrease of passenger demand. However, the trend begins to change around year five, driven by decreased passenger demand. Then, the airport has to pay the guarantee fee for the airline to fulfil the load factor discrepancy. Figure 9 illustrates that the both parties sometimes win and sometimes lose; thus, the airline–airport relationship is not a path-dependent system. It implies that the amount of the payments will probably be balanced in the long run according to the demand movement. However, it is highlighted that the airline must temporarily bear the negative financial situation for the entire period of the simulation. This situation might force the airline to withdraw from commercial operation of the entered airway route. Hence, we conclude that the airway is not likely to be sustainable under the baseline scenario. We then examine a certain measure for enhancing the coexistence of an airline and an airport.

4.2. Load factor adjustment scenario

We examined the load factor adjustment scenario highlighting the Load Factor Adjustment Subsystem. We assume that the both parties negotiate to adjust the Target Load Factor according to the discrepancy of the load factor in the previous year. We then implement a parametric study on the Load Factor Adjustment Rate (LFAR), setting it as 0% (baseline), 25%, 50%, 75% and 100%, without any adjustment on the demand side.

Figure10a through Figure 10d show the results of the Financial Stock of Airline and Financial Stock of Airport under the load factor adjustment scenarios. At 25% of LFAR (Figure 10a), the discrepancy between the two parties is smaller than that of the baseline scenario in the first six years. It implies that the load factor adjustment provide positive impact for the sustainability. However, the time-series behaviors have changed after year seven. The airline continuously accumulates cash to its stock while the airport continuously loose cash from its stock. The discrepancy of the financial stocks tends to increase overtime. It implies that the load factor adjustment provide negative impact for the sustainability. At 50% of LFAR (Figure 10b), the global trend of the time-series behaviors is the same as that of 25% of LFAR but there is less discrepancy between the two parties. It implies that the situation is more favorable for an airline and an airport for sustaining the commercial relationship. Furthermore, at 75% of LFAR (Figure 10c), the global trend of the time-series behaviors is the same as that of 25% of LFAR and 50% of LFAR but there is much less discrepancy between the two parties. It implies that the more LFAR increases, the less the discrepancy of the financial stocks of the two parties. When we set 100% of LFAR (Figure 10d), the financial stocks stay around zero for the both parties. We can conclude that control of LFAR work well for maintaining the financial equality of an airline and an airport.

In addition, we can find symmetry to the even level in all the time-series behaviors in Figure 10a through Figure 10d. When the result is positive for the airline, the result is always negative for the airport and vice versa. The movements were totally symmetrical, meaning that introducing the Load Factor Adjustment works satisfactorily to improve the benefit of the airline; at the same time, however, it also lessens the benefit of the airport. Thus, an appropriate trade-off must be designed between the airline and the airport for the sake of long-term coexistence. Introducing load factor adjustment can change the time-series behaviors but cannot break the symmetry to the even level. Next we examine a demand adjustment scenario to find a way to improve the airline's financial state without aggravating the airport's financial state.

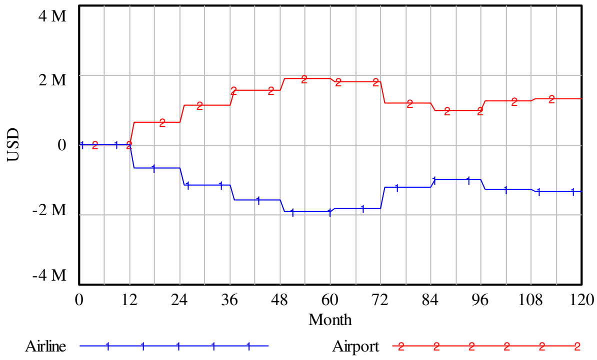

Figure 8: Financial stock of airline and airport
(Baseline Scenario)

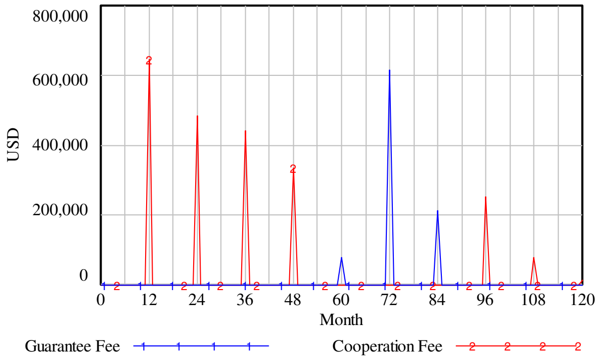

Figure 9: Guarantee fee and cooperation fee
(Baseline Scenario)

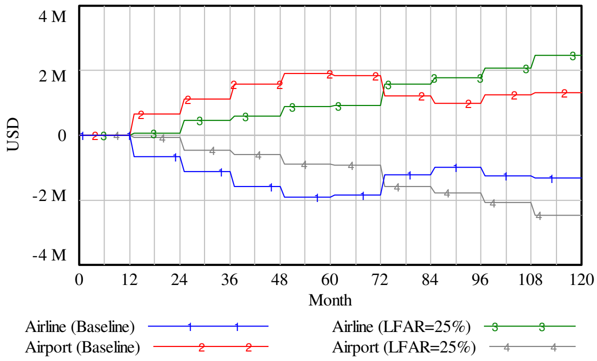

Figure 10a: Financial stock of airline and airport
(LFAR=25%)

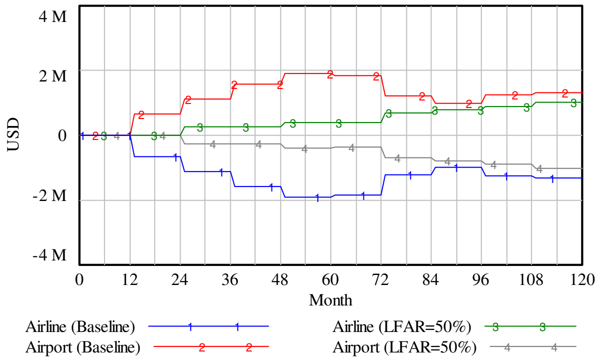

Figure 10b: Financial stock of airline and airport
(LFAR=50%)

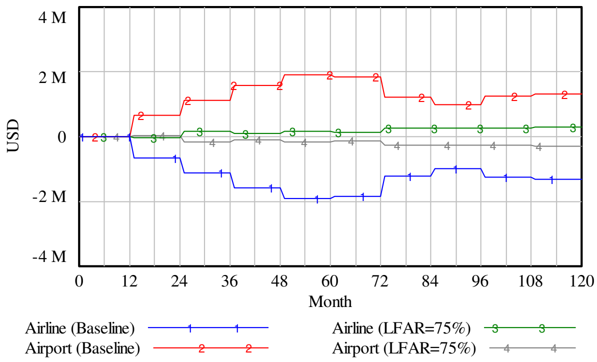

Figure 10c: Financial stock of airline and airport (LFAR=75%)

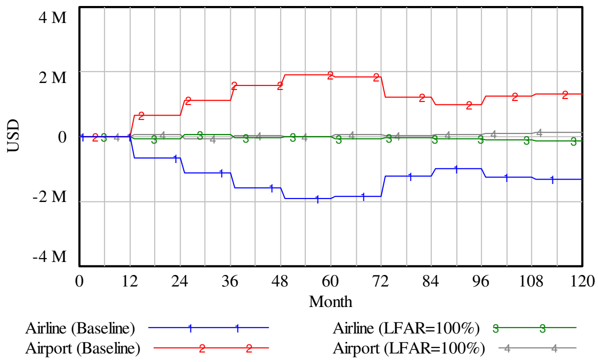

Figure 10d: Financial stock of airline and airport (LFAR=100%)

4.3. Demand adjustment scenario

We examined the demand adjustment scenario highlighting the Demand Adjustment Subsystem. We assume that an airport increases the number of air passengers when a certain discrepancy in the load factor exists. In this simulation, an airport increases demand using a ticket subsidy, assuming financial support from the local government that owns the airport based on the discrepancy in the load factor of the previous month.

The model includes the impact of the subsidy payment and demand increase for both parties. Payment for the subsidy was subtracted from the Financial Stock of Airport because the subsidy requires a certain amount of expenditures from an airport. In contrast, additional revenues were expected for the airline because the number of air passengers increased due to the subsidy effect. Additional Passenger Revenue is computed by multiplying Subsidized Passenger Demand and Average Ticket Price. We implemented a parametric study on the DAR, setting it as 0% (baseline), 25%, 50%, 75% and 100%, without any adjustment to the load factor side.

Figure 11a through Figure 11d show the results of the Financial Stock of Airline and Financial Stock of Airport under the demand adjustment scenarios. At 25% of DAR (Figure 11a), no distinction exists between the demand adjustment scenario and the base lines scenarios during the first five years, indicating that demand adjustment is inactive because air passenger demand was adequate. After year six, the demand adjustment is finally activated because of inadequate demand. We find a slight improvement of financial stocks for the both parties in the last half of the simulation period, but the distinction is not very clear. At 50% of DAR (Figure 11b), we can recognize clearer improvements of the financial stocks for the both parties after year five and the trend is the same as at 75% and at 100% of DAR. The results imply that introducing demand adjustment can provide positive impact for the both party given an appropriate DAR according to the demand scarcity.

In principle, we expect that the higher the DAR, the higher the expenditures from the airport, meaning that the airport's financial state is also worsened by an increased DAR. Interestingly, however, the airport's financial state improves as well with an increased DAR. We believe that it occurs because the Subsidized Passenger Demand's feedback effect contributed to an increase in the average load factor and thus ultimately a reduced Guarantee Fee airport payment.

In all demand adjustment scenarios (Figure 11a through Figure 11d), the financial stocks were improved in the end due to the additionally generated demands. Furthermore, one party's improvement is not realized at the cost of the other party. It implies that both an airline and an airport are likely to be satisfied with the business model and thus that airline–airport coexistence can be sustained.

We conclude that introducing a monthly demand adjustment, as in the simulation, can break the symmetry to the even level for the both parties and thus contribute to more favorable design of a commercial airway operation. However, the demand adjustment in this simulation does not seem to lessen the discrepancy of the financial state between the two parties. It means that the financial equality of an airline and an airport cannot be balanced in the long run by the demand adjustment system. Therefore, we explore a possibility of combining both LFAR and DAR in one scenario.

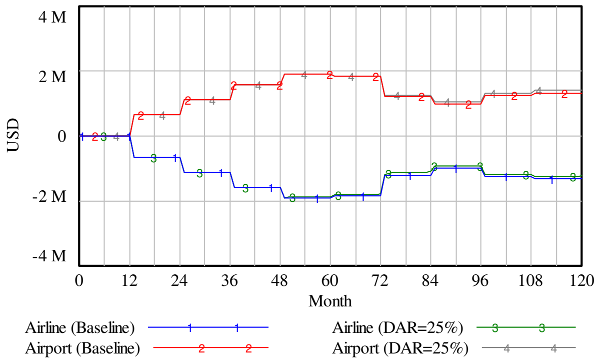

Figure 11a: Financial stock of airline and airport (DAR=25%)

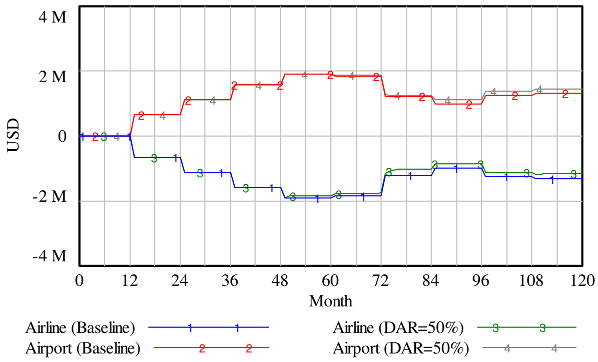

Figure 11b: Financial stock of airline and airport (DAR=50%)

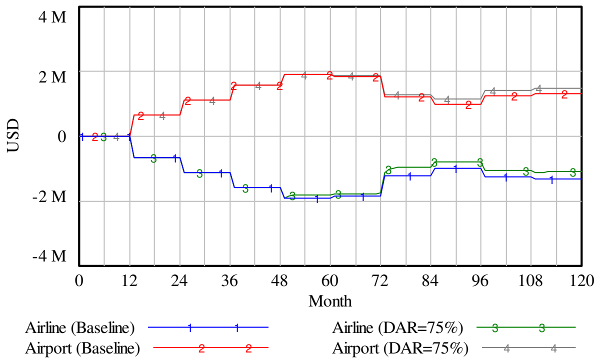

Figure 11c: Financial stock of airline and airport (DAR=75%)

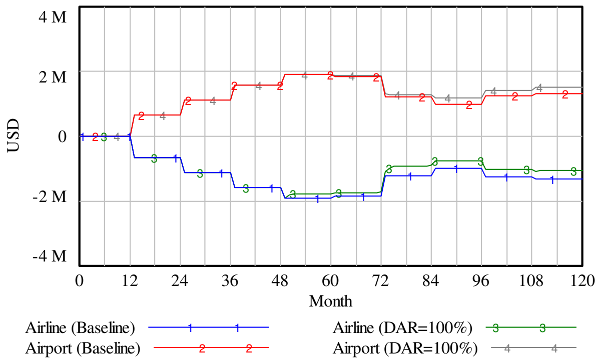

Figure 11d: Financial stock of airline and airport (DAR=100%)

4.4. Combination scenario

We next examine the combination scenario highlighting both of the Load Factor Adjustment Subsystem and the Demand Adjustment Subsystem. We implemented a parametric study on the Load Factor Adjustment Rate (LFAR), setting it as 0% (baseline), 25%, 50%, 75% and 100%, as well as on the DAR, setting it as 0% (baseline), 25%, 50%, 75% and 100%.

Figure 12a through Figure 12d show the results of the Financial Stock of Airline and Financial Stock of Airport under the load factor adjustment scenarios. When we set 25% for both LFAR and DAR (Figure 12a), the result is similar to that of at 25% of LFAR (Figure 10a). The discrepancy between the two parties gradually increases throughout the simulation. The symmetry to the even level is broken but the break is not very distinctive. It implies that the LFAR influences more on the system than the DAR at 25% setting. When we set 50% for both LFAR and DAR (Figure 12b), the discrepancy between the two parties become less comparing with the case of 25% setting (Figure 12a).Furthermore, both the airline financial state and the airport financial state shift upward to positive direction. The symmetry to the even level is totally broken. We can find the same trends in the case of 75% (Figure 12c) and in the case of 100% (Figure 12d).

As we discussed, LFAR can lessen the discrepancy of financial state between an airline and an airport. On the other hand, DAR can break the symmetry and shit the both parties' financial state to positive direction. We thus expected the similar behavior as the load factor adjustment scenarios (Figure 10a through Figure 10d) with a certain positive shift caused by the demand adjustment. However, the simulation result was contrary to our expectation, indicating that there is an effect of further demand generation resulting from the combination.

We think that the additional effect can be explained by the interaction of the load factor adjustment and the demand adjustment. In this model, the demand adjustment can generate additional demands until the annual average load factor reaches the target load factor. Given the target load factor is fixed, the load factor adjustment is functioned only to prevent negative financial state for an airport. In other words, an airport's reaction is limited to minimize the amount of a loss when a certain loss is expected in the end of each year. The only concern for an airport is the discrepancy between the target and the average load factor. There is no incentive for an airport to go beyond the target load factor.

However, introduction of the load factor adjustment removes the limitation. Since the target load factor changes annually, an airport must take care of the level to meet an airline's expectation. Given that an airport's endeavor is limited only to fill the discrepancy between the target and the average load factor, the target load factor continuously decreases until an airline decide to withdraw from the flight operation. Thus, there is a clear incentive for an airport to go beyond the target load factor for sustaining the airway. Furthermore, there is another incentive for an airport of receiving cooperation fees from an airline. The cooperation fees contribute to compensate for the subsidy expenditures. We think that this is why an airport proactively pay more subsidies to go beyond the target load factor under the combination scenarios.

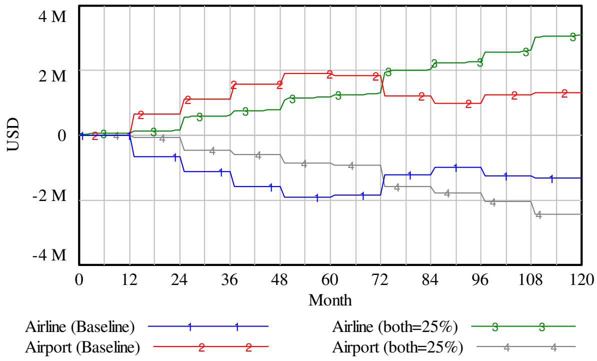

Figure 12a: Financial stock of airline and airport
(LFAR=25%, DAR=25%)

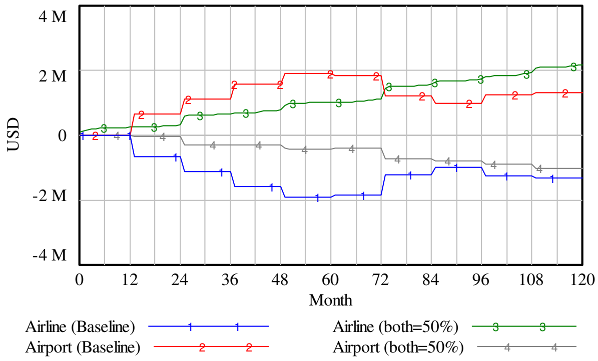

Figure 12b: Financial stock of airline and airport
(LFAR=50%, DAR=50%)

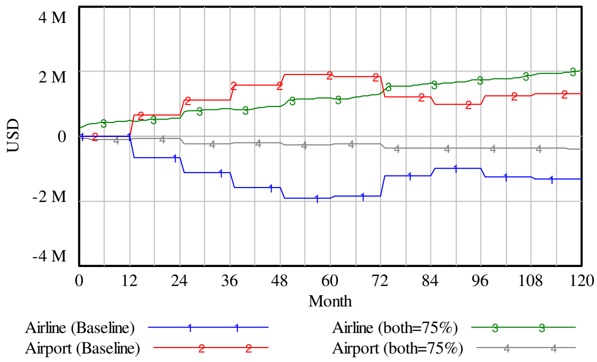

Figure 12c: Financial stock of airline and airport
(LFAR=75%, DAR=75%)

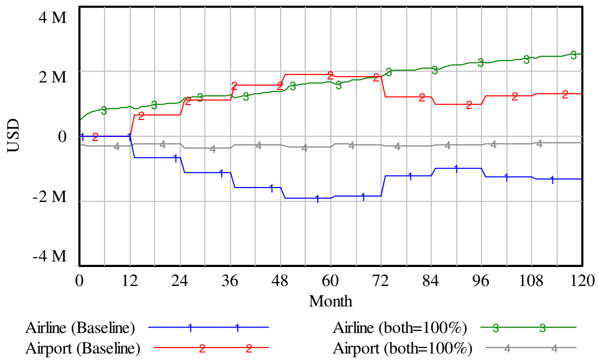

Figure 12d: Financial stock of airline and airport
(LFAR=100%, DAR=100%)

5. Conclusions

We used system dynamics to examine an inter-dependent business model between an airline and an airport for coexistence. It is called load factor guarantee in which an airline and an airport agree on the load factor of a flight and the either party compensates for any discrepancy between the actual and agreed upon load factor. The simulation results show that adjustments on the load factor side can lessen the discrepancy of the financial states between an airline and an airport. However, it cannot break the symmetry of the both parties' financial states. On the other hand, adjustments on the demand side can break the symmetry but cannot lessen the discrepancy. We conclude that integrating the load factor adjustment and the monthly demand adjustment is the key to successful airline and airport coexistence. Although integration of a subsidy with an LFG means a temporary financial loss for an airport, the research indicates that such a measure is an effective way of maintaining long-term airline and airport coexistence.

Current management practices are contrary to our findings. These practices introduce the LFG only to reduce the business risk to an airline when pursuing a new entry. In Japan, most local governments provide subsidies to maintain unprofitable regional flights, as is often the case throughout the world. However, such a subsidy policy is not optimally integrated with the LFG. Under the competitive environment after the air deregulation, airports and airlines need to work together to improve their relationship and to develop close links and partnerships (Graham, 2003). The proposed SD model can help an airport and an airline understand the interdependency of their business and the need to cooperate to enhance their business sustainability. The simulation model was designed for a regional airway in Japan. Although we believe that the model contributes to examining regional airways globally, further research will be necessary.

6. Acknowledgement

This paper was first presented at the International Conference of System Dynamics held in St. Galen in Switzerland (July 2012) and modified based on the comments received and data acquired after the conference. This study was supported by JSPS KAKENHI Grant Number 25870720 and 15K17124.

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Appendix

Table 2: Assumptions for baseline parameters (Source: NAPC, ANA, Ishikawa Prefecture)

Variable name	Value	Unit
Number of Flights per Day	4	Flights/Day
Number of Seats per Aircraft	126 (2003), 164 (2004), 166 (2005-2014)	Seats/Fleet
Number of Days per Month	30	Days/Month
Operation Reliability	0.9936 (2003), 0.9957 (2004), 0.9950(2005-2014)	
Fixed Ticket Price	135 ($1USD = 120JPY)	USD/Ticket
Airport Unit Payment	135 ($1USD = 120JPY)	USD/Ticket
Airline Unit Payment	90 ($1USD = 120JPY)	USD/Ticket
Price Adjustment Time	2	Month
Price Elasticity of Demand	−0.74 (Yamauchi 2000, 195-225)	
Load Factor Adjustment Rate	0	
Demand Adjustment Rate	0	

Table 3: Monthly passenger demand (NAPC, 2005-2014)

	Year									
Month	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Jul	12,993	13,037	12,598	13,938	12,704	12,780	12,050	12,774	12,100	12,086
Aug	16,370	16,738	15,443	14,612	14,073	14,258	15,149	15,112	15,372	15,796
Sep	12,252	12,141	13,809	12,853	12,405	11,420	13,222	12,807	13,988	13,345
Oct	13,501	14,393	12,394	12,289	12,063	13,371	13,766	13,896	14,171	13,522
Nov	13,321	13,770	13,379	11,711	11,833	12,246	13,342	14,143	13,797	13,206
Dec	13,418	13,054	13,587	12,384	12,244	10,047	11,680	10,581	11,242	10,072
Jan	12,525	13,026	12,166	12,885	11,577	10,752	9,816	10,267	10,576	10,746
Feb	11,645	12,804	11,844	11,661	11,235	10,913	10,560	11,834	8,804	9,729
Mar	15,511	12,776	13,288	13,443	13,209	9,348	11,314	12,851	12,657	11,782
Apr	10,516	10,406	10,253	10,901	9,680	7,237	9,757	9,882	9,259	11,068
May	14,521	11,421	14,711	12,589	13,725	10,792	12,761	13,630	13,052	13,811
Jun	13,920	13,016	14,906	10,811	14,418	10,162	14,564	13,437	11,827	15,419

Modelling the Preference for Business Charter in the Cross-Strait Market

Jin-Ru Yen and Jing-Xuan Chen*

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

**Corresponding Author*

Abstract

This paper aims at investigating business travelers' choice behavior between business charter (BC) and the business class of commercial airlines in the cross-strait market. This study applies the stated preference method and sets five scenarios with the combination of various levels of fares, waiting time, exclusive clearance services and inflight communication equipment. Data were collected by purposive sampling and interviewing business travelers near the VIP centers, departure lounges, and the baggage claim areas of Taiwan Taoyuan International Airport. A sample with 420 business travelers from Taipei to Shanghai was collected. Then, the binary logit model was employed to analyze how service attributes influence Taiwanese business travelers' choice behavior between BC and business class. Estimation results indicate that fare is the most important factor. Other factors such as gender, seniority, and the number of business trips during the previous year remain significant on the probabilities of choosing BC. Additionally, five specific features of BC were set as dummy variables in the model. Those are saving time from transit, control of trip-time, entertaining clients, visiting clients, and attending international conferences. All of them have positive effects on the preference for using BC.

Keywords: Business charter, Binary logit model, Stated preference, Cross-strait

1. Introduction

Since the aviation industry was deregulated in 1978, liberalization has created innovated market opportunities for various business models in the industry of air transportation, e. g., hub-and-spoke and low cost operations. Although the market is highly competitive, the service quality and the reliability provided by commercial airlines seem to decline (Jarchow, 2004). In the meantime, there is a different operating model named business aviation (BA) that focused on providing customization, such as meals, exclusive clearance service, and private space in the air. All of these aim to provide travelers with the top service experience. Moreover, in the dynamic global business market, company executives' demand in business travel grows steadily, and it also stimulates the development of BA (Agur, 2012).

Bombardier (2013) defines "business jet (BJ) penetration" as a measure of the number of BJs in a region relative to the size of the region's economy, as represented by its GDP. To normalize different population sizes in each region, penetration rates and GDP are best compared on a per capita basis. Based on this idea, General Aviation Manufacturers Association's (GAMA) annual report in 2009 established the relationship between the number of BJs and the GDP per Capita (Fig. 1). As illustrated in Figure 1, the most established market for BJs, North America, has the world's largest fleet, which is growing slowly. China, in contrast, has a very small number of BJs relative to the size of its economy but their fleets are now growing rapidly. According to Figure 1, Taiwan's GDP per capita reached 22,700 US$ in 2015, the average BJs per capita (M) should be 5. As the population of Taiwan is about 23 million in 2015, the amount of BJs in Taiwan should be 115 (5 business jets*23 (M)). However, there are only 9 BJs in Taiwan. Using the same calculation, the number of BJs in China should be 130, instead of the actual number of 62. Additionally, since the cross-strait direct flights commenced in 2008, the economic and trade intercourse between Taiwan and China have been dramatically increasing. It means that there is a tremendous opportunity to develop BA in the cross-strait market. Therefore, this study explores Taiwanese business travelers' preference for business charter (BC) in the cross-strait market.

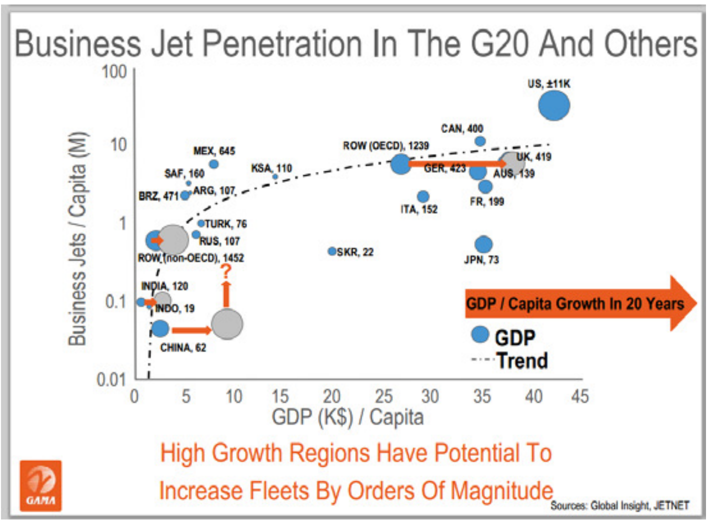

Figure 1: Business Jet Penetration (GAMA, 2009)

2. Literature Review

2.1 Business Aviation

2.1.1 Operational Models of Business Aviation

BA is a part of the general aviation that can be used for business purposes (NBAA, 2014). While organizations that rely on BA vary, they all have one thing in common, that is, the need for fast, flexible, safe, secure and cost-effective access to destinations worldwide. According to Bombardier (2013), BA is divided into five segments: (1) full ownership (2) fractional ownership (3) jet-card program (4) branded charters (5) air taxi (Figure 2). Full ownership is the case that a BJ is owned by a person or a corporate. The owner uses the BJ as his/her private vehicle. On the other hand, fractional ownership means that a BJ is owned by several individuals or corporates. An individual or a company purchases a fraction (as little as a 1/16 share) of one BJ and receives management and pilot services associated with the aircraft's operation. Jet card programs are a program that individuals or companies prepay the fare of flying hours (usually under 50 hours per year) in order to get a guarantee of providing air transport service for their needs and obtain a discount price on the contract. The fourth and fifth segments belong to the operation of BC and are under the investigation in the present research. Air taxi is per seat charter while branded charter is about chartering the whole airplane. In Taiwan, only full ownership and branded charter are allowed to operate. In this study, we focus on Taiwanese business travelers' preference for branded charter.

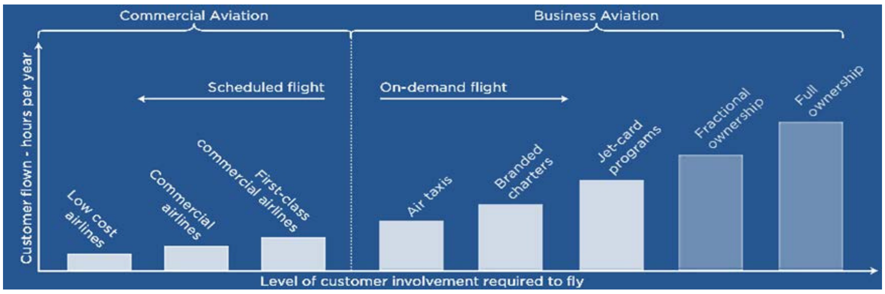

Figure 2: Operational Models of Business Aviation (Bombardier, 2013)

2.1.2 Benefits of Business Aviation

BA includes tangible and intangible benefits. In terms of tangible benefits, BA provides exclusives clearance service and BA centers, which help travelers to have a private and efficient experience. During the flight, travelers can consider the BJ as a flying office. They can plan, work, and have meetings in a secure environment, which enables them to discuss propriety information without fear of being eavesdropped, business espionage or physical threat (NBAA, 2014). Moreover, travelers can turn their flying hours into working hours with inflight communication equipment on the BJ.

BA brings lots of intangible benefits. The major differences between BA and commercial airlines are flexibility and time-saving (Brown, 2007). For example, BA decreases counter check-in time and provides efficient customs clearance service. BA also reduces flight time by providing point-to-point service and decreases the block or total travel time because it can utilize smaller airports closer to final destinations. In addition, people who travel by BJs do not have to alter their schedules to fit flight schedules provided by commercial airlines. Consequently, they have the freedom to change course en route and leave and arrive according to their own schedules. With comfortable facilities and customize service, business travelers can reduce their fatigue in the trip (Kaps et al., 2001; Lee, 2004; Krane, 2009). All of these intangible benefits will create more time value for travelers. BA can provide benefits that commercial airlines cannot (Brown, 2007). Considering the overall time utility that travelers could obtain, BA should be regarded as a cost-effective alternative (Sheehan, 2004; IBAC, 2008; Budda and Graham, 2009; Agur, 2012).

2.1.3 Users of Business Aviation

BA is frequently used by private companies, high-net-worth individuals, and sports teams to get from one place to another in the shortest time. Large multinational corporations such as Want Want China Holdings Limited and Nike both operate BJs. In business traveling, companies that recognize the importance and the need of getting the right people in front of their customers prefer using BA. According to NBAA (2014), a survey of 346 BA passengers was conducted by Louis Harris & Associates in 2009. It showed that the business aircraft were operated for: top managers (22 %), other managers (50%), technical/ professional/ sales (20%) and other types (7%). This survey revealed that 72% of passengers who chose business airplanes were non-executive employees. Additionally, in the United States, companies often use business aircraft to send teams of employees to a given destination because it is the most cost-effective and efficient way of transportation.

2.2 Influential Factors for Mode Choices

According to the decision making model provided by Pearmain et al. (1991), there were three important factors that influence travelers' choice behavior (Figure 3).

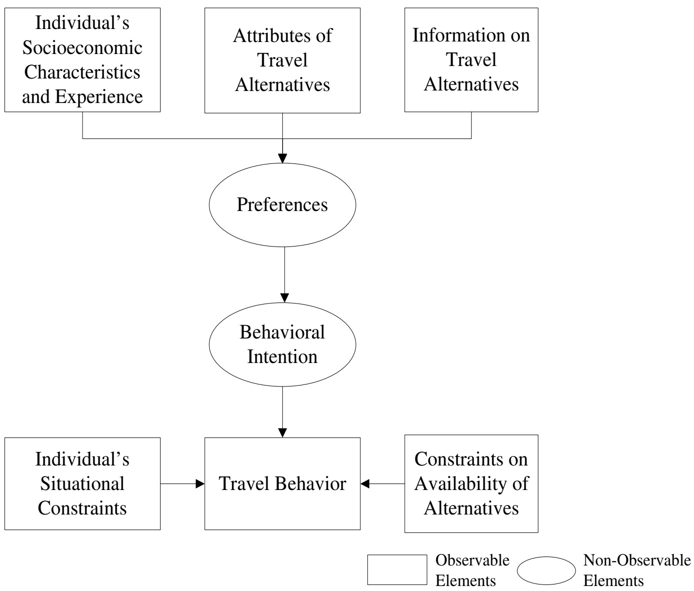

Figure 3: Components of Consumer Behavior (Pearmain et al., 1991)

The diagram distinguishes between elements that are external to the consumer and those that are internal. External reprints observable elements such as the attributes of travel alternatives. Internal refers to unobservable elements such as the intension and preferences of the consumer. Here, we only focus on the observable elements that are set as explanatory variables in this study. Those are individual's socioeconomic characteristics, trip experience and attributes of mode. Three parts of explanatory variables would be described in detail in the following pages.

2.2.1 Socioeconomic Characteristics

Aksoy et al. (2003) pointed out that demographic characteristics play a critical role in shaping customers' needs. Marketers et al. (2013) considered demographic characteristics as one of the major determinants of consumers' buying behavior and service expectations. In this paper, we aim to investigate business travelers' preference for taking BC as their travel tool; hence, social-demographic variables are one of the important factors that influence the traveler's decision making process. Specifically, several attributes are identified in the literature, such as title (Krane, 2009; Brown, 2007), marital status (Beaverstock et al., 2009; Gustafson, 2006), seniority (Brown, 2007), company size (Colette et al., 2006; Mason, 2001; Evanglho et al., 2005; Fourie and Lubbe, 2006), and industry categories of company (Lee, 2014).

Gustafson (2006) asserted that married female business travelers are more sensitive to the travel time of business trip. In terms of company size, business travelers from large companies tend to choose traditional airlines while travelers from the mid-size companies are more willing to take low-cost airlines (Fourie and Lubbe, 2006; Colette et al., 2006; Mason, 2001). In BA research, the survey of NBAA in 2009 found that typical travelers who took BA were usually mid-level managers, accounting for almost 70% of total travelers. NBAA also found that 70% of companies using BA had less than 1,000 employees, and three in five companies had less than 500 employees. This shows that business travelers' title and their company size may affect their travel choice behavior.

2.2.2 Trip Experiences

Travelers' travel experiences are important to their choice behavior. On the issue of air transportation, there are two common variables: trip frequency (Lee, 2004; Krane, 2009; Kaps et al., 2001) and the number of accompanying persons (Kaps et al., 2001; Lee, 2004). Lee (2004) conducted a survey to investigate a company's intention of using BA, with the consideration of variables such as the number of business trips per year, the class of the ticket, the number of accompanying persons, and the business activities of the trip. The business activities that business travelers conduct are illustrated more detail in the literature: conducting business, attending meetings, field research and education training (Mason, 2001; O'Connell and Williams, 2005). CWT (2014) found that the primary purpose of business travel was to meet clients or suppliers (38%), followed by team-related meetings (21%).

2.2.3 Attributes of Mode

In general, the quality of a transportation service can be measured from six dimensions: safety, comfort, convenience, reliability, travel cost and travel time. These six measure indicators can be divided into two categories: observable variables and unobservable variables. Observable variables usually include travel cost and travel time that can be measured directly. Others are regarded as unobservable variables. This section focuses on observable variables that can be directly measured. Other characteristics such as comfort and convenience of BA were discussed in section 2.1.2. These variables will also be included in the behavioral model estimated in section 4.

Travel Time

Travelers that take business trips are more sensitive to travel time they spend on the trip. Budd and Graham (2009) asserted that since the mid-1980s, the number of airline travelers world-wide has doubled, with more than 2.1 billion people boarding a scheduled flight in 2006. The airline industry became more crowded. Additionally, the inherent business risk of the industry was compounded by the event of September 11, 2001

(Brown, 2007). The result was long check-in and security lines, poor customer service, and increasing flight delays and cancellations. Business travelers may not be able to arrive at the right time and right place to conduct business. Besides, the time spent on transit and waiting made them feel exhausted and decreased their efficiency (Jarchow, 2004). Since commercial airlines could not satisfy business travelers' demand, many corporate travelers desire better air transportation alternatives.

Commercial airlines are experiencing poor on-time arrivals, more boarding denials, travelers' complaints, and congestion around major hubs. These problems also led to the market entry point for BA products to compete effectively (Kaps et al., 2001). BA with exclusive clearance service saves business travelers lots of waiting time for security inspection and enhances the privacy of business travelers. Moreover, it provides point-to-point service based on travelers' schedule, supports business travelers' demand, and emphasizes on customized service. Additionally, BJs are thought as "time-multipliers", that is, they enable travelers to work in the air, and optimize their time (Sheehan, 2003).

Travel Cost

Travel costs are important factors that influence mode choice behavior. They can be classified as tangible and intangible costs. Tangible costs can be observed directly, such as price, charge of changing flight, excess baggage charge, additional service fees, fees of using VIP centers and inflight Wi-Fi connection. Above all, price is the most important variable to be considered as travel cost from the viewpoint of travelers. Agur (2012) stated that potential users tend to reject using BA mainly because of its high monetary costs. Thus, without considering the intangible costs, the measurement of two modes is superficial. Agur's research (2012) also revealed that BA is the less expensive way of traveling when all costs and benefits are weighted appropriately. In many cases, BA can provide busy executives with up to a month of additional productive time as a result of travel hours they saved.

3. Methodology

3.1 Conceptual Framework

The conceptual framework to explore business travelers' preference for BC is showed in Figure 4. First, the influential factors of mode choice have been discussed in section 2.2. They include three groups of variables: socioeconomic characteristics, trip experiences, and attributes of BC and commercial airlines. Next, the stated preference method is employed to design five scenario combinations in the survey questionnaire to investigate travelers' preferences toward BC and business class service provided by commercial airlines. Third, the stated preference data are used in choice modeling, which reveals travelers' preferences.

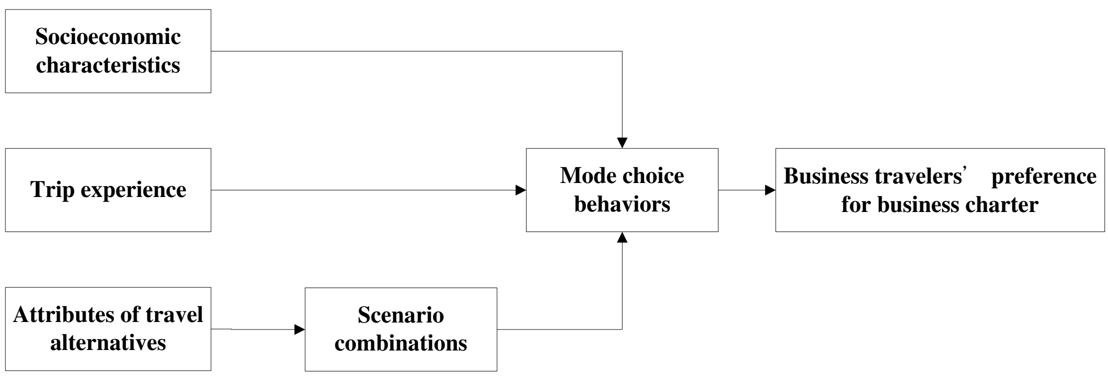

Figure 4: Conceptual Framework

3.2 Logit Model

According to our review, the development of probabilistic models on transport modal choices can be attributed to researchers such as Warner (1962), McGillivary (1967), Rassam et al. (1970), Charles River

Associates (1972), Ben-Akiva (1974), and Koppelman (1976). Among the variations of probabilistic choice models, the logit model is the most commonly used formulation to investigate travelers' choice behavior among transportation modes. The mathematical framework of logit models is based on the theory of utility maximization. Logit models are generally classified into two main categories, namely binary and multinomial logit models. Binary logit models are capable of modeling two discrete choices only, that is, the individual has only two possible alternatives for selection, whereas multinomial logit models imply a larger set of alternatives (Khan, 2007).

In this study, decision makers are assumed to choose the utility-maximized alternative from a choice set with two alternatives, i. e., BC and business class service provided by commercial airlines. We note that for a variety of reasons the utility of any alternative is, from the perspective of the analyst, best viewed as a random variable. This leads to the notion of random utility models in which the probability of the alternative i being selected by person n from choice set C_n as $\{i,j\}$ is given as the following (Ben-Akiva and Lerman, 1985):

$$\begin{aligned} P_n(i|C_n) &= Pr(U_{in} \geq U_{jn}, j \in C_n, j \neq i) \\ &= Pr(V_{in} + \varepsilon_{in} \geq V_{jn} + \varepsilon_{jn}) \\ &= Pr(\varepsilon_{jn} - \varepsilon_{in} \leq V_{jn} + V_{in}) \\ &= Pr(\varepsilon_n \leq V_{jn} + V_{in}) \end{aligned} \quad (1)$$

V_{in} and V_{jn} are called the systematic components of the utility of i and j; ε_{in} and ε_{in} are the random components. The choice set C_n here contains two alternatives: BC and business class of a scheduled flight. In this case, the binary logit model is employed to investigate business travelers' choice behavior. The binary logit model arises from the assumption that $\varepsilon_n = \varepsilon_{jn} - \varepsilon_{in}$is logistically distributed, namely:

$$F(\varepsilon_n) = \frac{1}{1+e^{-\mu\varepsilon_n}}, \mu > 0, -\infty < \varepsilon_n < \infty \quad (2)$$

where μ is a positive scale parameter. The assumption that ε_n is logistically distributed is equivalent to assume that ε_{in} and ε_{jn} are independent and identically Gumbel distributed. Under the assumption that ε_n is logistically distributed, the choice probability for alternative i is given by:

$$\begin{aligned} P_n(i|C_n) &= Pr(U_{in} \geq U_{jn}) \\ &= \frac{1}{1+e^{-\mu(V_{in}-V_{jn})}} \\ &= \frac{e^{\mu V_{in}}}{e^{\mu V_{in}}+e^{\mu V_{in}}} \end{aligned} \quad (3)$$

Equation 3 is the choice probability of alternative i derived from the binary logit model. Note that if V_{in} and V_{jn} are linear in their parameters:

$$\begin{aligned} P_n(i) &= \frac{e^{\mu\beta' X_{in}}}{e^{\mu\beta' X_{in}}+e^{\mu\beta' X_{jn}}} \\ &= \frac{1}{1+e^{-\mu\beta'(X_{in}-X_{jn})}} \end{aligned} \quad (4)$$

The probabilities of person n choosing alternatives i and j are:

$$P_n(i) = Pr(U_{in} \geq U_{jn}) \quad (5)$$

$$P_n(j) = 1 - P_n(i). \quad (6)$$

3.3 *Stated Preference Method*

The main advantage of the stated preference approach is that hypothetical and non-existent alternatives can be included in the experiment. New factors and innovations can also be included in the alternatives and the model results can be used for forecasting the future market share. Therefore, the stated preference method is suitable for investigating travelers' preferences toward BC that is considered as a new transportation service in the cross-strait market.

Stated preference methods include a range of survey methods to elicit an individual's priorities and preferences. Individual preference can be uncovered in stated preference survey by asking respondents to rank the option presented to them, to score them or to choose their most preferred. The different ways of measuring preferences correspond to different information they generated (Hensher, 1994). Three main measurable approaches in stated preference methods include rating, ranking-order and choice experiments. Rating approach asks the respondent to score each scenario, such as on a scale of 1-10. Rank-order asks individuals to rank a series of alternatives. Choice experiments design two or more alternate scenarios for respondents to choose. Among them, choice experiments are the most popular approach in transportation research and are used in this research.

Choice experiments share a common theoretical framework with discontinuous-choice contingent valuation in the random utility model (McFadden, 1973). Louviere and Hensher (1982) showed how a preference experiment could be extended to incorporate choice experiments. In which case, an individual chooses from among fixed or varying choice sets. This experiment enables the estimation of a discrete-choice model and hence can directly predict the market share.

3.4 Survey Design

This study explores the choice between BC and the business class service provided by commercial airlines for business travelers in the cross-strait market. Statistics indicate that the busiest route in the cross-strait market is from Taipei (TPE) to Shanghai (PVG), with 1,501,789 passengers on this route in 2013. Therefore, we take this route as designed condition for choices. There are five sections in the survey questionnaire: (1) socioeconomic characteristics, (2) trip experiences, (3) hypothetical scenarios by stated preference experimental design, (4) attractive factors of BC, and (5) purposes of using BC in the future.

3.4.1 Socioeconomic characteristics and trip experiences

Socioeconomic characteristics contain two parts in the survey. The first part includes individual characteristics such as gender, age, marriage status, monthly income, title, and seniority. The second part is information about the company where the business traveler employed, including company registered capital, number of employees, and industry category. The characteristics of trip experiences include cabin class, the number of business trips during the previous year, and the duration of the previous business trip.

3.4.2 Stated preference experimental design

To exam business travelers' choice behavior of BC and the business class of commercial airlines, we apply stated preference methods to conduct a questionnaire survey. As discussed in section 2.2.3, travel time and travel costs are the most important variables when investigating modal choice behavior. We develop a stated preference experiment based on the service attributes that not only takes travel time and travel costs into consideration, but also includes other possible influential factors such as exclusive clearance service and inflight communication equipment. Four explanatory variables are described in more details as follows:

Round-trip fare and waiting time

The BJ used in this study is set as Gulfstream G550 that accounts for 38% of BJs in the Great Asia (Asianskygroup, 2013). The round-trip flying time on the TPE-PVG route is about 3.5 hours. The fare of BC is set at USD 35,000 (USD 10,000 per flying hour). The fare per person in various scenarios is the total fare shared by the accompanying persons. When the number of accompanying persons is 14, 10 or 6, the average price per person is USD 2,500, USD 3,500 or USD 5,833, respectively. With respect to commercial airlines, since first class is not provided on the TPE-PVG route this study uses the fare of business class. The average price in the market in March, 2015 is USD 1,633 (including tax, fuel surcharges and airport service charges).

The BC company recommends that passengers arrive at the BA center at least 10 minutes before departure. On the other hand, airlines usually recommend that passengers arrive at the airport at least 2 hours before the scheduled departure time.

Exclusive clearance service and inflight communication equipment

The charge of the exclusive clearance service of BC is included in its package price. The exclusive clearance service of commercial airlines, however, should be purchased with about an extra fee of about USD 400per passenger. Passenger should arrive at the exclusive center at least 40 minutes before the scheduled departure time. Inflight communication equipment in this study refers to Wi-Fi Service and satellite phone.

A total of 144 experimental scenarios can be generated based on the possible combinations with the attributes listed in Table 1. The orthogonal design procedure in SPSS 20.0 software was used to reduce the number of scenarios to 16 combinations. Five scenarios were selected after deleting the extreme situations. The sample of scenarios are showed in Table 2.

Table 1: Attributes and Levels of Choice Experiment

Attributes / Alternatives	Round-trip fare (USD per Passenger)	Waiting time (Mins)	Exclusive clearance service	Inflight communication equipment
BC	5,833 3,500 2,500	10 20 30	Yes	Free
Business class service	1,633	40 60 90 120	Yes No	Free Payout

Table 2: Studied Scenarios

Scenario	Choices	Round-trip fare (USD per passenger)	Waiting time (Mins)	Exclusive clearance service	Inflight communication equipment
1	BC (6 passengers)	5,833	20	Yes	Free
	Business class service	1,633	120	No	Free
2	BC (6 passengers)	5,833	10	Yes	Free
	Business class service	1,633	40	Yes	Payout
3	BC (10 passengers)	3,500	10	Yes	Free
	Business class service	1,633	120	No	Payout
4	BC (14 passengers)	2,500	30	Yes	Free
	Business class service	1,633	120	No	Payout
5	BC (14 passengers)	2,500	10	Yes	Free
	Business class service	1,633	90	No	Free

Note: (1) USD: TWD = 1: 30.

3.4.3 The attractive factors of business charter

Many intangible characteristics of BC are not shown in the studied scenarios. For the purpose of exploring which characteristics of BC are the most attractive to business travelers, this study employes the Likert Scale to investigate it. This study summarizes nine features of BC, based on related literature and information provided by Taiwanese BC companies. Those are shown as follows:
(1) transfer time saving,
(2) travel time controlling,
(3) multiple destination arrangement,
(4) flying service in 24 hours,
(5) flexibility of changing the destination,
(6) BA center and exclusive clearance service,
(7) high privacy in the air,
(8) comfortable beds, customized meals and entertainment system, and
(9) exclusive pick-up service with a luxury car.

3.4.4 The purposes of using BC in the future

The reasons for travelers to go on business trip may affect their travel choices. O'Connell and Williams (2005) found that business travelers going to events such as conferences and training courses, which are considered as being less urgent, were more likely to choose low cost airlines. According to Lee (2004), client entertainment is one of the potential reasons of using BA. There are seven purposes of business trips included in the survey questionnaire: client entertainment, client visits, expanding business, field research, international conference attendances, company internal meetings, and professional training. This article aims to find out how trip purposes affect business travelers' consideration of using BC in the future.

The present study also added the unplanned business trip as an influencing factor for using BC. One of of BA's advantages is offering travelers on-demand service. Since business travel usually is regarded as unpredictable and urgent. It is reasonable to assume that business travelers might need to go on an unplanned business trip by BC under several situations.

4. Empirical Study

The survey was conducted on May 1-8, 2015. Business travelers were selected by purposive sampling and interviewed in front of TPE's VIP centers, departure lounges and the baggage claim areas. A total of 570 questionnaires were distributed and 494 of them were collected (86.66%). Among the received sample, 420 were valid and 74 invalid questionnaires were removed, mainly due to incompleteness). The effective response rate was 73.68%.

4.1 Data Analysis

4.1.1 Characteristics of Survey Respondents

The majority (89.3) of the respondents are male and about 41% of the sample are between 40 and 49 years of age. As for the title of respondents, 5.5% are chairman, 27.8% are president, chief executive officer (CEO) or vice-president (VP), 39.8% are assistant vice president (AVP) and manager. In terms of companies that respondents are employed, the majority of companies registered capital is under USD 3.33 million (38.6%) and the number of employees is under 50 (31.4%). The main industry is information technology (IT) (34.5%) and the second is manufacturing (33.10%). The average personal income is USD 6,980 per month and the average seniority is 12 years. With respect to the respondent's journey information, about 84% of the sample takes economic class. The average number of business trips during the previous year is 10 and the previous business trip lasted for 14 days.

4.1.2 Characteristics of Senior Executives

Senior executives are the potential customers for BC. Among the 420 respondents, 140 are senior executives. About 90 % of them are male and 41% of them are between 50 and 59 years of age. Most senior executives are married (87.9%). As for the title of senior executives, 16.4% are chairman, 83.6% are president, CEO or VP. In terms of companies that senior executives belonged to, the majority of companies registered capital is under USD 3.33 million (52.9%) and the number of employees of companies is under 50 (47.1%). The main industry is also information technology (IT) (26.4%), and the second is manufacturing (33.10%). The average monthly income is USD 12,507, which is about twice of the income of all respondents. The average seniority is 15 years. About trip information, the majority of senior executives take economic class (70.7%). The average number of business trips during the previous year is about 14 and the previous business trip lasted for 14 days. Senior executives' average length of previous business trip almost same as all respondents.

4.1.3 Cross Tabulation Analysis

This section employs cross tabulation analysis to examine the association between the attributes and travel mode choice. According to the results of the cross-tabulation analysis (Table 3), this study illustrates that all respondents' gender, cabin classes, age and title have effects on their travel mode choice.

Table 3: Cross-tabulation Analysis (χ^2 test)

Variable	Significance (p-value)
Gender	0.003***
Classes	0.030**
Age	0.000***
Marriage	0.533
Title	0.000***
Company capital	0.948
Employee	0.495
Industry	0.130
Long-term Expatriates	0.191

Note: *** and ** represent significance at 1% and 5%, respectively.

4.2 Binary Logit Model Specification and Estimation

Based on the stated preference data, the binary logit model is used to investigate the choice behavior of business travelers between BC and the business class provided by commercial airlines. NLOGIT version 4.0 is used for model estimation. The procedure of model estimation is illustrated in more detail as follows.

4.2.1 Model Specification

To explore the preference of business travelers for BC, we apply the binary logit model to investigate business travelers' choice behavior. The stated preference data consist of a dataset with information of 2,100 cases (from all 420 respondents). With respect to model specification, U_i is the utility function of BC and U_j is the utility function of the business class service as in equations 7 and 8. Explanatory attributes include fare, socioeconomic variables, trip experiences, and characteristics of BC. These variables are described in more details in Table 4.

$$U_i = bo_1 1 + b_2 FARE + b_3 SEN + b_4 TRI + b_5 DUA + b_6 GEN + b_7 AGE + b_8 MAR + b_9 EMP + b_{10} SAV + b_{11} CON + b_{12}\, ENT + b_{13} VIS + b_{14} INT \qquad (7)$$

$$U_j = bo_1 0 + b_2 FARE + b_3 \;\; 0 \;\; + b_4 \;\; 0 \;\; + b_5 \;\; 0 \;\; + b_6 \;\; 0 \;\; + b_7 \;\; 0 \;\; + b_8 \;\; 0 + b_9 \;\; 0 \;\; + b_{10} \;\; 0 \;\; + b_{11} \;\; 0 \;\; + b_{12} \;\; 0 \;\; + b_{13}\, 0 \;\; + b_{14}\, 0 \qquad (8)$$

Table 4: Independent Variables in the Utility Function

Variables	Meaning
Constant	Constant term of BC
FARE	The round trip fare (USD 5,833, 3,500, 2,500, 1,633 / passenger)

SEN	The years of working experience in the company
TRI	The number of business trip during the previous year
DUA	The duration of the previous business trip
GEN	Dummy variable of gender (1: Male; 0: Female)
AGE	Dummy variable of age(1; 50~59; 0: Others)
MAR	Dummy variable of marital status (1: Married; 0: Others)
EMP	Dummy variable of the company employees (1: less than 50; 0: Others)
SAV	Dummy variable of saving time from transit
CON	Dummy variable of control of trip-time
ENT	Dummy variable of client entertainment
VIS	Dummy variable of client visits
INT	Dummy variable of international conference attendances

4.2.2 Estimation Results

As it is speculated that senior executives are more likely to choose BC, two models are estimated in this research, with Model A using all respondents and Model B using senior executives (140 respondents). For comparison, two estimation results are shown in Table 5. As indicated in Table 6, the χ^2 test statistics show that both models are statistically significant, with both p-values being less than 0.001. The $\hat{\rho}^2$ of Model B (0.30) is greater than Model A (0.20). In terms of the accuracy of models, the accuracy rate of Model A is 74.7% while the accuracy rate of Model B is 81.5%.

Significant variables in Model A include (1) fare, (2) gender, (3) seniority, (4) the number of business trips during the previous year, (5) transfer time saving, (6) travel time controlling, (7) client entertainment, (8) customer visits, and (9) attending international conferences. Fare has a significant coefficient with negative sign, meaning that a higher fare will reduce the probability of choosing an alternative. The coefficient of Gender is also negative, indicating that female is more likely to choose BC than male. The coefficient of seniority is positive, which means that senior respondents are more likely to use BC, compare with other respondents. Additionally, respondents with fewer business trips during the previous year have higher possibility to choose BC.

In addition, five more variables picked from the characteristics of BC are also considered in the model, which include two attractive factors of BC (transfer time saving and travel time controlling) and three trip purposes (client entertainment, customer visits and attending international conferences). The coefficients of the five variables remain significantly positive. This indicates that the attractive factors of BC and the three main trip purposes of using BC have positive effects on the probability of choosing BC. When respondents need to make transfers to arrive at their destinations, they prefer to use BC than commercial airlines. Also, in business trips, when respondents take cancellations or delays of scheduled flights into account, they are more likely to choose BC. Respondents have a higher preference for BC when considering the purpose of using BC for entertaining clients. Customer visits is another appealing reason for respondents to choose BC. Furthermore, attending international conferences also has positive effects on the probability of choosing BC.

In Model B, significant variables include (1) fare, (2) gender, (3) marital status, (4) age, (5) duration of the previous business trip, (6) number of company employees, (7) client entertainment, (8) customer visits, and (9) attending international conferences. The coefficient of fare remains negative, which means that the probability of senior executives to choose BC will decrease when the fare is increasing, assuming that the fare of business class is fixed. Gender also has negative impacts in Model B, which indicates female senior executives prefer BC. The magnitudes of the coefficients of Gender in both models indicate that the family factors have greater influences to senior executives that to the whole sample.

In addition, the coefficient of age is positive, which indicates that if senior executives are between 50~59 years old, they prefer BC. It also implies that elder senior executives may have more decision power for their business trip. When mentioning the duration of the previous trip, the fewer days spent on the previous business trip, the more likely respondents choose BC. It shows that when senior executives go on temporary business travels, they prefer BC. For the companies the senior executives belong to, the coefficient of the number of employees remains negative. It shows that when the amount of company employees is less than 50, the probability of senior executives to choose BC is lower.

In terms of the features of BC, the purposes of using BC remain as statistically significant variables. If senior executives consider client entertainment as one of the purposes for their business travel, they prefer to use BC. Additionally, when senior executives have to visit clients and attend international conferences, they are more willing to use BC.

Table 5: Estimation Results of Binary Logit Model

Samples / Variable code		Model A (Total Respondents)		Model B (Senior Executives)	
		Coefficient estimate	*t* statistic	Coefficient estimate	*t* statistic
Constant	BC	-0.63155**	-2.52	1.98098**	2.09
Generic Variable	FARE	-0.23680***	-17.75	-0.25455***	-5.48
Alternative Specific Variables	SEN	0.02374***	3.96	--	--
	TRI	-0.00988**	-2.47	--	--
	DUA	--	--	-0.03450***	-2.93
Alternative Specific Dummy Variables	GEN	-0.32106*	-1.92	-2.29883***	-2.78
	AGE	--	--	1.19418***	2.64
	MAR	--	--	1.33553**	2.03
	EMP	--	--	-1.75904***	-3.82
	SAV	0.62055***	3.78	--	--
	CON	0.93045***	6.08	--	--
	ENT	0.20492*	1.89	1.14361***	2.77
	VIS	0.58336***	5.03	0.83914*	1.87
	INT	0.58240***	4.43	0.89605**	1.96
Summary statistics					
L (0)		-1455.61		-138.63	
L (c)		-1360.87		-136.93	
L (β)		-1076.92		-90.74	
-2 [L (0) - L (β)]		757.37		95.78	
-2 [L (c) - L (β)]		567.90		92.38	
ρ^2		0.21		0.34	
$\bar{\rho}^2$		0.20		0.30	
Number of observations		420		40	
Number of cases		2100		200	

Note: (1) ***, **, * represent significance at 1%, 5%, 10% level.
(2) Executives: Include chairman, president, CEO and VP.

After analyzing the estimation results of both models, this study compares the results of Model A with the results of Model B. In both models, the fare is set as a generic variable. The coefficient of fare indicates that when fare rises, the utility of respondents decreases. It shows that fare is an important factor that has strong impacts on the probability of choosing BC. Gender also is a significant negative variable in both models. Female may care more about privacy or travel time, and they were more likely to choose BC than male respondents. In addition, the three main purposes of using BC have positive effects in both models.

The coefficients of all dummy variables give us an opportunity to compare the importance of the explanatory variables. For Model B, the most significant variable is gender, followed by the number of company employees and marital status. In Model A, the most important factor is travel time control, next is transfer time saving and the third is customer visits. As the results show, this study finds that socioeconomic characteristics have higher effects on senior executives (Model B) for choosing BC while the features of BC have more positive effects on all respondents for choosing BC (Model A).

In conclusion, the fives features of BC have stronger effects on the probability of choosing BC in Model A than in Model B. However, socioeconomic variables have stronger effects on the probability of choosing BC in Model B. Also, in both models, fare is an important factor that has negative impacts on the probability of choosing BC. In addition, the alternative specific constant for BC shows positive effects in Model B. It indicates that senior executives are more likely to choose BC when all else is equal. Moreover, in Model A, the choice probability for BC is 35.09% and in Model B, the probability of choosing business charter is 43.50%. Both sample results show that there is potential in developing business charter for business travelers in the cross-strait market.

4.2.3 Choice Probabilities in Different Scenarios

This study developed five scenarios based on stated preference choice experiments. After estimation of the utility functions in the binary logit model, this study calculates the choice probability of each alternative in the five scenarios. The probability of choosing BC with respect to various fares for using BC is listed in Table 6.

In Model A, the lowest probability of BC is 0.1258 and the highest is 0.5527. For Model B, the lowest one of BC is 0.2196 and the highest is 0.6208. It seems that there is a relationship between the fare of BC and the probability of choosing BC. Since the choice probabilities presented in Table 6 are calculated based on the characteristics of the whole respondents, the numbers can also be interpreted as the percentage of the sample that chooses BC. In Model A, when the number of accompanying persons is 6, the fare of BC per passenger is USD 5,833. As a result, the percentage of all respondents choosing BC is 0.1258 while the percentage of all respondents choosing business class is 0.86. Additionally, when the fare of BC is USD 3,500, the percentage of choosing BC rises up to 0.3978. As shown in Table 6, both the percentages of choosing BC in scenarios 4 and 5 are higher than the percentage of choosing business class.

In Model B, there is a critical point, when the BC is USD 3,500, where the percentage of both alternatives becomes closer. The percentage of BC is 0.4942 while the percentage of business class of commercial airlines is 0.5058. In addition, when the fare of BC is USD 2,500, the percentage of BC goes up to 0.6208.

Table 6 presents that when the fare of the BC decreases, the percentage of business travelers choosing BC becomes higher. In comparison of the two models, the gap of scenarios 1 and 2 in Model A is bigger than the gap in Model B. It shows that when the fare of BC is USD 5,833, respondents are less likely to choose BC in Model A than the senior executives in Model B. The gap of scenarios 4 and 5 in Model A is smaller than the gap in Model B. The percentage of BC is 0.6208 in Model B, which is higher than the percentage of BC in Model A. It shows that senior executives are more willing to choose BC when the fare of business charter is USD 2,500.

Moreover, this study also investigates the price elasticity of choice probability for BC. In Model A, the price elasticity of choice probability for BC is -2.0663. For Model B, the price elasticity of probability of choosing BC is -1.9505. The effects of price elasticity of BC are consistent with Table 6.

Table 6: Choice Probabilities for Five Scenarios

Scenarios (BC Fare)	**Model A**		**Model B**	
	BC	Business class of Commercial Airlines	BC	Business class of Commercial Airlines
1 (USD 5,833)	0.1258	0.8742	0.2196	0.7804
2 (USD 5,833)				
3 (USD 3,500)	0.3978	0.6022	0.4942	0.5058
4 (USD 2,500)	0.5527	0.4473	0.6208	0.3792
5 (USD 2,500)				

Note: Fare represents the average price per passenger for business charter.

5. Conclusions

In this research, we aim to investigate business travelers' preference for BC in the cross-strait market. The binary logit model is used to investigate their choice behavior. In order to explore the preferences of Taiwanese senior executives, two models were estimated. Model A is built with all respondents and Model B is built with senior executives. In addition, the explanatory variables consist four categories: socioeconomic characteristics, trip experiences, mode attributes and specific features of BC.

In mode attributes, fare is the only significant variable. The length of waiting time, the fees of inflight commercial equipment and the provision of exclusive clearance service seem to be insignificant for choosing BC. In terms of the waiting time before the airplane departures, business travelers often wait in VIP lounges. This may explain why shorter waiting time does not have significant effects on the choice for BC.

When mentioning the fees of inflight communication equipment, the fees do not have impacts on the choice probability of two alternatives whether if it is free or not. The flight time of business travelers on the route of TPE-PVG is short, which may be the reason that the inflight commercial equipment is not a significant variable for cross- strait business travelers. In addition, TPE has built the facilities of automatic clearance service called e-Gate that raised the efficiency of the clearance process. Business travelers who travel abroad can register for the e-Gate service which probably explains why the provision of exclusive clearance service is not an influential factor in the choice probability for BC.

In both models, gender, client entertainment, customer visits, and attending international conferences have strong effects on the choice probability of BC. In Model A, in the following situations, business travelers have a higher probability of choosing business charter: (1) travelers are female, (2) travelers have high levels of seniority, (3) travelers have few business trips during the previous year, (4) when transfer time is reduced, (5) when travel time is under control. However, in Model B, senior executives that have the following profiles: (1) female, (2) married, (3) aged between 50 and 59, (4) on short-term business trips, or (5) in a company with more than 50 employees have higher preference for BC.

Additionally, the scenarios in Table 6 show that the fare per person of BC will decrease if there are more travelers. Hence, the percentage of choosing BC will rise up. The price elasticity of the choice probability of BC is shown at the end of this study. The results indicate that fare has a significant and negative impact on the choice probability of BC.

After exploring the preference for using business charter, this research finds that 68% of business travelers are more willing to consider using BC in the future. The top three most attractive factors to business travelers in using BC are "client entertainment", "customer visits" and "attending international conferences". Lastly, when it comes to the unplanned business trip, 32% of the respondents will consider using BC if the trip can be arranged within a day.

In conclusion, this study finds that there is great potential in developing BC in the cross-strait market. This study is the exploratory and original research on the choice behavior between BC and business class. This information is helpful for air charter companies when making market strategies in the future.

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Applying Ramsey Pricing on Airport Landing Charges

Jin-Ru Yen, Chia-Yi Shih and Chia-Ping Tsou

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

**Corresponding Author*

Abstract

The total revenue of the airport authority is divided into aeronautical and non-aeronautical ones. Landing fees are the main sources of aeronautical revenue. Therefore, it is essential to formulate a suitable charging mechanism for landing fees. Traditionally, pricing methods for airport landing fees are based on the maximum takeoff weight or maximum landing weight, which has little theoretical rationale. Airports landing fees charged in Taiwan are also based on the aircraft weight. There are various pricing methods in academic research, such as average-cost pricing, marginal-cost pricing and Ramsey pricing. 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, Taiwan Taoyuan International Airport (TPE) suffers from congestion in peak periods. 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 pricing mechanism is then validated at TPE and Taipei Songshan Airport (TSA). Although price elasticity is essential to Ramsey pricing, it is difficult to directly calculate this elasticity of airline demand in landing. The ordered probit model is used to find the price elasticity from different passenger groups, and then the estimation results are put in the Ramsey pricing model in order to substitute the price elasticity of airline's landings. In empirical research, the results indicate that in most of the case, as the aircraft is larger and the distance is longer, the landing fees are higher. Additionally, calculation results reveal that in every case the current charge at TPE and TSA is less than the land fees based on the Ramsey pricing mechanism.

Keywords: Landing Fee, Ramsey Pricing, Airport Pricing, Ordered Probit Model

1. Introduction

Traditionally, pricing methods for airport landing fees are usually adopted by the maximum takeoff weight (MTOW) or maximum landing weight (MLW). However, these pricing standards have few theoretical bases to back them up. The economic theory is that the price is affected by supply and demand factors. The airport landing fees charged in Taiwan are also based on the MTOW and thus are not entirely determined by the supplies and demands 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 increasing volume and usage frequency of the airports in Taiwan, peak and off-peak hours become more and more obvious. Therefore, the landing fees should be set in different rates according to peak and off-peak hour pricing. In theory, this will allow the airport operations become more efficient.

This study aims to calculate the landing fee of the two airports in Taiwan during off-peak hours with the Ramsey pricing model. There are two main airports in Northern Taiwan. One is the Taipei Songshan Airport (TSA), which locates at the center of Taipei city. The other is the Taiwan Taoyuan International Airport (TPE) that locates in Taoyuan. The distance between the two airports is 41 kilometers, which is approximately 40 minutes by car. TPE is the busiest international air entry point in Taiwan and is also an important East Asia transit hub. TSA on the other hand, is smaller than TPE. TSA does not serve continental-flights yet, such as North America routes, Europe routes, and Oceania routes etc. TSA mainly serves chartered flights, most of which are to and from China, domestic flights, and some short-haul flights in Asia. As a result, TSA is set to be a “business airport”, and many of the flight destinations departing from Songshan are major business centers. Aircraft types adopted in this research are Boeing 747-400, Boeing 777-300ER and Airbus 330-300 in TPE, which holds the top three highest landing frequencies. TSA on the other hand, Airbus 330-300, Airbus 321-200 and Boeing 737-800, which holds the three highest landing frequencies in TSA.

The structure of the Ramsey pricing model has 4 variables, the marginal cost of landing to the airport, the price elasticity of the airline’s demand in landing of different aircraft types, the different 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 ordered 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), Los Angeles (LAX), San Francisco (SFO) and Brisbane (BNE) as well as from TSA to Shanghai Pudong (PVG), Shanghai Hongqiao (SHA), Gimpo (GMP), Tokyo Haneda (HND) and Tokyo Narita (NRT) 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. Chang and Yen (2014) 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. The average cost pricing method is applied in this study to allocate the costs on TPE and TSA. The result indicates that the location of airports should be considered when determining their landing fees.

2.2 Marginal cost pricing

Marginal cost pricing is one of the pricing methods which 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 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 fee that maximize a weighted sum of airline consumers’ surpluses subject to a revenue requirement. Thus, optimal landing fee 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, and the main result is that commuter airlines are much more favored than others.

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. Thus, Ramsey pricing would result in increased fees for small planes on long flights and decreased fess for large planes on short flights. Martín-Cejas (1997) establishes an airport pricing structure for landing fee which reflects the overall costs that air transport operators impose on others. This paper analyzes one application of Ramsey Pricing on uncongested Spanish airport by considering the CO_2 emission costs as a valuable input. The results present that the landing fee for each type of aircraft increases with distance, and as the aircraft size increases the landing fee increase. Ramsey prices are optimal for airports with cost recovery problems, but are inefficient for busy airports (Hakimov and Muelle, 2014)

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

$$\max_{Q_1,\ldots,Q_n} \ \mathrm{NSB} = \mathrm{SB} - \mathrm{SC} \qquad (1)$$

$$\text{s.t.} \quad TR - \mathrm{TC} = 0 \qquad (2)$$

where $Q_{1,\ldots,}\mathrm{Q_n}$ = 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

TC = total cost to the airport authority (including total variable cost and total fixed cost)

Social benefit (SB) is the demand functions for the different aircraft types of the landings. That is the sum of the demand from aircraft individual demand of category 1 to category n.

$$SB = \int_0^{Q1} \mathrm{P_1(Q_1)dQ_1} + \cdots + \int_0^{Qn} \mathrm{P_n(Q_n)dQ_n} \qquad (3)$$

where P_i = the landing fee charged to aircraft in category i (a category is given by an aircraft type and length of flight).

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.

$$\mathrm{SC} = \mathrm{C(Q_1, \ldots, Q_n)} \qquad (4)$$

Total revenue (TR) is landing charges collected from landing aircraft of category 1 to category n.

$$\mathrm{TR} = \sum_{i=1}^{n} P_i Q_i \qquad (5)$$

Total cost (TC) includes total variable cost and total fixed cost incurred by the airport authority to serve all types of aircraft.

$$\mathrm{TC} = \mathrm{C(Q_1, \ldots, Q_n) + F} \qquad (6)$$

where F =the fixed costs which must be covered.

The above objective function and constraint can be expended 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 ε_i is the (absolute value) elasticity of demand for landings with respect to the landings fee. And, $\partial C/\partial Qi$ 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 ε_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 the demand for landings (ε_i) is difficult to get, Morrison reformulated formula 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 1flight), the airline's demand elasticity for landings is equivalent to the passenger's demand elasticity of trips with respect to ticket prices 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 demand for landings can be replaced by the product of the elasticity of demand for passenger trips. 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

$$\frac{\mathrm{d}P_x}{P_x} = \frac{\mathrm{d}(b \cdot w_L)}{P_x} = \frac{b \cdot w_L}{P_x} \cdot \frac{\mathrm{d}w_L}{w_L} = \upsilon_\mathrm{L} \cdot \frac{\mathrm{d}w_L}{w_L} \tag{13}$$

$$\mathrm{d}\log P_x = \upsilon_\mathrm{L} \cdot \mathrm{d}\log w_L \tag{14}$$

where υ_L is the share of L in costs. The demand elasticity of consumer (η^D) is

$$\eta^\mathrm{D} = \frac{\mathrm{d}Q_x / Q_x}{\mathrm{d}P_x / P_x} = \frac{\mathrm{d}\log Q_x}{\mathrm{d}\log P_x} \tag{15}$$

But the price (P_x) increase reduces output (Q_x):

$$\mathrm{d}\log Q_x = \eta^\mathrm{D}\, \mathrm{d}\log P_x = \eta^\mathrm{D} \cdot \upsilon_\mathrm{L} \cdot \mathrm{d}\log w_L \tag{16}$$

And, since production is by fixed proportions, the proportional fall in each factor is the same as the proportional fall in output.

$$\mathrm{d}\log L = \mathrm{d}\log Q_x \tag{17}$$

$$\mathrm{d}\log L = \eta^\mathrm{D} \cdot \upsilon_\mathrm{L} \cdot \mathrm{d}\log w_L \tag{18}$$

Hence, the firm's demand elasticity of L (variable factor) is share of L in costs multiplied by demand elasticity of consumer.

$$\frac{\mathrm{d}\log L}{\mathrm{d}\log w_L} = \varepsilon_{LL} = \upsilon_\mathrm{L} \cdot \eta^\mathrm{D} \tag{19}$$

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. And, 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 share of landing in total flight cost multiplied by the elasticity of demand for passenger. Thus, equation (11) results in

$$\varepsilon_i = \eta_i \left(\frac{P_i}{P_i + TC_i} \right) \qquad i = 1, \dots, n \tag{20}$$

where η_i =the (absolute value) price elasticity of demand for passenger trips of the i category.

TC_i = the cost of the flight for the ith category exclusive of landing fee.

Finally, combing equations 11 and 20, the result of landing fee of Ramsey pricing for category i is

$$P_i = \frac{MC_i + \frac{\mathrm{k}}{\eta_i} TC_i}{1 - \frac{\mathrm{k}}{\eta_i}} \qquad i = 1, \ldots, n \tag{21}$$

where $\mathrm{k} = \frac{\lambda}{1+\lambda}$

MC_i = the marginal cost to the airport authority of the landings.

Equation (21) shows that the landing fee charged to aircraft in category i is related to marginal cost of a landing to the airport authority, 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 authority; that is, there are no congestion externalities.

3.2 Aggregate demand function and elasticity

According to Daganzo (1979), the estimated discrete choice model is a choice probability function of a vector of specified attributes $\mathbf{a}$ and a parameter vector θ. The choice function of alternative j can be stated as $\mathrm{P_j}(\theta, \mathbf{a})$, $\mathrm{j} = 1, 2, \ldots, \mathrm{J}$, 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:

$$\mathrm{D_j} = \mathrm{N} \int_{\mathrm{a_1}} \int_{\mathrm{a_2}} \ldots \int_{\mathrm{a_K}} \mathrm{P_j}(\theta, \mathbf{a})\, \mathrm{f_A}(\mathbf{a})\ \mathrm{d}\mathbf{a} \tag{22}$$

where N is the population size, K is the number of attributes specified in the choice function, and $\mathrm{f_A}(\mathbf{a})$ is the probability density of the attribute vector $\mathbf{a}$ across the population. By definition, $\mathrm{P_j}(\theta, \mathbf{a})\mathrm{f_A}(\mathbf{a})\,\mathrm{N}$ represents the density of decision makers with an attributes vector $\mathbf{a}$ who choose alternative j. Therefore, the integral in equation (22) is the expected value of $\mathrm{P_j}(\theta, \mathbf{A})\, \mathrm{f_A}(\mathbf{A})\mathrm{N}$ with respect to $\mathbf{A}$, and aggregate demand function $\mathrm{D_j}$ can be written as $\mathrm{E_A}[\mathrm{N}\, \mathrm{P_j}(\theta, \mathbf{A})]$ or $\mathrm{N}\, \mathrm{E_A}[\, \mathrm{P_j}(\theta, \mathbf{A})]$, with $\mathrm{E_A}$ as the expectation function with respect to the vector of random variables $\mathbf{A}$.

Theoretically the elasticity of the aggregate demand for choice alternative j with respect to attribute a is (Yen, 2000):

$$\varepsilon_{\mathrm{a}}^{\mathrm{D_j}} = \frac{\partial \mathrm{D_j}}{\partial \mathrm{a}} \frac{\mathrm{a}}{\mathrm{D_j}} = \frac{\partial\ \{\mathrm{E_A}[\, \mathrm{P_j}(\theta, \mathbf{A})]\}}{\partial \mathrm{a}} \frac{\mathrm{a}}{\mathrm{E_A}[\, \mathrm{P_j}(\theta, \mathbf{A})]} \tag{23}$$

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

$$\varepsilon_{a}^{D_j} = \frac{\partial P_j(\theta, \overline{\mathbf{A}})}{\partial a} \frac{a}{P_j(\theta, \overline{\mathbf{A}})} \qquad (24)$$

where $\overline{\mathbf{A}}$ is the vector of the population mean values of the explanatory variables. Empirically, the partial derivative in equation (24) is approximated by a differentiation in equation (25).

$$\varepsilon_{a_K}^{D_j} = \frac{P_j(\theta, \overline{\mathbf{B}}) - \partial P_j(\theta, \overline{\mathbf{A}})}{\Delta a_K} \frac{a_K}{P_j(\theta, \overline{\mathbf{A}})} \qquad (25)$$

where the elements of vector $\overline{\mathbf{B}}$ are the same as in vector $\overline{\mathbf{A}}$ 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 3-32 is referred as an arc elasticity, with $P_j(\theta, \overline{\mathbf{A}})$ in the denominator being replaced by the average of $P_j(\theta, \overline{\mathbf{A}})$ and $P_j(\theta, \overline{\mathbf{B}})$.

4. Empirical Study

4.1 Price elasticity of passenger demand (η_i)

The derivation presented in section 3.1 shows that the airline's demand elasticity in landing (ε_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 choice probability function, $P_i(\theta, a)$, is important to obtain the aggregate demand function and the demand elasticity of passenger for various aircraft types. The choice probability function, based on the ordered probit model, was estimated by Yen et al. (2015).

The data of this study and Yen et al. (2015) were collected from passengers in different aircraft types and to different destinations at TPE and TSA. The survey was conducted in May 1-24, 2015, collecting data by purposive sampling and interviewing travelers from the departure lounges at TPE and TSA. Among those 1,139 who completed the questionnaire, 18 respondents were excluded from the data set. Therefore, a total valid sample is 1,121. Among them 661 departed from TPE, and others from TSA.

Details of the questionnaire can be referred to Yen et al. (2015). To summarize, according to different aircraft types and different destinations, the questionnaire contains 9 versions at TPE and 6 versions at TSA. For TPE, 3 aircraft types were adopted in the survey, including Airbus 330-300, Boeing 777-300 ER and Boeing 747-400. Each aircraft type is further divided into short-haul, regional, and continental. The destination of short-haul is PVG. The destination of regional-flights is NRT. Furthermore, the destinations of continental-flights are BNE (A330-300), LAX (B777-300ER), and SFO (B747-400). For TSA, 3 aircraft types were adopted, including Airbus 321-200, Boeing 737-800 and Airbus 330-300. Each aircraft type is divided into 2 distances, short-haul and regional. The destinations of short-haul are PVG (A321-200 and B737-800) and SHA (A330-300). On the other hand, the destinations of regional-flights are GMP (A321-200 and B737-800) and HND (A330-300). TSA currently does not serve continental-flights. Therefore, the questionnaire for TSA just has 6 versions. All versions contain 6 questions on travel experiences, 5 questions on individual demographic characteristics and 3 different scenarios. In the questionnaire, each respondent was asked of their willingness of choosing this route for how many times in three different rating scenarios.

Data from TPE

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, 60% of the respondents traveled by air more than 2 times per year. Approximately 57% of the respondents travel with business purpose, and 51% of the respondents travel within 7 days. Secondly, there are 74 respondents in regional-flights with B747-400, 46% of them are male. Approximately 70% of the respondents hold a bachelor degree. More than 73% of the respondents travel for leisure, and 83% of the respondents travel within 7 days. Lastly, there are 74 respondents continental-flights with B747-400, among those 49% are male. Approximately 38% of the respondents hold a Master or Ph.D. degree and 51% of the respondents hold a bachelor degree. More than 60% of the respondents travel for leisure or to visit friends and relatives (VFR), and 47% of the respondents travel within 8-14 days.

Next is Boeing 777-300ER. In short-haul with B777-300ER, there are 62 respondents, in which 58% are male. Approximately 52% of the respondents travel less than 2 times per year by air. 76% of the respondents travel with business purpose, and 67% of the respondents travel within 7 days. In regional-flights with B777-300ER, there are 60 respondents, 42% of which are male. More than 70% of the respondents hold a bachelor degree. Approximately 83% of the respondents travel for leisure, and 75% of the respondents travel within 7 days. In continental-flights with B777-300ER, there are 95 respondents, 51% of which are female. 52% of the respondents travel for business purpose, and 51% of the respondents travel within 8-14 days.

Lastly, in short-haul with A330-300, there are 76 respondents, 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 with A330-300, there are 63 respondents, 52% of which are male. Approximately 62% of the respondents travel for leisure, and 68% of the respondents travel within 7 days. As for continental-flights with A330-300, there are 92 respondents and 38% of which are male. More than 66% of the respondents travel within 2 times per year by air. Approximately 33% of the respondents travel within 7 days and 28% of the respondents travel for 31 days or over.

Data from TSA

Firstly, the research observes the passenger information of A330-300. There are 99 respondents in the short-haul with A330-300, 59% of which are male, 63% of the respondents traveled by air more than 2 times per year. More than 68% of the respondents hold a bachelor degree. Approximately 87% of the respondents travel with business purpose, and 59% of the respondents travel within 7 days. Secondly, there are 98 respondents in regional-flights with A330-300, 56% of them are female. Approximately 69% of the respondents hold a bachelor degree. More than 52% of the respondents travel for leisure, and 74% of the respondents travel within 7 days.

Next is Airbus 321-200. In short-haul with A321-200, there are 60 respondents, in which 53% are male. Approximately 68% of the respondents travel is more than 2 times per year by air. 68% of the respondents travel with business purpose, and 75% of the respondents travel within 7 days. In regional-flights with A321-200, there are 73 respondents, 81% of which are female. Approximately 92% of the respondents travel for leisure, and 86% of the respondents travel within 7 days.

Lastly, in short-haul with B737-800, there are 63 respondents, 63% of which are female. Approximately 38% of the respondents travel by air within 2 times per year and 46% travel by air within 3-5 times per year. Approximately 41% of the respondents travel with business purpose. As for regional-flights with B737-800, there are 67 respondents and 78% of which are female. More than 63% of the respondents travel within 2 times per year by air and 78% travel with leisure purpose. Approximately 88% of the respondents travel within 7 days.

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, business or VFR. On the other hand, what's worth mentioning is that in all 3 aircraft types in short-haul from TSA, most respondents travel for business. Passengers traveling for leisure also mostly exist in regional-flights. In addition, the proportion of female is higher than male in regional-flights.

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 ordered probit model for TPE and TSA 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 and distance combination is divided into two groups. 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 choice probability 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 1 lists the calculated results. The negative values for each group reflect that decreasing prices of ticket will increase passenger air travel demand. At TSA, the results indicate that the price elasticity of the passenger for small aircraft is greater (absolute value) than the one for large aircraft. This phenomenon merits special investigation. In addition, the price elasticity of the passenger for regional-flights is greater (absolute value) than the passenger for short-haul. This might reflect the situation that the competition in the regional market is higher than in the short-haul market.

Table 1: Price elasticity of passenger demand

Aircraft type / Distance	TPE			TSA		
	B747-400	B777-300ER	A330-300	A330-300	A321-200	B737-800
Short-haul	-1.24	-1.37	-1.58	-0.72	-1.21	-1.80
Regional-flights	-0.86	-1.34	-1.27	-1.65	-1.77	-3.13
Continental-flights	-1.56	-0.24	-1.35	-	-	-

4.2 Cost of flight (TC_i)

As we concentrate on the cost for the landing of each flight the following formulation 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). The aircraft characteristics are summarized in Table 2.

Table 2: Aircraft Characteristics at TPE

Aircraft Characteristics	Aircraft Type				
	Boeing 747-400	Boeing 777-300ER	Airbus 330-300	Airbus 321-200	Boeing 737-800
USD per block hour	15,629	11,007	10,484	4,537	5,173
Seats(2-class)	524	451	335	185	162
MTOW(ton)	397	352	230	94	79

4.3 Parameter k

The value of k depends on the extent to which the revenue constraint is binding. If the constrain is not binding, then k=0 and Ramsey pricing reduces to marginal cost pricing P=MC. At the other extreme, when revenue requirements is at the maximum attainable level, the value of λ tends to infinity and we get k=1that reduces the Ramsey pricing formula to P=MR. The unknown k will be calculate and used because the fees generate with that value for k are of the same order of magnitude as current fees. At TSA, the estimated value of k is 0.0021. At TPE, the estimated value of k is 0.0093.

4.4 Marginal cost for airport authority (MC_i)

This paper assumes that TPE and TSA are 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 Chang and Yen (2014) as the indicator of the average cost for landing at TPE and TSA. Table 3 shows the average costs of different aircraft types at TPE and TSA, which are used as marginal costs (MC_i) in equation 21.

Table 3: Average costs of different aircraft types in 2012 (in US$)

Airport	TPE			TSA		
Aircraft Type	B747-400	B777-300ER	A330-300	A 330-300	A321-200	B737-800
Average Cost	810	2,107	1,370	1,913	687	467

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 various selected aircraft types are calculated and shown in Table 4. The structure of the Ramsey pricing for landing fees is related to distances and aircraft types. In most of the case, 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). 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, reginal, and continental, respectively. This phenomenon applies to other two air craft type at TPE. At TPE, for each distance category the calculated landing fees of B747-400 is greater than the one of A330-300. However, the landing fee of B777-300ER is greater than the one of B747-400 due to the much higher average costs of B737-300ER.

Table 4 also lists the current landing fee for each aircraft type at both airports. Since neither airport charges landing fees according to flight distances, there is only one current charge for each aircraft type at every airport. The comparison between the calculation results and the current charge reveals that in every case the current charge is less than the land fees based on the Ramsey pricing mechanism. This finding is consistent with the fact that both TPE and TSA have deficits on their financial performances at airside. Since A330-300 aircraft serves both TPE and TSA, it is interesting to compare the calculation results at both airports. The landing fees based on Ramsey pricing in both distance categories at TSA is greater than the ones at TPE, respectively, mainly due to the higher average costs at TSA. The current landing charges of A330-300 at both airports also show that same pattern.

Table 4: Calculation results of landing fees with Ramsey pricing (in US$)

Aircraft type / Distance	TPE			TSA		
	B747-400	B777-300ER	A330-300	A330-300	A321-200	B737-800
Short-haul	1,832	2,409	1,053	3,159	1,002	703
Regional-flights	2,692	2,710	1,408	2,960	1,007	735
Continental-flights	3,174	10,666	2,207	-	-	-
Current charge	1,970	1,743	1,053	2,283	830	703

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 and TSA 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. In addition, this elasticity for regional-flights is greater than the one for short-haul, due to higher competition.

The calculation results of the landing fees at TPE and TSA demonstrate that the structure of the Ramsey pricing for landing is related to distances and aircraft types. At TSA, the landing fee is higher for larger aircraft in any distance range. TPE shares the same results except that the landing fee of B777-300ER is greater than the one of B747-400 due to the former's higher average costs incurred by the airport operator.

The comparison between the calculation results and the current charge reveals that in every case the current charge is less than the land fees based on the Ramsey pricing mechanism. This finding might give the reason that both TPE and TSA have deficits on their financial performances at airside. Although the empirical study was conducted using data from two airports in Taiwan, the mechanism can be applied to airports world-wide.

6. Acknowledgement

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Discussion on Urban Freight Deliveries Policies Based on Urban Morphology

Xiaoxia Wang and Zhanqiang Li

School of Traffic and Transportation, Beijing Jiaotong University, Beijing

Abstract

Urban car transportation is a cause of climate change but is also associated with additional burdens such as traffic congestion and air pollution. Working with business partners to deliver a safer, greener and more efficient logistics service, this paper reviewed literature and practices about urban freight deliveries (UFD), presented its general cause and effect analysis framework under historic view, e.g. 5-10 years, then drew lessons by comparison between the developing and developed metropolis, points out UFD actually influenced by public policies, which have long term impact on spatial structure or land-use planning with the reaction by people choices. The diverse mixture of land uses, dense urban environment and vast transportation infrastructure, urban areas require a distinct set of rules and regulations to govern the operation of trucks and commercial vehicles. Due to the differences patterns of traffic congestion among areas inside the city, here take Beijing traffic as a case study and visualize its patterns, hopefully will shed some light on mapping out efficient, sustainable and smart transportation policies for mega-cities plagued by traffic jams and emissions problems.

Keywords: urban freight, spatial pattern analysis, transport policy, urban morphology

1. Introduction

Trucks and commercial vehicles are essential to mega-cities, providing goods and services to millions of residents every day. In the last decades, urban freight deliveries (UFD) have raised considerably attentions. Freight vehicles hamper mobility, slowing down the traffic and sometimes double parking. UFD generally coincides with peak-hour traffic, because deliveries have to be done during business hours. Some cities have adopted actions aimed to reduce freight vehicles circulating in peak-hours, but such actions usually come up against the receivers, who are not willing to change how they receive their goods (Dominguez et al., 2012).

Congestion costs, including emission, are emerging as one of the most important challenges faced by metropolitan planners and transport authorities in developed economies. High-efficient traffic system is very important for the economy and society of cities. Cities around the world are trying out a multitude of transportation policy and investment alternatives with the aim of reducing the deterioration of the urban traffic environment, which is part of the main externalities brought by the agglomeration of population and industry in metropolitan areas. The detrimental effect is accompanied not only by reduced efficiency of transportation systems, environmental pollution problems (energy consumption), public health and safety problems, but also by severe social inequity (Zhang and Gao, 2008). Policy should be taken in response to the spatial distribution of residents with different socio-economic features. However, trucks and commercial vehicles both cause and suffer from congestion on urban streets. Because of this congestion, deliveries made during the business day cost us all – as stores pass on the expenses of wasted time, lost revenue, missed deliveries and parking tickets.

The structure of this paper as follows: (1) learn from developed and developing cities proposed a universal analytical framework for UFD under historic view, e.g. 5-10 years; illustrate public transport policies affect urban morphology and morphology change. (2) with the facility of big data, the city transport policies could be smarter. Taking Beijing as a case study, discuss UFD policies ongoing and challenges in the age of the Internet.

2. Cause and Effect Analysis Framework for UFD

UFD is actually influenced by public policies, which have a long term impact on spatial structure or land-use planning with the reaction by people choices. Figure 1 illustrates cause and effect analytical framework for UFD from the aspects of supply and demand. And key points are developed in following sections 2.1 and 2.2.

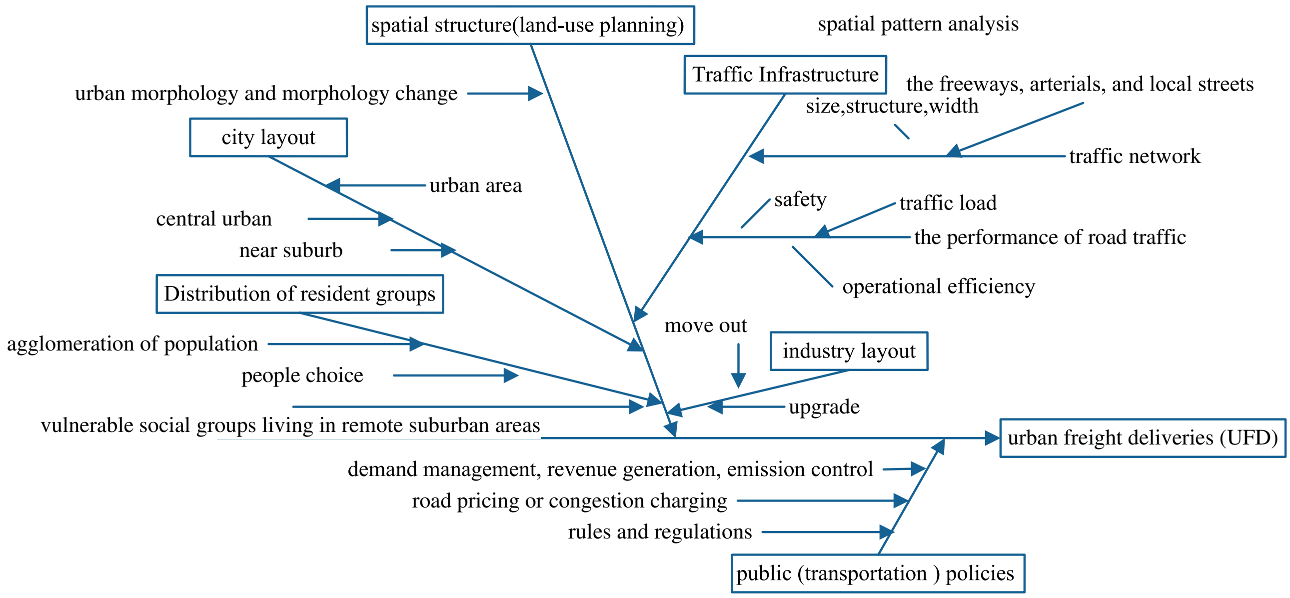


Figure 1: Cause and Effect Analytical Framework for UFD

For the developing cities, the supply of spatial structure plays the leading role. For instance, with a large-scale survey data of the residents' degree of satisfaction with the traffic environment, spatial differentiations were identified across space and social groups. Zhang and Gao(2008) revealed that Beijing's traffic problems are closely related to land-use planning and public policies. Ji and Gao (2010) developed a method to evaluate the efficiency of urban structure from the perspective of accessibility of public transportation, considering public transportation, local economics, regional features, and road construction, with the satisfaction of people toward public transportation. As the developed, the demand or policies regulation will as the dominant.

2.1. Urban morphology and morphology change set the solution boundary

First of all, population distribution and movement are confined by urban morphologies to a great extent.

2.1.1. Historic development of city layout and traffic infrastructure

Table 1 compares urban road network layout between developed cities and Beijing(Map of 2.5kmby google earth, Nov.2015). Obviously, the density of road network in Beijing is the smallest. In China before the reform and opening up policy, enterprises and institutions usually provided canteen, hospital, kindergarten, even schools for their employees. Naturally each enterprise or institution fence their own territory and municipal vehicles could not effectively access their roads. As a result, the usage of road totally different from abroad as Table 2. Not until 1984 Feb., national policy for the first time cleared the legitimacy of private purchase vehicles in China. In 1994 July, the State encourages individuals to purchase cars. In 2000 Oct., encourages car into the family. So the traffic congestion in mega cities of China could be viewed as a problem in the development process which should be solved partly by the same way.

As a large and permanent human settlement, a big city or metropolis usually has associated suburbs and exurbs. Once a city expands far enough to reach another city, this region can be deemed a conurbation or megalopolis. For example, Yanjiao Town, located west of Sanhe City (Hebei Province), daily tremendous crowds commuting to work of Beijing downtown 30km away. April 2015 "Beijing-Tianjin-Hebei (BTH) Coordinated Development Planning" passed, which take Beijing-Tianjin and some cities in Hebei province as a whole to harmonize development and planning, although this plan has been through from the "Jing-Jin-Ji Metropolitan Regional Planning" during the Eleven-Five plan, to the "Capital Economic Zone Development Plan" of the

Twelve-Five, adjusted to the "Capital Economic Circle Integrated Development Planning" (as Figure 2). Besides Code for Inter-City Railway Design (TB 10623-2014) enforced from March 1, 2015, in which intercity rail refers to specialized services in adjacent cities or urban agglomerations, fast, convenient, high density the passenger trains with designed speed below 200 km/h. Beijing-Tianjin intercity railway 120km long takes 29min and RMB ¥54.5 for 2nd class, operated in Aug. 2008, with the smallest headway 3min and the fastest speed 350km/h. The area of BTH is building inter-city railway network that have 24 new lines full length of 3453km; According to the planning targets, the 24 inter-city railways will form three circles in the region of BTH: "half an hour to 1 hour" traffic circle of central core area of the main cities; "1 hour to 2 hours" traffic circle between the key cities; "half an hour to 1 hour" traffic circle of the key cities and surrounding towns. Among the recently constructed 8 inter-city railways, all except Beijing-Shi Jiazhuang can be incorporated into the "half an hour to 1 hour" traffic circle. Jing-tang intercity railway starts this year, this might be also true to Jing-bin intercity railway, the 2nd Beijing-Tianjin intercity railway. All these contribute to urban space evolution.

Table 1: City road network layout

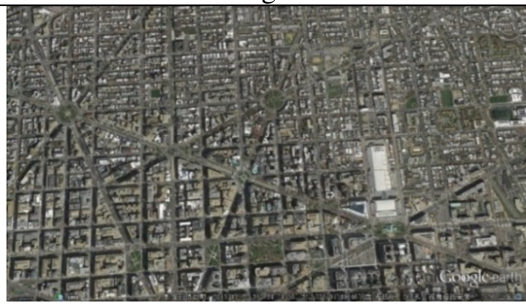
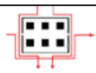
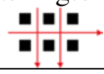
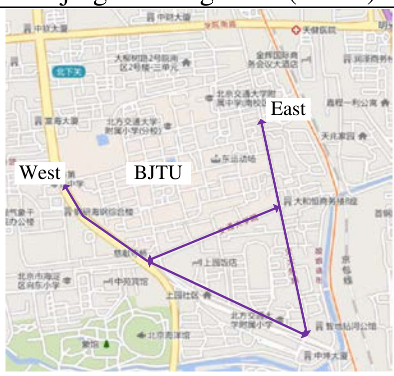
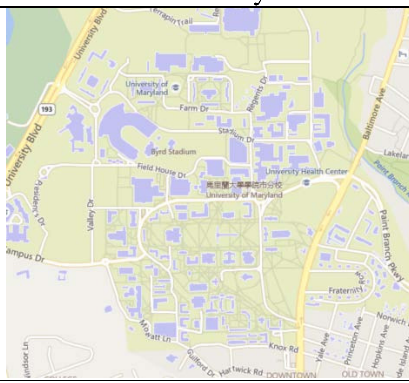
City	Tokyo	Washington DC
Road layout		
City	Paris	Beijing
Road layout		

Table 2: Usage of road network compared home and abroad

City, drive direction	Beijing, 	Tokyo/ Washington DC/ Paris, 
e.g.	Beijing Jiaotong Univ.(BJTU)	Univ. of Maryland
Bing map, scale 250m		
Notes	Drive from east to west or vice versa detour 1.7km	drive through via Dr. roads

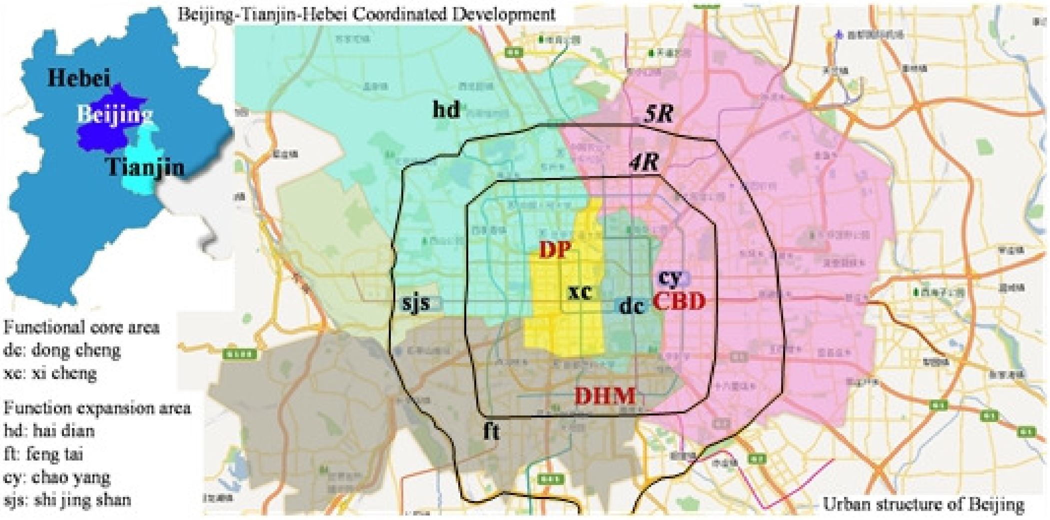


Figure 2: Beijing-Tianjin-Hebei Coordinated Development and Urban Structure of Beijing

2.1.2. Distribution of resident groups and their choice

Land use patterns are restricted to macro data such as population and area attribution; and there is a quantitative relationship between travel intensity and land use patterns. Sun et al. (2014) quantified the average travel intensity of each land use pattern based on the analysis of travel origin and destination between traffic zones based on the mobile data of 100000 residents in Beijing and Point of Interests data in typical traffic zones combined with construction area investigation. Secondly, the detection of clustering in a spatial phenomenon of interest is an essential issue in spatial pattern analysis. For instance, certain spatial phenomena related to human activities are inherently constrained by a transportation network thanks to our strong dependence on the transportation system. Yamada and Thill (2007) introduced an exploratory spatial data analysis method named local indicators of network-constrained clusters, for detecting local-scale clustering in a spatial phenomenon that is constrained by a network space. Yamada and Thill (2010) expounded as local indicators of network constrained clusters. Around 2001, Beijing launched Huilongguan culture residential quarter, the largest affordable housing projects in China, with the total planning area of 8.5 million m2 and dwell close to 300000 people. Most of the residents rely on the Light Rail to travel around. May 2014, operational mileages of Beijing urban rail transit system was 544km with 18 lines, the world's 2nd - largest city subway system (the 1st to Shanghai). Average daily passenger volume of Beijing metro business day at about 10 million, peak volumes up to 11.5592 million (April 30, 2014). The end of 2014, Beijing subway 18 lines, operational mileage 527 km. Especially when combined with a lower price strategy refer to following part 2.2.2, this result in distorted commuting behaviour to some level.

A solid understanding of how people make their transportation and residential location choices help to tell which of transportation policies and investments are really doing the work and which are wasting precious city resources. By survey data from 1997 to 1998 collected in New York City (NYC), Salon (2009) focused on the determinants of car ownership and car use for commuting with discrete choice econometrics. The conclusion is that New Yorkers are more sensitive to changes in travel time than they are to changes in travel cost. So the most effective ways to reduce both auto ownership and car commuting involve changing the relative travel times for cars and transit, making transit trips faster by increasing both the frequency and the speed of service and making auto trips slower. Population density also seems to have been a substantial effect on car ownership in NYC. Therefore, it is possible to achieve a behavioral change in UFD, by combining these policies and targeting the incentives for specific business sectors in order to achieve better results. Dominguez et al. (2012) used a mixed logit model considering repeated observations (panel data) and taste variations. In the light of the results obtained, the receivers are more inclined to adopt an urban distribution centers (UDC) policy, especially in Barcelona, whose receivers oppose firmly off-peak deliveries (OPD). As expected, the incentives strongly influence receivers to adopt these policies; however, this influence is quite more important in certain business sectors, such as food (for OPD in Barcelona), restaurant and hotel, and furniture (for UDC in Santander and

Barcelona, respectively). This is followed by the lines of the results from NYC, where there are seven sectors more sensitive to the incentives.

2.1.3. Projects for Public Spaces revitalization

Street, as municipal public spaces, should properly meet the transportation and public realm needs of residents, employees, tourists, and businesses. Urban provides people with shared spaces that make them interact with these plazas, each other and traffic while they enjoy the new view corridors and experiences in the city. For instance, physical aspects of the site namely site geometry and features, should take patrons' patterns of use, user path tracking or activity mapping into account, e.g. overpass might not a good choice over the intersection. As early as 2004, the Lower Manhattan Development Corporation funded the NYC Economic Development Corporation and the NYC Department of Transportation to contract Arup to undertake a multi-year comprehensive planning study to consider ways to reduce traffic congestion, manage placard parking, and create complete streets and engaging public spaces in Lower Manhattan (Lethco et al., 2009). Lately, the NYC Department of Transportation is experimenting with creating new public spaces quickly in the public right-of-way. Through the use of painted asphalt, planters, folding chairs, rotating public art, and other temporary materials, construction time and costs are minimal. This innovative strategy allows the department to make immediate neighbourhood change while formalized design and construction move through a longer capital planning process. (Harvey et al., 2013) Shopping malls provide leisure and entertainment, social activities with friends, even all kinds of O2O (Online To Offline) practices vigorously growing with the development of E-commerce.

UFD should adapt to the new trend of Internet age, namely customers are on the Internet and waiting for the “door to door” service under “public innovative, much entrepreneurial” social environment in developing countries like China. According to the 36th Statistical Report on Internet Development in China (July 2015), by June 2015, Internet users in China reached 668 million, Internet penetration rate of 48.8%; 594 million mobile Internet users. Li Keqiang, in 2015, in the government work report of NPC and CPPCC sessions, propose to develop “Internet+” action plan, to promote the mobile Internet, cloud computing, big data, the Internet of things combined with modern manufacturing industries. On Sept. 29, 2015, the State Council issued “the opinions on accelerating the innovation, development, transformation and upgrade of trade and commerce via promoting the interaction of online and offline”, which marked that the O2O is incorporated into the national top-level design.

Beijing is experiencing a major reform in his history: with the reposition of capital function, some non-core functions will be mediated from the capital. To prepare a wonderful 2008 Olympic Games, Beijing upgrades environmental protection standard. June 30, 2005, the demolition of Shougang’s NO.5 blast furnace marked the start of Shougang steel sector’s 5-years relocation from Beijing to Caofeidian of Tangshan in Hebei Province, one of the top ten steel enterprises in China. As a result, new Shougang comprehensive service area visualized. Shijingshan district focus on cultural services, digital content production and dissemination; collaborative innovation and creative design services, cultural and ecological tourism.

Beijing is focused on finding new ways to manage competing demands for diverse uses of limited street space. Improving street management is paramount to enhance the quality of public space and speeding public spaces’ revitalization. Since the end of 2013, Beijing begins to mobilize some huge wholesale markets, for instance Zoo wholesale markets (DP), Dahongmen clothing wholesale markets (DHM) and Xinfadi agricultural wholesale market, to move out low-end function like storage. DP have 0.3 million m^2 business areas, about 13000 wholesale clothing stalls, more than 20 logistics enterprises, over 30000 employees, annual turnover reached RMB ¥20 billion, average daily passenger flow over 100000. As for the "Big Mac." DHM in 2010, has more than 1 million m^2 business areas, over 100000 employees, average daily passenger flow over 200000, the annual turnover more than RMB ¥30 billion. These changes present an unprecedented opportunity to create a more liveable and environmentally sustainable neighbourhood by reducing traffic and managing parking while giving residents and employees better, greener mobility options.

2.2. Public transport policies: philosophy of the administrator to regulate demand

Table 3 lists some regulations or policies carried out by metropolis like London, New York and Beijing.

Table 3: Policies comparison between London, New York and Beijing

City	Policies, strategies and other terms
London	Congestion Charge; Low Emission Zone; Parking and Loading legally; Plan; Data & research
New York	Parkway restrictions; trucks and commercial vehicles; Off-Hour Delivery; Weekly Traffic Advisory; Truck Route Geodata; Community
Beijing	Regional traffic forbidden management measures; Traffic management regulation to some vehicle in Beijing to reduce pollutant emission; Traffic management measure on regional restrictions at peak-hour of weekday (vehicle license plate tail number); Comprehensive traffic operation monitoring service; Real-time air quality; "Beijing real-time bus" demonstration route

Table 4 lists regulation rules practices for trucks by New York. Based on the traffic data routinely collected at all toll lanes by PANYNJ, Ozbay et al. (2006) analyzed the traffic impacts of the time-of-day pricing program initiated by the PANYNJ on March 25, 2001. Although it is not the only factor affecting the truckers' travel pattern, it was successful in spreading weekday peak period traffic to the hours just before or after the peak toll rates are in effect, mainly for passenger cars. And J. Holguín-Veras et al. (2011) highlighted that the users have limited flexibility to change time of travel or they would like to maintain their preferred time of travel, as a result staggered/flexible work hours undoubtedly have an important role to play in demand management. Cordon time-of-day pricing, time–distance pricing, and comprehensive financial policies have a limited use as a freight demand management tool, only if financial incentives made available to receivers in exchange for their commitment to doing off-hour deliveries (José Holguín-Veras 2011).

Table 4: Dynamic trucks regulation rules practices by New York

Regulation rules	Responsible authorities	Year	refer
time-of-day pricing program	Port Authority of New York and New Jersey (PANYNJ)	2001	(Ozbay et al., 2006)
Off-Hour Truck Delivery Pilot program	USDOT worked with Rensselaer Polytechnic Institute	2009-2010	

However, philosophy of administrator or the social developed stage constrained the solution.

2.2.1. Open big data for proper tapping is the trend under cloud with mobile device widely accessible

Information on “Transport for London”(Tfl) web pages can help travellers or drivers plan better journeys, reduce Penalty Charge Notices and other charges and keep up with freight industry developments. And Tfl provides “open data” for developers to be used for their own software and services for innovative services for customer and travel information. NYC also provides data feeds for subscribing. All these facilitate better social services provided by profitable business.

March 2014 "big data" first emerged in the Chinese Government Work Report. With the development of e-Government, a large number of data closely related to public life have accumulated at all levels of Government, master 80% of the information resources of the whole society, including more than 3000 databases. The Chinese Government data to be made public as much as possible, except for confidential by law, so that cloud computing enterprise provides services for the social, as well as government policy and regulatory. When the Internet combined with the traditional industries, various trades and industries accelerate progress. The 5th plenary meeting of the 18th Session Central Committee of the Communist Party of China further proposed the implementation of network strategy, the implementation of the “Internet +” action plan, the development of the sharing economy, the implementation of national big data strategy.

2.2.2. Dilemma: congestion charging vs. social welfare

Traffic congestion across developed cities is a serious problem that is very unlikely to be resolved by adding more road capacity. Following the shifting focus from the supply side to the demand side, congestion charging or road pricing as an efficient measure to improve urban mobility and reduce transport emissions through an adequate management of the available capacity (Zunder and Ibanez, 2004). By inducing road users to internalize congestion and other externalities, congestion charging, as a measure to relieve rush-hour traffic congestion given the obstacles increasingly encountered in expanding road capacity in urban areas, has been exercised in a number of places like Singapore, London, Norway, Stockholm, Hong Kong, five metropolitan areas in U.S. (Albalate and Bel, 2009). (Heyns and Schoeman(2006) reported the results of an empirical investigation in London and formulates initiatives in the form of a package approach aimed at alleviating the negative effects of congestion tolling. The Environment, Transport and Works Bureau of the Hong Kong Special Administrative Region Government announced on Oct. 26, 2005 that it is considering the feasibility of introducing electronic road pricing in Hong Kong (Hau and Li, 2005). Doherty et al. (2010) summarised the main results that were obtained by central London charging scheme with some reflections; Whilst nurturing public and political acceptance, based on surveys in Atlanta, Washington DC and NYC, Odioso and Smith (2008) revealed that respondents who were familiar with congestion charging, who trusted the reported benefits, or who often used transportation modes other than cars were more likely to express support. Sabounchi et al. (2014) assessed the impact of an area-based congestion pricing scheme in terms of its effectiveness on mitigating traffic congestion by using a system dynamics model. Unknown parameter values are calibrated basing on the data available from the area-based pricing scheme implemented in the London metropolitan area. The key features of their model are that individual behavior is a function of the level of congestion, the cost of driving, and the supply/capacity and demand associated with metro transit. Creutzig and He (2009) demonstrated that a road charge could not only address congestion but also has environmental benefits. The paper investigated the role of demand elasticity and demonstrates that joint demand and supply-side policies provide considerable synergies. However, gaining approval of pricing will require changing how motorists view the effect of pricing on them personally, namely pricing proposals need to be perceived as benefiting drivers individually and not simply society at large(Schaller 2010) by assessing the implications of NYC's experience for pursuing congestion pricing and mileage-based taxes in the United States. Engelson and Kristoffersson (2013) carried out the cost benefit analysis against the actual outcome of the Stockholm congestion charging scheme with mesoscopic dynamic models, namely METROPOLIS and SILVESTER.

Over the past three decades, the urban transportation system in Beijing has been through tremendous changes. Beijing has been transformed from a city dominated by non-motorized transportation to an almost car-saturated city. The retrospective examination of municipal transportation development helps to understand why some policy makers in Beijing encourage or gear their infrastructure system toward private automobiles (Liu and Guan, 2005). Creutzig and He (2009) analyzed different externalities of car transportation in Beijing and show that social costs induced by motorized transportation are equal to about 7.5-15.0% of Beijing's GDP. Cities should promote the environmental benefits of congestion charging improve public transit accessibility, and make a clear plan for revenue spending to increase public approval.(Odioso and Smith, 2008) For Beijing buses from 2007, passengers enjoy 60% off, students 80% off, by swiping the Beijing municipal traffic all-purpose card. As a result, the majority of trips just cost RMB ¥0.4 per person. In Oct. of the same year, metro transit for the entire network, except Airport Express, becomes RMB ¥2 per person for a single trip. Low travel fare induced great travel demand. From 2010 to 2013, the subsidies of Beijing public transport rose from RMB ¥13.53 billion to RMB ¥20.01 billion. From 2007 to 2013, operational revenues of Beijing Railway grew by 1.7 times, but the operation expenses of Beijing Mass Transit Railway Corporation and Beijing MTR Corporation Limited increased 4 times. To combat the ever-growing traffic gridlock, Beijing now has been working proactively on building a transit city(Song, 2013). Dec. 28th, 2014 the new transit fare system carried out in Beijing. Low emission zone and the issue of traffic congestion charge are currently under consideration.

3. Beijing Case Study: Spatial Differentiations of Traffic Environments in Various Areas

Yang et al.(2011) noted the traffic congestion differences among areas inside the city, which previous studies ignored and mostly took a city as a whole during the traffic comparison. In order to combat congestion, help businesses control costs and improve air quality, the city's diverse mixture of land uses, dense urban environment and vast transportation infrastructure requires a distinct set of rules and regulations to govern the operation of trucks and commercial vehicles. To understand and analysis for the dynamical properties of the whole structure of road traffic at macro-level, Zhang et al. (2011) construct the Variable-Structure Dynamic Network model and the Extended Variable-Structure Dynamic Network model for urban road traffic systems, basing on the Level-Of-Service and the traffic reachability. Here explores VBA crawler program within Microsoft Excel grabs average speed and traffic index issued by URL (Beijing Municipal Commission of Transport) every 15 minutes, and carries out preliminary data clean and visualization with program R. Figure 3 combines the micro-level time-varying characteristics into the macro-level topology, which illustrate that the structure of the urban road traffic network varies with time, such as seasonal change or school term, holiday break (like Spring festival or Qingming vacation), new freight regulation policy (2014/4/11), or special events traffic regulation, like Asia-Pacific Economic Cooperation leaders' informal meeting, college entrance examination, or extreme weather. To characterize urban road traffic networks, Figure 4 carry out the experiments with traffic data and topology data of the Beijing road traffic system, which represents the significant change of topological features of urban road traffic networks. Weekdays or working days with significant two humps, especially for the central area, like ehn, xc, dc. Weekends the peaks shift greater for them. Suburbs, like sjs, have totally different patterns.

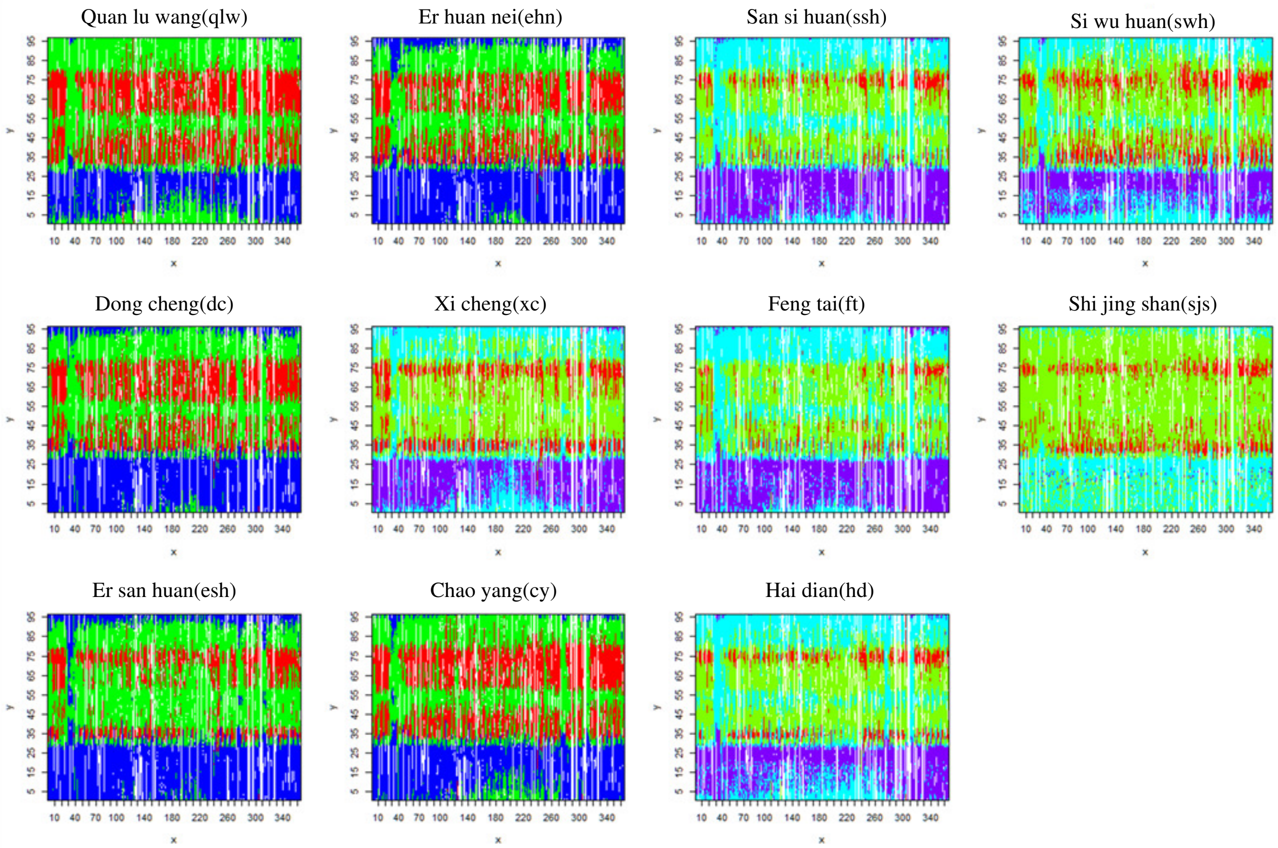


Figure 3: Daily traffic speed time sequence image for each area

4. Conclusion

The latest technologies support us to understand the traffic demand more and more accurate. For instance, Liu et al.(2014) simulate the impacts of 3D urban morphologies on urban transportation under the Digital Earth framework with a combination of factor analysis, spatial regression analysis and Euclidean allocation. Liu et al. (2014) indicates three general results. First, building capacity in the urban space has the most significant impact on traffic condition. Second, obvious urban space otherness, reflecting both use density characteristics and functional characteristics of urban space, mostly results in heavier traffic flow pressure. Third, a combination of morphology density and urban structure can reflect its contribution to the pressure of traffic flow directly. When those innovations combined with the internet and smart devices, which represents a new form of economy, namely, play as the factor of production. If the government department design proper regulation policies, and allow enterprises properly tapped big data, all these provides all kinds of possibilities of innovations in depth and enhance productivity in the real economy. This is also dedicated to the traditional transport industry, especially in the urban area.

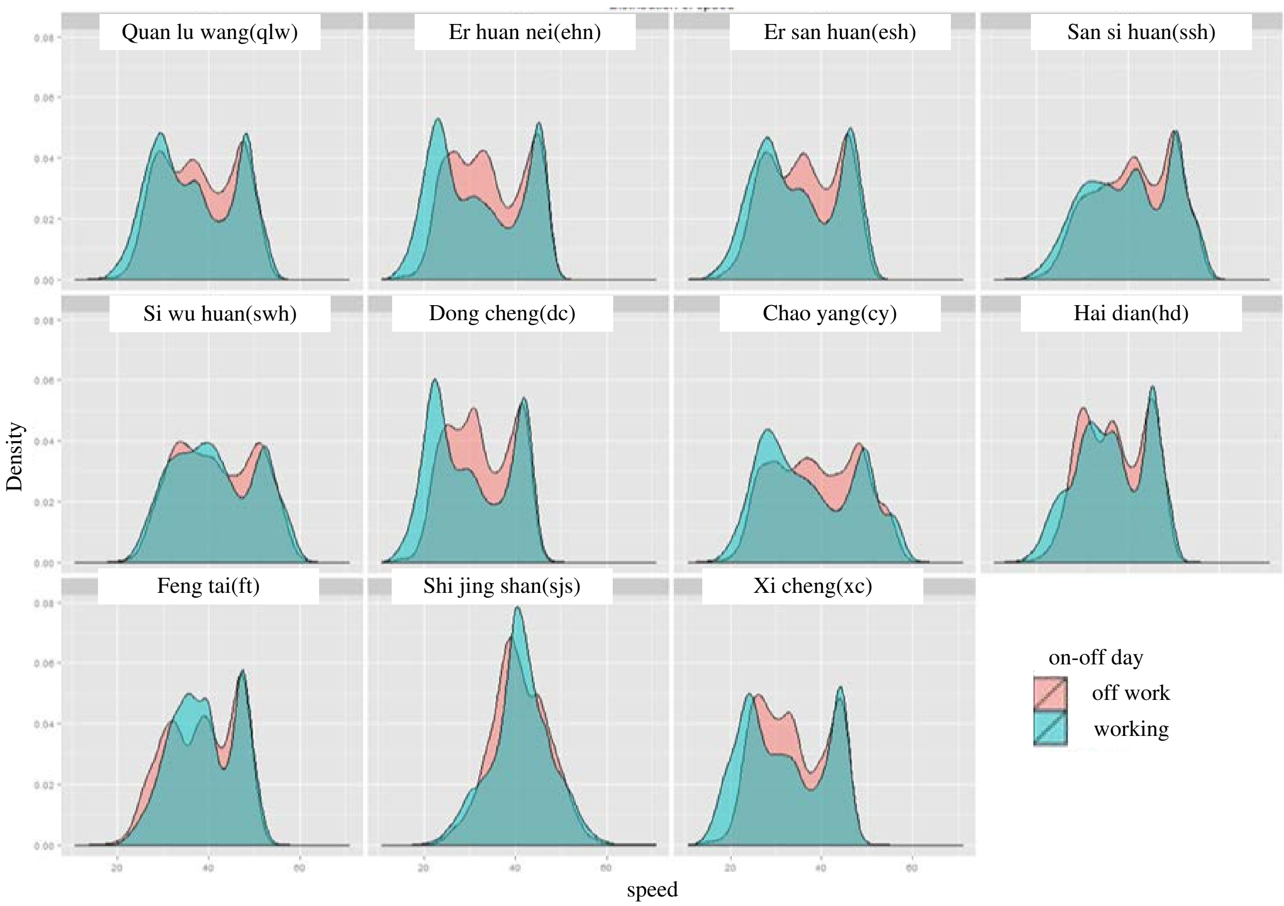


Figure 4: Distribution of speed for different area of weekday or weekend

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Carbon Footprint and Sulphur Emissions for International Wine Distribution using Alternative Routeing and Packaging Scenarios

Irina Harris[1], Vasco Sanchez Rodrigues[1], Stephen Pettit[1], Anthony Beresford[1] and Rodion Liashko[2]

[1]Logistics and Operations Management Section, Cardiff Business School, Cardiff University
[2]Yusen Logistics

[1]Corresponding Author

Abstract

There is a large body of research related to carbon footprint reduction in supply chains and logistics from a wide range of sectors where the decarbonisation of freight transport is frequently explored from a single mode perspective and at domestic/regional level (Jardine, 2009; Maersk, 2013; Wiesmann, 2010). The decarbonisation of global freight transport chains needs to take into account a range of alternative transport modes and routes in addition to the decisions related to the alternative product packaging at source or closer to the demand points. This paper intends to address these shortcomings and the research presents a "gate to gate" carbon footprint and Sulphur calculations methodology related to the distribution of wine from Australia and Italy to the UK.

The methodology adopted in this paper uses secondary data gathered from academic and industrial sources on the distribution of wine from source to market. These were used to evaluate the environmental impact of international wine transport to the UK from two sourcing areas: Italy and Australia. A number of options were evaluated to calculate the carbon footprint and Sulphur emissions of alternative route, mode and packaging combinations. The estimation of CO2e emissions incorporates three main elements - cargo mass, distance and transport mode whereas Sulphur emissions are derived from actual ship routing, engine power and travel times. The decision made related to the bottling of wine either at source or destination is also integrated into the model. The key findings are: there are major differences between the environmental footprint of different routing and packaging scenarios, the international shipping leg almost always has a much larger footprint than inland transport within the UK except in the hypothetical case of the rail scenario using flexitank (Italy). With reference to sulphur, the lowest cost scenario among the sea maximising options is also the lowest value for sulphur emissions and the general pattern is that there seems to be a linear relationship between costs and emissions for European wine shipments. However, the sea maximising scenario (scenario 2) for Australian wine shipments to UK appears to have higher Sulphur impact than alternative scenarios.

Keywords: international freight transport, wine port/node/route selection, CO2e reduction, sulphur emissions

1. Introduction

As Christopher (2011) states, global supply chains, which cover long distances, can be very carbon-intensive. This notion can be directly applied to the global nature of wine sourcing, since the absolute greenhouse effect of wine consumption is roughly estimated at around 0.4% of all UK CO2e emissions and about 0.3% of annual global CO2e emissions (Garnett, 2007). It has been estimated that each bottle of wine produced is responsible for 1.6kg of CO2 where significant contributions are related to agricultural machines (9.3%) and products transportation (8.2%) (Ardente et al., 2006). At the same time, the distribution and post-production logistics within wine supply chains are carbon intensive and can be the source of up to 50% of the total GHG emissions from the industry (Cholette and Venkat, 2009; Point et al., 2012). Therefore, improving the understanding of the environmental impact in the wine industry's in general and its carbon footprint in particular are important targets for further development of wine industry within the concept of sustainable production and consumption.

Recent research on carbon mitigation in freight transport has focused on the reduction of CO2e emissions in separate modes of transport. For example, the carbon mitigation of maritime legs of freight transport was investigated by Qi and Song (2012) and Chen et al. (2014). However, the literature on port selection in international supply chains does not seem to incorporate other logistics operations in the estimation of CO2e emissions of supply chains. One key aspect, which is not sufficiently well researched in literature, is how changes in packaging operations can bring efficiency improvements to freight transport movements by increasing the freight weight carried in transport movements from origin to destination. Another factor, which should be included in the assessment of how supply chains can reduce their carbon intensity, is inventory handling and packaging. As Murphy and Poist (2003) found, packaging and warehousing improvements initiatives can bring significant reductions in the overall carbon footprint of supply chains.

The objectives of this study, therefore, are: 1) to model the carbon footprint and Sulphur emissions of the respective wine supply chains, and 2) to present a series of scenarios with alternative combinations of modes and nodes for movements from two geographically distinct areas – Europe and Australia – to the UK. The underlying reasons for selecting these two source regions are that one is a traditional wine production region, whereas the other is new world. A second reason is that wine sourced from continental Europe is moved over relatively short distances, whereas Australian wine, as an exemplar of new world sourcing involves much longer supply chains. Thirdly, the structure of the respective chains is different, with European wine often being bottled close to source, while Australian wine is commonly transported in bulk and bottled close to market. For Europe, the exemplar country used is Italy as it is produces significant quantities of wine for export and it offers a diverse mix of potential routeings and methods of carriage, including both land only, and land –sea combinations. Specific data for volumes moved along the respective channels are not known and are commercially confidential, so this paper uses aggregated data and applies a cost minimisation model to produce best estimates of flows along the respective routes.

Australian and Italian wine imports represent 24.3% and 17.2% of the total volume of wine imported to the UK, according to recent statistics published by the UK Wine and Spirits Trade Association – WSTA (2014). Furthermore, in the case of Italy-UK distribution, there is a wide range of options available for freight transport movement, including road, rail or sea, or multimodal combinations, for example, cargo transported by train through the channel tunnel, or by container ship via Gibraltar and by road and ferry via Calais. However, most of the cargo moved within the UK is moved by road, which represents 89% of the total modal split in the freight transport market according to Eurostat (2012). The very large mode split road justifies the core practical purpose of the paper, which is to show other more carbon efficient ways of transporting imports from UK ports to destinations.

2. Literature

In order to better understand the environmental footprint created by the wine distribution from Europe and Australia, reference is made to the body of literature on node, mode and route selection in international freight transport which has grown substantially in recent years (see, for example, Jonkeren at al., 2007; Beresford et al., 2009; Nieuwenhuis, 2012). In addition, there is now a large and growing literature on carbon efficiency and carbon footprinting; here, the papers most applicable to long-distance shipping, transport and distribution are reviewed. Much of the research on supply chain structures relates to the coordination of the supply chain and the distribution of economic value among supply chain partners (see, for example, Leslie and Riemer, 1999; Oro and Pritchard, 2011; Alvarez-San Jaime et al., 2013). Ports are important nodes in international freight transport networks, but other decisions (e.g. packaging, container handling) can be vital to enhancement of the supply chain performance. International freight transport literature mainly concentrates on port choice where a significant body of research focuses on economic aspects (Suykens and Van de Voorde, 1998; Tongzon, 2001; Malchow and Kanafani, 2004; Gonzalez and Trujillo, 2008; Tongzon, 2009; Steven and Corsi, 2012). Leachman (2008) and Tongzon (2009) concentrate on inland freight transport management as a port choice factor whereas Steven and Corsi (2012) examine port selection in the context of US logistics.

A more contemporary aspect of improving the performance of global maritime-based supply chains is carbon efficiency improvement. CO2e emissions reduction can be achieved by decarbonizing each of the supply chain elements, which include supply chain processes such as production, inventory handling, freight transport and packaging. Early studies on the transport mode selection and route choice (e.g. Hayuth, 1986; McKinnon, 1989) have been updated and refined by, for example, Beresford (1999), Jonkeren et al. (2011), Sanchez Rodrigues et al. (2014) and Sanchez Rodrigues et al. (2015). These papers, respectively, examine European transport costs taking a multimodal approach, model the modal split effects of climate change with particular emphasis on the competitive position of waterway transport, and superimpose a carbon footprint algorithm on international supply chains, again in a European context. Sanchez Rodrigues et al. (2014; 2015) examined the relationship between cost/CO2e efficiency and supply chain structures in relation to international container flows with the focus on port selection as an enabler of carbon efficiency improvements. Another study with emphasis on both multimodal transport costs and on the carbon footprint of alternative automotive production locations was carried out by Nieuwenhuis et al. (2012). The alternative locations considered were Korea, and the United States, where Korea has a lower production cost alternative and the United States is a close-to-market option. In all cases it is clearly demonstrated that for long supply chains, transport solutions are invariably multimodal and complex and they operate within a range of physical, organisational and geo-political constraints. It is widely acknowledged that the further cargo is transported the more likely it is to be economic to use a transport method other than road haulage. This principle is clearly demonstrated by, for example, Jonkeren et al. (2011) who show that, at least in theory, short inland freight movements should be performed by road, medium hauls should be by rail, and longer inland transport movements performed most cheaply by inlands waterway, provided that all three modes are available. Importantly, although the longer haul distances would appear to be most attractive for multimodal, road – rail or road – rail – waterway solutions, freight volumes sharing a common origin and common destination reduce as transport distances increase thus mitigating against modes other than road haulage for long distance deliveries (Beresford, 1999). It is also the case that the longer the transport distance within Europe, for example, the more likely it is that interoperability barriers are encountered (European Commission, 2014).

Among their business strategies, wine companies make improvements related to the quality of their product and serving the customers in the best way possible to gain competitive advantage. However their perspective on sustainability efforts remains unclear, diminishing potential business improvements (Soosay et al., 2012). Moreover, occasional controversies in emissions calculations and consumer surveys can be observed which is detrimental to developing a low pollution, sustainable industry (Fearne et al., 2009; Amienyo et al., 2014). Rugani et al. (2013) indicate the necessity for a holistic and integrated approach towards environmental performance in the wine industry avoiding an over-reliance on carbon footprint calculations. However, it should be noted that the distribution phase of wine is largely independent from grape farming and wine vinification (Cholette and Venkat, 2009). Moreover, logistics within the wine supply chain includes multiple phases of storage and transportation by several modes of transport prior to reaching the final consumer. This means that carbon emissions from wine distribution need to be evaluated in their own right. Despite the plethora of LCA (life-cycle analysis) studies within the wine industry only a few focus on logistics provision within the supply chain even though improvements within the transport and storage of wine supply chain can lead to substantial carbon reductions irrespective of the wine production phase (Cholette and Venkat, 2009). Indeed, it can be argued that logistics services within the wine industry should be a primary focus. According to the research, even though recent wine LCA highlights a wide selection of environmental issues, it is the carbon footprint that makes the largest impact in logistics provision and can therefore be used for mitigation strategies. It is especially valid when a large spread of results concerning carbon footprint of the distribution phase is observed in different LCA research based on location and the length of the supply chain (Colman and Päster, 2009; Daniel and Susan, 2009; Barry, 2011).

3. Wine Production

3.1.1. Wine Production in Italy

According to statistics estimated by Italian Wine Central (2015), Italy produces a wide variety of wines and is the world's largest wine producer by volume with production totaling around 40 to 45 million hecto-litres per annum. Grapesare grown in almost every region of the country with more than one million vineyards under cultivation. Italy has twenty wine regions corresponding to the twenty administrative regions. Wines produced within regions carry specific designations. Vini IGP (Protected Geographical Indication) is traditionally implemented in Italy as IGT - Typical Geographical Indication) and follows a series of regulations regarding authorised varieties, viticultural and vinification practices. In 2014 there were 118 IGPs/IGTs. A higher level of designation is Vini DOP (Protected Designation of Origin) which includes two sub-categories; Vini DOC (Controlled Designation of Origin) and Vini DOCG (Controlled and Guaranteed Designation of Origin) which generally come from smaller regions, within a certain IGP territory. In 2014 there were a total of 405 DOPs comprised of 332 DOCs and 73 DOCGs. Of the twenty regions, the northern regions of Emilia-Romagna, Friuli-Venezia Giulia, Liguria, Lombardy, Piedmont, Tuscany, Trentino-Alto Adige, Valle d'Aosta and Veneto, and account for around 56% of production. Key cities in these regions are Modena (Emilia-Romagna), Udine (Friuli-Venezia Giulia), Genoa (Liguria), Milan (Lombardy), Turin (Piedmont), Florence (Tuscany), Bolzano (Trentino-Alto Adige), Aosta (Valle d'Aosta), Treviso (Veneto) and which are used as the exemplar cities for production. All of these are substantial road distances from the UK, varying from 1060 km to Calais from Turin to 1430 km from Florence; onward haulage to the market within the UK will typically add another 100-700 Km, depending on the location of the local distributor.

3.1.2. Wine Production in Australia

According to an Australian Bureau of Statistics (2012) report on Australian wine production, Australia is the world's fourth largest exporter of wine, producing around 750 million litres a year for the international export market. For wine distribution from Australia, it is first necessary to understand where the principal wine production areas are. Although wine is produced in every state, Australia's wine regions are mainly in the southern, cooler parts of the country. Since the 1960s, Australia has used an appellation system known as the Australian Geographical Indication (AGI or geographical indication) which distinguishes the geographic origins of the grape a requirement being that 85% of the grapes must be from the region designated on the label. In the late 1990s, more definitive boundaries were established that divided Australia up into Geographic Indications known as zones, regions and sub regions. A significant proportion of wine is produced in New South Wales which has eight large GI zones, which also includes grapes grown in Victoria, Tasmania and parts of Queensland and South Australia.

An Australian Bureau of Statistics (2012) report discusses the key regions which account for around 60% of Australian wine production are the 'Lower Murray', 'Big Rivers' and 'Murray Darling Swan Hill' regions. The Big Rivers region includes the sub-regions of Perricoota, Riverina plus Murray Darling and Swan Hill which are shared with the state of Victoria. The Big Rivers Zone is the largest wine producing area in New South Wales and Australia's second most prolific wine producing region. The major wine producing centre is located around the Riverina area and the city of Griffith where the major crush facilities are located. Griffith is thus used as the indicator city for the source of production for the Big Rivers region. The Murray Darling Swan Hill regions account for approximately 24% of Australian grape production and are centered on Swan Hill, which is used as indicator city for the source of production. In South Australia a fourth geographical indication known as a super zone is used which consists of a group of adjoining zones. The Adelaide Super Zone consists of the Barossa, Fleurieu and Mount Lofty Ranges zones. Other zones are the Far North zone, Limestone Coast zone, Peninsulas zone and Lower Murray zone. The Lower Murray zone is located to the east of the Adelaide super zone and is bordered by the Limestone Coast zone to the south, the Far North zone to the north and by Victoria to the east. It includes the Riverland wine region where a large percentage of Australia's bulk and box wines are produced. The indicator city used for production in this zone is Renmark.

4. Research Methodology

An Excel based model (cost minimisation) was developed to model all scenarios discussed in this section. The input data used in the model are demand, source/bottling plant/destination locations, multimodal cost structures, environmental factors, transport mode combinations, packaging forms (bottles/flexitanks) and port locations of exit from Italy and Australia and entry to UK. The UK ports used in the study are the main UK ports of entry for wine imports. These ports are the Port of Felixstowe, Bristol Avonmouth Port, Teesport and Port of Liverpool. A different combination of ports is used for different scenarios depending on the objective of each scenario. In addition, four UK bottling plants that are currently used by UK grocery retailers are included in the study. These bottling plants are located in Avonmouth (Accolade Wine, 2015), Corby (The Chapel Down Winery, 2015), Stanley (Green Croft Company, 2015) and Runcorn (Lakeland, 2015).

There are many different containers can be used for transportation, with various characteristics and purposes. However this research is based on a container with a standard size and type: 20ft reefer unit. Such standardisation made it possible to utilize an intermodal approach towards the wine transportation, where the wine is loaded in containers and transported from a winery to a distribution centre without being unstuffed. Two different types of packaging are used: wine bottles and flexitank. In this case wine bottles are first packed in boxes and then stacked onto pallets, while bulk wine is either shipped in steel T1 ISO standard tank containers (very rarely) or Flexitanks that are fitted inside ordinary dry containers (British Glass, 2008). Depending on the container size and wine allotment stowage factor the amount of wine that can be transported may be restricted either by the container internal dimensions or by the shipment's weight.

4.1. Wine consumption

Table 1 shows the estimated quantities and percentages of wine consumption in the UK by region and sub-region reference city. The table illustrates large variations related to the wine consumption among different sub-regions in the UK. For example, London accounts for over one quarter of total UK wine consumption, where the main driver for high consumption is high population rather than the consumption rate. A number of sources (ONS, 2011; ONS, 2012) are used to derive the percentage of wine consumed by each reference city in UK. Data related to the UK adult population, the average number of alcohol units consumed by UK adult, the total number of alcohol units (8 units per 750ml bottle) are used in calculations related to each city.

Table 1: Wine consumed in thousands of 9 litre consignments per UK reference city (ONS, 2011; ONS, 2012)

Region	Population (000's)	Adult population (%)	Adult population (000's)	Units of wine per week per avg. adult	Bottles of wine per week (000's)	9l per week (000's)	Wine consumed per region (%)	Sub-region (reference city)	Wine consumed per sub region (%)
Inner & Greater London	7,612	82	6,242	16.1	12,562	113,054	12.86	London	28.07
South East-East Anglia	8,380	82	6,872	17.3	14,860	133,739	15.21		
South West & Wales	5,209	83	4,324	16.9	9,134	82,203	9.35	Exeter	4.67
								Swansea	4.67
East & West Midlands	10,624	82	8,712	17.7	19,275	173,471	19.73	Derby	19.73
North East	2,575	82	2,112	19.0	5,015	45,133	5.12	Newcastle	5.13
North West	6,876	82	5,638	21.6	15,223	137,005	15.58	Manchester	7.79
								Liverpool	7.79
Yorkshire & Humberside	5,213	82	4,275	20.6	11,008	99,071	11.27	Leeds	5.63
								Sheffield	5.63
Scotland	5,328	84	4,475	19.0	10,629	95,657	10.88	Glasgow	5.44
								Edinburgh	5.44

4.2. Costs and CO2e Emissions

Wine, when bottled, is a heavy cargo, both because of its density *per se*, and because of the weight of the glass. As a result, transport of wine by road has traditionally been weight limited rather than volume constrained with the result that containers used for wine transport are almost invariably fully laden in kilogramme terms, although the containers are not full volumetrically. The consequence is that wine transport in bottled form has a substantial cost and carbon footprint whichever mode or modal combination is chosen. Table 2 presents the carbon coefficients expressed as carbon emission factors for all the main freight transport modes (CCWG, 2012). The table also shows the carbon coefficient or emission factors attributable to container handling (Geerlings and van Duin, 2011).

Table 2: CO_{2e} emissions coefficients (CCWG, 2012)

Transport / Handling	Emission Factor (kg CO_{2e}/T-km)
Road (Heavy or Articulated Truck)	0.1150
Train	0.0264
Sea (Ship: Asia-North Europe Trade Line)	0.0070
Sea (Ship: Intra-Europe Trade Line)	0.0130
Barge	0.0310
Container handling	0.0002 (kg CO_{2e} per tonne)

Table 3 presents the figures related to the cost coefficients in £ per tonne-km for the three freight transport modes used in the study and the cost coefficient of the handling stage of the distribution of containers (Sanchez-Rodrigues et al., 2014;Sanchez-Rodrigues et al., 2015; Eurotunnel, 2015; private communication).

Table 3: Costs related to transport and handling of containers

Transport Method	£ per T-km	Handling Costs	£ per tonne
Road	0.15	Ship to road/Train to road	9.09
Rail	0.01	Ship to train/Ship to Barge	13.64
Rail (Channel Tunnel)	0.37		
Ship (Asia-North Europe Trade Line)	0.02		
Ship (Intra-Europe Trade Line)	0.03		
Water (Barge)	0.04		

It is notable that rail, ship and barge transport costs per tonne-km are all of the similar order but road transport, with high unit operating costs, and the Channel tunnel, with very high fixed costs, are respectively out of line with other transport modes in terms of cost per tonne-km. Channel tunnel cost calculations were carried out based on average vehicle flows, typical working conditions and shoulder season pricing. Intermodal handling costs vary somewhat by method, but variations are not great. In this paper, it is assumed that handling costs per tonne are held at £9.09 (ship to road, train to road) and at £13.64 (ship to train/ ship to barge) for convenience. These were calculated based on 11tonne average load per container. It is recognised that, in reality, costs can vary substantially from terminal to terminal and from port to port; such variations can be captured in future research.

4.3. Sulphur Emissions

An additional important pollutant derived from sea transport is that of sulphur. There have been various estimates of the amount of sulphur produced through the combustion of heavy fuel oil used in ocean transport. Agrawal et al. (2010) estimate that the emission factor for sulphur dioxide is 11.53g per kilowatt hour. Similarly, the United States Environmental Protection Agency [EPA] (2007) suggests that sulphur emissions are 11.29g per kilowatt hour for gas phase and 0.35 g per kilowatt hour for the particulate phase of fuel burning. In order to convert these emission factors, the engine sizes for ships using the export routes were ascertained, shown in Appendix A. The grammes per kilowatt hour emission figure was then converted to total kg of sulphur per voyage and allocated to the number of containers on the relevant vessel. The kg of sulphur per TEU–km then was used to calculate the emissions per tonne - km, where an average of 11 tonnes of wine cargo per container was assumed.

4.4. Description of the scenarios

Two wine sourcing countries, which import significant volume of wine to the UK, are included in the study, namely Australia and Italy. The selection of these two sourcing countries can firstly be justified because Australia and Italy are the first and third ranked countries that import significant volumes of wine to the UK. Australian wine represents 24.3% of the total wine imported by the UK while Italian wine represents 17.2% of the total, according to recent statistics published by the Wine and Spirits Trade Association - WSTA (2014). In addition, Italian annual wine import volume is very close in volume to French wine, which represents

17.2%. of imports. However, the reason why Italian wine is selected for the modelling over French wine is because the distribution from Italy to the UK offers a wider range of scenarios than France-to-UK distribution.

4.4.1. *Case 1: Distribution of Italian wine to the UK*

Table 4 details the volumes of wine produced in each region in the north of Italy and the proportion the Italian wine producers ship to the UK. All data was sourced from Italian Wine Central (2015). The European ports used in the study were La Spezia, Port of Le Havre and Port of Rotterdam. It is assumed that bottling of the wine took place at different bottling plants, depending on the scenario (refer to the Table 5). In some scenarios, the bottling has been done at one location, in others, bottling is undertaken at several locations close to the destination points or close to the port of entry. The purpose of the scenarios is to calculate the cost/CO2e/ sulphur impacts of routeing variations from origins, via alternative ports and bottling plants to destinations using alternative packaging forms.

Table 4: Exports of Italian wine to the UK by source region and reference city (Italian Wine Central, 2015)

Region	Reference City	Total production (9 litre cases x 1 mln.)	Volume exported to the UK (9 litre cases x 1 mln)	% allocation to regions of UK demand
Emilia-Romagna	Modena	75.0	33.5	27.10
Friuli-Venezia Giulia	Udine	12.0		4.34
0.5	Genoa			0.18
Lombardy	Milan	14.0		5.06
Piedmont	Turin	29.0		10.48
Tuscany	Florence	30.0		10.84
Trentino-Alto Adige	Bolzano	16.0		5.78
Valle d'Aosta	Aosta	0.2		0.08
Veneto	Treviso	100.0		36.14
Total production in north of Italy		276.7		
Other regions		216.6		
Total		493.3		

Table 5: Description of scenarios for Italy - UK wine distribution

Scenario	Main Transport Mode	Packaging	EU/UK points of exit/entry	Route
1A	Road	Bottles	Channel Tunnel	Road (Supplier's Vineyard - Channel Tunnel) - train (Channel Tunnel) - road (Channel Tunnel - Destinations)
1B (h)		Flexitank	Channel Tunnel	Bottling Plant locations are nearest to Destinations - different demand proportions (depends on region) allocated to facilities: road (Supplier's Vineyard - Channel Tunnel) - train (Channel Tunnel) - road (Channel Tunnel - Bottling Plants (Avonmouth, Corby, Stanley, Runcorn) - road (Bottling Plants - Destinations)
2A	Rail	Bottles	Train (Milan, Hams Hall, Glasgow)	Different Rail Terminals for different Destinations: road (Supplier's Vineyard - Milan) - rail (Milan – Hams Hall - Glasgow) - road (Rail Terminal - Destinations)
2B		Bottles	Train (Milan, London, Hams Hall, Manchester, Glasgow)	Different Rail Terminals for different Destinations: road (Suppliers Vineyard - Milan) - rail (Milan - London - Hams Hall - Manchester -Glasgow) - road (Rail Terminal - Destinations)
2C (h)		Flexitank	Train (Milan, London, Hams	Different Rail Terminals for different Bottling Plant locations: road (Supplier's Vineyard - Milan) - rail

			Hall, Manchester, Glasgow)	(Milan - London - Hams Hall - Manchester - Glasgow) - road (Rail Terminal - Bottling plants) - road (Bottling Plants - Destinations)
3A (h)		Flexitank	EU : Port of Le Havre UK : Bristol Avonmouth Port	Road (Supplier's Vineyard - Port of Le Havre) - sea (Port of Le Havre– Bristol Avonmouth Port) - road (Bristol Avonmouth Port - Avonmouth Plant) – road (Avonmouth Plant – Dest.)
3B		Bottles	EU: La Spezia ; UK: Port of Felixstowe	Road (Supplier's Vineyard - La Spezia Port)- sea (La Spezia Port – Port of Felixstowe - road (Port of Felixstowe – Dest.)
3C(h)	Sea/Water	Flexitank	EU: La Spezia ; Port of Le Havre ; Port of Rotterdam UK: Bristol Avonmouth Port; Port of Liverpool; Teesport; Port of Felixstowe;	road (Supplier's Vineyard- La Spezia Port), then different demand proportions (depends on region) allocated to routes: 1) sea (La Spezia Port - Port of Le Havre) - sea (Port of Le Havre - Bristol Avonmouth Port) - road (Bristol Avonmouth Port - Avonmouth Plant) - road (Avonmouth Plant – Dest.) 2) sea (La Spezia Port - Port of Le Havre) - sea (Port of Le Havre - Port of Liverpool) - barge (Port of Liverpool - Runcorn Plant) - road (Runcorn Plant - Destinations) 3) sea (La Spezia Port – Port of Felixstowe) - road (Port of Felixstowe - Corby Plant) -road (Corby Plant - Destinations) 4) sea (La Spezia Port - Port of Rotterdam) - sea (Port of Rotterdam - Teesport) - road (Teesport - Stanley plant) - road (Stanley Plant - Destinations)
3D		Bottles	same as 3C	same as 3C, except there is no movement to the bottling plants

(h) hypothetical scenario

Table 5presents the key elements of the scenarios used for Italy-UK wine distribution. In order to transport wine from the selected regions (Emilia-Romagna, Friuli-Venezia Giulia, Liguria, Lombardy, Piedmont, Tuscany, Trentino-Alto Adige, Valle d'Aosta and Veneto), a number of alternative options are available. Three main scenarios were modelled to minimise the distances travelled by road, rail or water respectively. Scenarios 1, 2 and 3 include sub-scenarios with the purpose to include the bottling plants locations where alternative packaging (flexitank) is used. Traditionally, Italian wine is bottled in Italy, nevertheless the paper explores a "hypothetical" scenarios where the wine is shipped in flexitanks to UK bottling plants, and then transported to destinations. Sub-scenarios 2A and 2B also include variations related to the number of rail terminals. Similarly, sub-scenarios 3A and 3B introduce variations in the number of port terminals.

The principal option is to transport the wine by road to Calais, then to use the Channel Tunnel shuttle and then use the road to move the wine to the bottling facility or demand points. Alternative options are to move the wine to a railhead in Milan, then to UK terminal from where road transport is used. The third alternative is to move the wine by road to the port of La Spezia or Port of Le Havre where sea transport can then be used to ship the wine to either Port of Felixstowe, Port of Le Havre or Roterdam. In the former case road transport is then used to move the wine to the destination/ or bottling plants, in the latter further sea transport is required to reach an appropriate UK port. In this case, road transport is then used to complete the journey to the bottling plant and then to the destination.

4.4.2. *Case* 2: Distribution of Australian wine to the UK

Table 6shows the volumes and percentages of wine grapes produced in the main Australian wine regions. The total global exports of Australian wine derived from this production volume for 2012 was 1.236 billion litres (Australian Bureau of Statistics, 2012) which converts to 137.4 million 9 litre cases. Of this 24.3 million 9 litre cases were exported to the UK via the Australian export ports e.g. Port Botany, Sydney which is used in this study. The UK market equates to around 18% of Australian wine exports.

Table 6: Australian wine production by major regions (Department of Agriculture Fisheries and Forestry, 2012)

Region	Reference Point	Total Wine grape production Kilotonnes	%
Murray Darling Swan Hill	Swan Hill	381	39.0
Lower Murray	Renmark	339	34.7
Big Rivers	Griffith	258	26.3
Total production in regions included		978	
Other regions		629	

Table 7 outlines the key elements of the scenarios used for the Australian case study. Three main scenarios minimise the distances travelled by road, rail and water respectively. Also, scenarios 1 maximises the use of the road transport; whereas Scenarios 2 and 3 maximise sea and rail transport respectively where four bottling plants located closer to the destinations or consumption points.

In order to export wine from these regions, the closest logical port is Port Botany, Sydney. Movement of wine to the port is by road, as rail transport is not available, and thus considerable road transport distances are required. The road distances to Port Botany from the exemplar cities are Swan Hill - 920 km, Renmark – 1150km and Griffith – 570 km. The wine is then transferred to the ship where it is moved by scheduled liner container services to Europe. Here two options are explored. The first option is direct carriage to Felixstowe and subsequent road transport to the bottling facility at Avonmouth. In the second option, the proportion of demand is transshipment to Port of Le Havre and further sea transport to Bristol Avonmouth Port or Port of Liverpool; other routes include from Port of Felixstowe to Corby plant and Port of Rotterdam to Teesport and then to Stanley bottling plant. In the goods movement to the Port of Liverpool, further water transport by barge is required to move the wine to the bottling facility at Runcorn. The rail scenario (Scenario 3) uses Port of Tilbury as an entry port to UK, then the wine is moved by rail trough Tilbury rail terminal to different bottling plants.

Table 7: Description of scenarios for Australia - UK wine distribution (flexitank)

Scenario	Main Transport Mode	International/ UK points of exit/entry	Route
1A	Road	International: Port Botany UK: Port of Felixstowe	Bottling Plant locations are nearest to Destinations - different demand proportions (depends on region) allocated to Facilities: road (Supplier's Vineyard -Port Botany) - sea (Port Botany- Port of Felixstowe) - road (Port of Felixstowe - Bottling Plants (Avonmouth, Corby, Stanley, Runcorn) (relevant proportion of demand)) - road (Bottling Plants - Destinations)
1B		International: Port Botany UK: Port of Felixstowe	Bottling Plant location is closest to UK port of entry: road (Supplier's Vineyard -Port Botany) - sea (Port Botany- Port of Felixstowe) - road (Port of Felixstowe - Corby Plant) - road (Corby Plant - Destinations)
2	Sea	International: Port Botany Port of Le Havre Port of Rotterdam UK: Bristol Avonmouth Port; Port of Liverpool; Teesport; Port of Felixstowe;	Bottling Plant locations are nearest to Destinations - different demand proportions (depends on region) allocated to Facilities: road (Supplier'sVineyard–Port Botany) then different demand proportions (depends on region) allocated to following routes: 1) sea (Port Botany- Port of Le Havre) - sea (Port of Le Havre -Bristol Avonmouth Port) - road (Bristol Avonmouth Port- Avonmouth Plant) - road (Avonmouth Plant - Destinations) 2) sea (Port Botany- Port of Le Havre) - sea (Port of Le Havre -Port of Liverpool) -barge (Port of Liverpool - Runcorn Plant) - road (Runcorn Plant - Destinations) 3) sea (Port Botany-Port of Felixstowe) - road (Port of Felixstowe-Corby Plant) -road (Corby Plant - Destinations) 4) sea (Port Botany- Port of Rotterdam) - sea (Port of Rotterdam–Teesport) - road (Teesport - Stanley plant) - road (Stanley plant - Destinations)

3	Rail	International: Port Botany UK: Tilbury	Different Rail Terminals for different Bottling Plant locations (closest to Destinations):road (Suppliers Vineyard - Port Botany) -sea (Port Botany- Port of Tilbury), then different demand proportions (depends on region) allocated to following routes: 1) rail (Tilbury Terminal -Daventry Terminal) - road (Daventry Terminal -Corby Plant) - road (Corby Plant-Destinations) 2) rail (Tilbury Terminal-Avonmouth Terminal) - road (Avonmouth Terminal- Avonmouth Plant) - road (Avonmouth Plant-Destinations) 3) rail (Tilbury Terminal - Manchester Terminal) - road (Manchester Terminal- Runcorn Plant) - road (Runch Plant -Destinations) 4) rail (Tilbury Terminal - Cleveland Terminal) - road (Cleveland Terminal- Stanley Plant) - road (Stanley Plant -Destinations)

In order to export wine from these regions, the closest logical port is Port Botany, Sydney. Movement of wine to the port is by road, as rail transport is not available, and thus considerable road transport distances are required. The road distances to Port Botany from the exemplar cities are Swan Hill - 920 km, Renmark – 1150km and Griffith – 570 km. The wine is then transferred to the ship where it is moved by scheduled liner container services to Europe. Here two options are explored. The first option is direct carriage to Felixstowe and subsequent road transport to the bottling facility at Corby (or to four different bottling plants). In the second option, the proportion of demand is transshipment to Port of Le Havre and further sea transport to Bristol Avonmouth Port or Port of Liverpool; other routes include from Port of Felixstowe to Corby plant and Port of Rotterdam to Teesport and then to Stanley bottling plant. In the goods movement to the Port of Liverpool, further water transport by barge is required to move the wine to the bottling facility at Runcorn. The rail scenario (Scenario 3) uses Port of Tilbury as an entry port to UK, then the wine is moved by rail trough Tilbury rail terminal to different bottling plants.

5. Findings

5.1. Case 1: Distribution of Italian wine to the UK

As can be seen from Table 8, it is striking that, in terms of distribution and handling costs per bottle, the most expensive scenario is four times more costly than the cheapest route. Similarly, the carbon footprint of the most environmentally intrusive route is four times as great as the footprint of the route with the smallest environmental impact. Just as striking is the very strong positive relationship between the environmental footprint and economic costs of the nine scenarios. That is to say, the most expensive routes in commercial terms are road based (bottles, Scenario 1A) and scenario 3D, that is the sea maximizing scenario (bottles) where the cargo enters the UK through four different ports. Conversely, the cheapest options all involve substantial rail transport and the packaging is in both flexitank and bottle form. The most cost effective route (Scenario 2C) is a flexitank, to which we refer to as a hypothetical scenario because traditionally wine is shipped only in bottles across the European Union (including Italy) for regulatory reasons. It is noteworthy that Scenario 2C also carries the lowest emissions value. Although this is a hypothetical case, these findings suggest that use of flexitanks for wine transport within Europe could be both cheaper and environmentally less intrusive. On the other hand, Scenario 2B is also very low in costs and emissions and this scenario uses bottles during the transportation.

Table 8: Results, Italy - UK wine distribution

Scenario	£ per Bottle	kg CO_{2e} per Bottle	Sulphur (kg per Bottle)
Scenario 1A	0.37	0.26	-
Scenario 1B (h)	0.23	0.16	-
Scenario 2A	0.14	0.11	-
Scenario 2B	0.11	0.10	-
Scenario 2C (h)	0.08	0.07	-
Scenario 3A (h)	0.23	0.16	0.000260199
Scenario 3B	0.31	0.16	0.002292172
Scenario 3C (h)	0.32	0.18	0.002056422
Scenario 3D	0.43	0.29	0.004135012

(h) hypothetical scenario

With regard to sulphur (Table 8), the lowest cost scenario among sea maximizing options is also the lowest for sulphur emissions. Similarly, the highest cost/emission route produces highest sulphur output. The number of data points however (only four) restricts the value of this particular part of the research. Nonetheless, it is clear that the further the ships travel, carrying the wine in either in bottled or flexitank form, the larger the sulphur footprint and the more expensive the shipping, this reflects the fact that shipping costs and sulphur emissions increase roughly linearly with distance covered. Fuel usage is clearly is the distance related and emissions levels also reflect this usage.

Table 9: International flows, UK inland flows and handling components, Italy - UK wine distribution

Scenario	Cost (£)			CO_{2e} (kg CO_{2e})			Sulphur (kg)
	International flows	UK inland flows	Handling	International flows	UK inland flows	Handling	
Scenario 1A	119,316,545	30,509,021		81,900,630	22,644,856		-
Scenario 1B(h)	67,031,767	26,912,080		46,011,590	19,975,082		-
Scenario 2A	29,202,294	16,339,895	9,757,636	27,187,117	15,347,345	181	-
Scenario 2B	26,550,151	9,227,046	9,757,636	29,092,190	11,471,464	181	-
Scenario 2C(h)	14,903,838	11,989,728	5,481,818	16,318,739	11,488,260	101	-
Scenario 3A(h)	64,456,009	23,129,400	5,481,818	45,840,149	17,167,445	101	104,600
Scenario 3B	87,506,847	28,036,939	9,757,636	45,210,912	20,809,991	181	921,453
Scenario 3C(h)	97,177,925	14,722,796	15,297,218	60,029,561	10,927,607	283	826,682
Scenario 3D	134,450,170	11,405,490	26,534,346	107,851,911	8,465,551	491	1,662,275

(h) hypothetical scenario

From Table 9, it can be seen that, in almost all cases, the big majority of the transport costs is incurred in the international leg (transport and shipment of the wine from country of origin to the UK port) and the minority of costs are incurred between the UK port and the destinations. An exception is the route via train in the hypothetical scenario (Scenario 2C) where an international leg and UK leg are almost equal in terms of transport costs. This pattern is repeated in the case of CO2e, which broadly reflects the linear relationship between carbon emissions and transport distances. What is also notable is that the most expensive scenario in terms of its international leg cost is an order of magnitude more expensive than the lowest cost international leg (Scenario 3D vs Scenario 2C). For CO2e emissions, the pattern is repeated though the variations are less extreme. The variation in CO2e footprint for the UK inland leg is fairly conservative (compare Scenario 3D with Scenario 1A).

5.2. Case 2: Distribution of wine from Australia to the UK

Table 10 lists the cost per bottle and carbon footprint data for the four scenarios related to wine shipment from Australia to UK. There is very little difference between these scenarios where all wine was shipped in flexitanks, and where the overall geometry of the movements is very similar. Again, the train option provided the lowest figures in terms of costs and emissions, where a train from Tilbury travels to different bottling plants.

Table 10: Results, Australia-UK wine distribution

Scenario	£ per Bottle	kg CO_{2e} per Bottle	Sulphur (kg per Bottle)
Scenario 1A	0.50	0.25	0.0081755
Scenario 1B	0.51	0.25	0.0081755
Scenario 2	0.51	0.23	0.0124222
Scenario 3	0.48	0.22	0.0084408

Table 11 again illustrates that, amongst the scenarios, the international leg is virtually constant in terms of its cost and CO2e footprint. However, the UK inland leg, varies by roughly a factor of two for both cost and CO2e emissions between the lowest and highest costs/emissions. Both for cost and carbon emissions, the international leg is dominant. From a UK perspective, there also should be a focus on reducing the UK inland leg that will link to congestion reduction and commensurate improvements in carbon output. In terms of sulphur, it can be seen in Scenario 2, the level of sulphur emissions is higher compared to CO2e emissions, suggesting that there appears to be a trade-off between the two key pollutant types that needs to be investigated further in future research.

Table 11: International leg, UK inland leg and handling components, Australia-UK wine distribution

Scenario	Cost (£)			CO_{2e} (kg CO_{2e})			Sulphur (kg)
	International leg	UK inland leg	Handling	International leg	UK inland leg	Handling	
Scenario 1A	123,982,298	17,554,780	3,974,073	58,524,749	13,029,768	74	2,382,611
Scenario 1B	123,982,298	19,884,931	3,974,073	58,524,749	14,759,288	74	2,382,611
Scenario 2	126,530,052	10,673,368	11,089,798	59,643,188	7,922,026	205	3,620,238
Scenario 3	120,544,725	9,725,141	8,941,664	57,208,159	8,267,855	147	2,459,927

6. Conclusions

In this paper, as part of the analysis of the international wine distribution, a range of different scenarios we reevaluated where different transport modes, routes, packaging forms were used. The methodology related to the CO2e and sulphur emissions was discussed. Data from two wine trade routes, namely Australia – UK and Italy – UK, were gathered from shipment companies using real distances, ship services and engine configurations. From the analysis, it is shown that there are major differences between the environmental footprint of different routing and packaging scenarios. The international shipping leg in most of the cases has a much larger footprint (CO2e) than the inland transport legs within the UK except in the hypothetical case of the rail scenario using flexitank, where the deep sea shipping and the inland movement yield to similar impact. With reference to sulphur, the lowest cost scenario among the sea maximising options, also yields the lowest sulphur emissions value and the general pattern is that there appears to be a linear relationship between costs and emissions for European wine shipments though with considerable variation. The sea maximising scenario (scenario 2) for Australian wine shipments to UK appears to have higher Sulphur impact than alternative scenarios.

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Appendix A

Route	Ship	Containers	Engine kw	Days Sailing at 15 knots	Total kwh	Sulfur (total g, gas phase)	Sulfur (total g, part phase)	Total Sulfur (kg)	Sulfur (kg/teu)	Sulfur (kg teu/km)	Sulfur (kg tonne/km)
Route Sydney to Teesport											**0.00112915**
Sydney to Tanjung Pelepas	Safmarine Nomazwe	3,700	45,588	11	12,035,232	135,877,769	4,212,331	140,090.10	37.86	0.00501552	0.00045596
Tanjung Pelpas to Rotterdam	Munkebo Maersk	18,300	64,000	24	36,864,000	416,194,560	12,902,400	429,096.96	23.45	0.00146166	0.00013288
Rotterdam to Teesport	Gerda	373	3,825	1	91,800	1,036,422	32,130	1,068.55	2.86	0.00594347	0.00054032
Sydney to Tilbury	ANL Windarra	2,805	36,560	34	29,832,960	336,814,118	10,441,536	347,255.65	123.80	0.00547782	**0.00049798**
Route Sydney to Felixstowe											**0.00046455**
Sydney to Tanjung Pelepas	Maersk Virginia	4,824	43,070	11	11,370,480	128,372,719	3,979,668	132,352.39	27.44	0.00363442	0.00033040
Tanjung Pelpas to Felixstowe	Mary Maersk	18,270	64,000	24	36,864,000	416,194,560	12,902,400	429,096.96	23.49	0.00147565	0.00013415
Route Sydney to Le Havre											**0.00055696**
Sydney to Tannjung Pelepas	Maersk Virginia	4,824	43,070	11	11,370,480	128,372,719	3,979,668	132,352.39	27.44	0.00363442	0.00033040
Tanjung Pelepas to Le Havre	MSC Lawrence	12,400	72,240	24	41,610,240	469,779,610	14,563,584	484,343.19	39.06	0.00249218	0.00022656
Sydney to Liverpool											**0.00062001**
Sydney to Le Havre	CMA CGM Auckland	2,492	21,650	34	17,666,400	199,453,656	6,183,240	205,636.90	82.52	0.00365160	0.00033196
Le Havre to Liverpool	Pengalia	690	7,200	1	172,800	1,950,912	60,480	2,011.39	2.92	0.00316854	0.00028805
La Spezia to Felixstowe	MSC Samantha	5,711	64,351	6	9,266,544	104,619,282	3,243,290	107,862.57	18.89	0.00475379	**0.00043216**
La Spezia to Rotterdam											**0.00172119**
La Spezia to Felixstowe	MSC Samantha	5,711	64,351	6	9,266,544	104,619,282	3,243,290	107,862.57	18.89	0.00475379	0.00043216
Felixstowe to Rotterdam	MSC Samantha	5,711	64,351	1	1,544,424	17,436,547	540,548	17,977.10	3.15	0.01417929	0.00128903
La Spezia to Le Havre	MSC Samantha	5,711	64,351	6	9,266,544	104,619,282	3,243,290	107,862.57	18.89	0.00506349	0.00046032
Le Havre to Avonmouth	CMA CGM Victoria	280	3,825	1	91,800	1,036,422	32,130	1,068.55	3.82	0.00532253	0.00048387
Liverpool to Runcorn	Barge	366	3,825		11,475	129,553	4,016	133.57	0.36	0.00729885	0.00066353

Influence of Brand Reputation and Switching Barrier on Customer Loyalty for International Express Carriers

Shih-Liang Chao and Che-Feng Tsao

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

Abstract

The role of international express carriers is important in the international transportation industry because they can deliver cargo for customers timely and punctually, especially for high value cargoes. However, it is such a competitive market, it's worthy to identify the relationships among critical constructs that might influence customer satisfaction and loyalty. This research investigated the influence of brand reputation, service quality, switching barrier, customer satisfactory on customer loyalty for international express carriers. The population of our empirical study is the top 500 import and export firms of Taiwan. Sampling was conducted by distributing 420 questionnaires. The results were as follows: service quality has a significantly positive influence on customer satisfactory and customer satisfactory has a significantly positive influence on customer loyalty. Moreover, service quality has a significantly positive influence on customer loyalty. Beside, brand reputation has a significantly positive influence on customer satisfactory, customer loyalty and service quality. Finally, switch barrier has a significantly positive influence on customer loyalty.

Keywords: International express industry, switch barrier, customer loyalty, brand reputation

1. Introduction

Friedman (2005) indicated that the world is flat and views the world of globalization as a level playing field in terms of commerce, where all competitors have an equal opportunity. As times change, the way and scope of cargo circulation are totally different from the past. According to 2014-2015 Global Air Cargo Forecast Report, published by Boeing in 2014, global air cargo transportation will grow up 4.7% per year following twenty years, so development of international express market in foreseeable future is very optimistic. There are three main international express carriers (DHL), (UPS) and (FedEx) in Taiwan to form competitive market, under this condition, Customers are susceptible to competitor's low prices which will cause the loss of existing and potential customers. However, brand reputation is the most valuable intangible asset, and therefore it can let commodity and service to add to the value and facilitate the identification of a product easily. Furthermore, it can also provide a competitive advantage for the company to simplify and quicken client's decision of purchase. Beside, after customers purchase goods, it will generate their feeling of trust. As far as customers are concerned, brand reputation is related to quality. Once a brand is trusted, it will become a strong and competitive asset and have significant influence on customer's choice. Thus, carriers should consider the ways of increasing customer loyalty and establishing brand reputation in customer's mind. To the author's knowledge, there are few studies about reputation of international express carriers. Therefore, based on literature of service quality, brand reputation, switching barriers, customer satisfaction and customer loyalty, we established a research model composed of these constructs. The purpose of this research is to identify the determinants of customer satisfaction and loyalty for international express carriers in addition to the emphasis on service quality. The remainder of this paper is organized as follows: Section two reviews related literature related to international express carriers and the constructs, and then proposes our hypotheses. The methodology used in this study is presented in Section three. Section four conducts an empirical study by a questionnaire survey to validate the hypotheses. The conclusions and suggestions are summarized in the last section.

2. Literature Review

2.1 Characteristics of international express carrier

Lin (2003) pointed out that international express industry is integrated with pickup, delivery of distribution, custom clearance and air transportation on land, providing door to door shipment and rapid international cargo delivery service. Because the operational costs of international express industry are quite high including not only the main transportation vehicles such as cargo airplane, but as well advanced equipment and a great amount of labor costs. Therefore, these operational costs formed a high barrier for other competitors to be involved in the process, implying only few carriers are providing service in the market. The international express delivery service means a professional company which charges high freight fee to obligate its operator to ensure customer’s cargo can be delivered to an assigned address for a recipient located abroad via fast path. Nowadays, most industries are facing an extremely competitive modern business environment in the era of rapid changes, hence high efficiency logistics or carriers are needed to run their business. Because the international express carrier meets such a requirement, it is getting playing more important role.

The international express carrier originated in the end of 1960s, but having this kind of company engaging in delivery only within the US at the beginning. After the development and expansion over 30 years, the international express carriers have gradually extended their business scope from the US to the world. The international express carriers have already entered Taiwan’s market and made the international express industry in Taiwan bloomed rapidly having a great impact and influence on the emerging air cargo market.

2.2 Service quality

Han and Baek (2004) indicated the most common definition of service quality is the difference between customer’s expectation and cognitive service. Therefore, service quality is defined as how to offer better level of service to meet customer’s expectation. Parasuraman et al. (1988) used ten elements of service quality (tangibility, communication, access, competence, courtesy, credibility, reliability, responsiveness, security and understanding/knowing their customers) defined by Parasuraman et al. (1985) to analyze five constructs (tangibility, reliability, empathy, assurance and responsiveness) through factor analysis to measure these five constructs. In calculating SERVQUAL scale scores, the difference between customer’s expectation and cognitive element of real service can be measured. The five constructs of SERVQUAL scale has been applied in many studies to measure the quality of service, including this study. According to the above literature review, we can summarize that the service quality in international express industry is the difference between customer’s expectation and the cognitive element of real service.

2.3 Customer loyalty

Wong and Sohal (2003) pointed out that customer loyalty is generally described as a repurchasing of commodity or service while having a good attitude towards a company providing particular goods and/or services. Customer’s loyalty is a customer’s attachment to a brand, store, manufacturer, service provider or other entities based on favorable attitudes and behavioral responses such as repeat purchase (Baran, Galka & Strunk, 2008).As most shippers of international express are frequent users, a good long-term relationship with shippers is helpful to carriers to maintain a stable volume of shipment, and even attract more customers in order to increase profit. This study regards customer loyalty in international express industry as a confidence of a shipper who has used the service provided by an international express carrier. In addition, despite the freight increases, a shipper will still be willing to use the service and recommend it to others.

2.4 Customer satisfaction

Deng et al. (2010) thought that customer satisfaction reflects positive attitude after using the service provide by a certain carrier. As far as service provider is concerned, service satisfaction is an important basis for carriers because it can reflect the expectation about the product and service from customers. Kotler and Keller (2006) pointed out that customer satisfaction is the degree of someone’s feel about a product/service, which is made up of the customer’s cognitive of product and customer’s expectation about the product. If a product can’t meet expectation of customers, customers will be dissatisfied but if a product can exceed expectation of customers, customers will have high satisfaction and enjoyable experience. Liu et al. (2011) emphasized that customer satisfaction is the antecedent of customer loyalty, satisfaction can significantly influence on customer loyalty. Miller (1979) defined satisfaction as a gap between expected degree of feeling and actual cognitive performance. If expected degree of feeling is more than actual cognitive performance, it will produce positive customer satisfaction; on the contrary, if actual cognitive performance is more than expected degree of feeling, it will produce displease feeling. According to above literature review and considering the characteristics of international express industry, this study regard that customer satisfaction is the gap between customers' expectation before using the express service and the emotional reaction and attitude after using the express service.

2.5 Brand reputation

American Marketing Association (1960) indicated that brand is consist of name, term, sign, symbol and design in order to identify organization's product or service and be different from competitors. Chaudhuri (2002) regards brand reputation as the sum of past performance, basis of customer of trust and origin of establishing loyalty and trust. In addition, it can directly impact on brand sales, market share and relative price, so brand reputation is important to company to make huge value. Herbig and Milewicz (1997) thought that brand reputation is a valuable commodity, customer is willing to pay more to purchase it when facing commodity with higher brand reputation and it also enables company to increase profit as well. Punjaisri et al. (2007) stated that brand reputation is a constant evaluation for customer in mind for a long term. Thereby, this study regards brand reputation can make customer to identify a service or product easily and have higher value in customer's mind even it directly or indirectly influences the market share.

2.6 Switching barrier

Jones et al. (2000) claimed that intention of consumption may change because of degree of switching barrier. They conducted a research about how the switching barrier impacts on repurchase of intention of customers and thought switching barrier should include interpersonal relationships, switching costs and attractiveness of alternatives. Kim et al. (2004) stated that switching barrier means when customers change their current supplier, they will face inconvenience on economic and psychical of aspect. Jones et al. (2000) pointed out switching barrier is to probably encounter degree of difficulty or cost and influence on intention of behavioral purchase. Balabanis et al. (2006) conducted a research about bases of e-store loyalty, perceived switching barriers and satisfaction for students who surf the internet. They found companies should pay attention to the importance of switching barrier on customer retention process. After questionnaire data was analyzed, they obtained seven different switching barrier types: familiarity, convenience, parity, economic, speed, unawareness and emotion, in which familiarity is the most important among switching barriers. Based on above literature review, this study defined switching barrier as a facing level of barrier when customer uses an express service provided by other carrier rather than the current one.

2.7 Relationship among constructs and proposing hypothesis

The hypotheses in our study are proposed as follows: Shanka (2012) measured service quality of Ethiopian Banking Sector and found a positive correlation between service quality and customer satisfaction. Mutaz et al. (2012) also indicated that service quality can influence the degree of customer satisfaction and willingness to keep using the service. In other words, providing high level of service quality might has positive influence on entire customer satisfaction. Hence, this study proposes the following hypothesis:

H1: The service quality of an international express carrier has positively impact on customer satisfaction.
Bigne et al. (2008) conducted a research about experiential consumption and found that customer satisfaction and customer loyalty was correlated. Ganiyu et al. (2012) investigated that if customer satisfaction can be an indicator as a customer loyalty. The result of their study supported this point, meaning customer satisfaction have a strong relationship with customer loyalty. Akbar and Som (2011) also pointed out customer satisfaction has influence on customer loyalty. Therefore, this study proposes the following hypothesis:

H2: Customer satisfaction has positively impact on customer loyalty in the international express industry.

Kim and Park (2004) though service quality is the core of customer and increase on service quality can enhance customer loyalty. Therefore, this study proposes the following hypothesis:

H3: Service quality has positively impact on customer loyalty in the international express industry.
Fredericks and Slater (1998) found brand image will decide customer perceived value. Therefore, this study proposes the following hypothesis:

H4: Reputation of an international express carrier has positive impact on customer satisfaction.
Aaker and Keller (1990) thought that high reputation and good image of brand can enhance brand loyalty for customer and willingness to purchase. Thus, we propose the following hypothesis:

H5: Brand reputation of an international express carrier has positive impact on customer loyalty.
Selnes (1993) though brand reputation is usually associated with service. In some cases, many customers associated products or services only by brand. Sharp (1993) pointed out that the quality of product and service had a relationship with brand reputation. Richardson et al. (1994) indicated brand image is usually evaluated by customers as an external clue of quality. Hence, this study proposes the following hypothesis:

H6: International express carrier's reputation has positive impact on service quality.
Ping (1993) stated that when customers have sensed the expensive switching cost of transferring to other company, they will tend to stay loyally. Kim et al. (2004) conducted a research about the effects of customer satisfaction and switching barrier on customer loyalty in Korean mobile telecommunication service. The result showed that switching barrier had positively impact on customer loyalty, in other words, high switching barrier may have positive influence on customer loyalty. Therefore, we proposed the following hypothesis:

H7: Switching barrier has positive impact on customer loyalty in the international express industry.

3. Research Methodology

3.1. Research model

This study aims to explore the relationship among service quality, customer satisfaction, brand reputation, switching barriers and customer loyalty in the international express industry. Our research model of study is summarized in Figure 1 illustrating the relationships among the constructs in the international express industry.

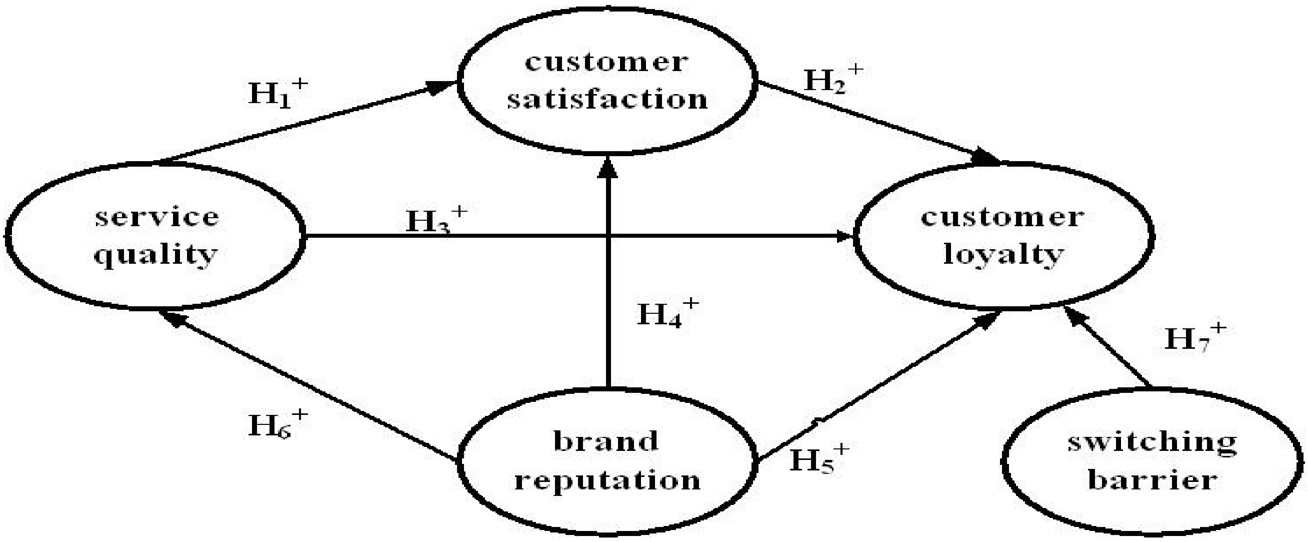

Figure 1: Research model of study

3.2. Questionnaire design

The empirical study adopted Likert scale to measure satisfaction of different services which carriers provided over shippers' thinking. Besides, the sequential options were showed from "very satisfied", "satisfied", "general", "dissatisfied" to "very dissatisfied" to give 5,4,3,2 and 1point respectively. Higher scores indicated the higher level of satisfaction. Questionnaire was designed according to the SERVQUAL scale and related studies to measure the constructs: service quality, satisfaction, loyalty, reputation and switching barrier showed in table 1 and table 2.

Table 1: Service quality measure items

Constructs	Question item
Intangibility	Reputation and image of company.
	Set up 24 hour customer service center
	Competent professional staff
	Driver uniform recognition and organized delivery van space
	Offering service on weekends (include public holidays)
Reliability	The carrier we are using uses latest advanced equipment (device/vans/fleet/e-platform)
	Complete global network coverage and distribution
	The carrier we are using offers express cargo delivery
	100% error free delivery service to your corporation
	Consigned goods are delivered undamaged in their original packaging
Assurance	Carrier's delivery service is faster than all its competitors
	Consigned goods are delivered on time
	Consigned goods are delivered to the correct address
	The carrier we are using comes to us to pick up the goods on time
Responsiveness	Attitude when dealing with lost or damaged goods.
	Prompt reaction when dealing with lost or damaged goods.
	The way to provide compensation for lost or damaged goods
	If the goods are damaged during shipping, the company will notify the customer immediately
	Document revisions can be dealt with immediately
	Offering online cargo tracking system
Empathy	Convenient procedures for sending and receiving goods
	Options to assign time and place to receive goods
	Proactively inform consignee of arrival time of goods
	Offering flexible rates and discounts
	Convenience of payment options

Table 2: Customer satisfaction, loyalty, switching barrier and brand reputation measure items

Dimension	Questionnaire	Source
Customer satisfaction	Our company is satisfied with decision to use current international express carrier.	Olorunniwo, F., Hsu, M. K., & Udo, G. J. (2006)
	There is no other international express carrier providing the same level of service as the currently used carrier.	Roos et al. (2004)
	Overall, our company feels satisfied with current international express carrier which we cooperate with.	Lin (2007)
Customer loyalty	Our company will keep using current international express carrier's service.	Oliver (1999)
	Our company can recommend using international express carrier to peers.	Gronholdt et al. (2000)
	Our company usually talks to other about positive news of international express carrier we cooperate with	Kheiry and Alirezapour (2012)
	Our company and our partner of international express carrier will increase work each other in the future.	

Switching Barriers	Our company thinks it takes much time and energy to replace international express carrier 本公司認為更換國際快遞業者會花費很多時間與精力	Edward et al (2011)
	Our company thinks it is trouble to change international express carrier.	
	Our company thinks changing international express carrier would bring additional expenses.	Kheiry and Alirezapour (2012)
	Our company thinks changing international express carrier can cause a burden to the company.	Burnham et al. (2003)
Brand reputation	Our company thinks the main international express carrier currently we cooperate with is well-known.	Han and Terpstra. (1998)
	Our company thinks the main international express carrier currently we cooperate with is respected	
	Our company thinks the main international express carrier currently we cooperate with is excellent.	
	Our company thinks the main international express carrier currently we cooperate with has good reputation.	

3.3 Statistical analysis

The analysis method used in this study includes descriptive statistics and structural equation modeling (SEM). Descriptive statistics is a system and technique to collect, observe, organize, describe and explain data. A descriptive statistical analysis was conducted after the samples had returned. SEM is a common analytical tool composed of confirmatory factor analysis, path analysis and multiple regression analysis. The two-step procedure proposed by Anderson and Gerbing (1988) is used in this study. Namely, a measurement model is established and testes first to ensure the fitness of the data for the model. Afterwards, a structural model is constructed to validate the relationship among latent variables and examining the hypothesized paths among the constructs.

4. Empirical Analysis

4.1 Questionnaire design

The questionnaire used in this study was composed of two parts. The first part was the basic information of respondents and the other part was the experience of using the express service of the respondents. There were 40 items in the questionnaire which were designed by referring to related literature and interviewing professional experts in this industry. Before issuing the questionnaires, we had interviewed two professors related to the shipping and logistics fields and practitioners in this industry to conduct a pilot test. The questionnaire was refined by their opinion to ensure the questionnaire with a good content validity.

4.2 Sampling and data collection

The population of this empirical study was the top 500 import and export firms in Taiwan. Questionnaires were sent to 420 of them who had used express service. A total of 218 of the 420 questionnaires were returned accounting for an effective rate of 51.9%. Table 4 describes the characteristics of the returned samples.

By analyzing the basic information of the returned samples, we found that most companies were frequent users who used express service more than ten times a week as 75.69%, respondents who have worked for their companies over 10 years were 41.29% and the company scale over 500 employees accounted for 60.55%. In according to above data, the respondents had an experienced knowledge and worked for a certain period, showing that the result in this study is quite reliable.

Table 3: Returned sample statistical distribution

Item	Personal information	Frequency	Percentage (%)
Gender	Male	29	13.30%
	Female	189	86.70%
Age	Under 25 years	10	4.59%
	26-30 years	27	12.39%
	31-35 years	50	22.94%
	36-40 years	56	25.69%
	41-50 years	51	23.39%
	Over 51 years	24	11.01%
Level of education	Over high school	10	4.59%
	Junior college	44	20.18%
	College	140	64.22%
	Master/Doctor	24	11.01%
Working experience	Below 1 year	7	3.21%
	2-3 years	34	15.60%
	4-5 years	18	8.26%
	6-10 years	69	31.65%
	11-15years	42	19.27%
	16-20 years	18	8.26%
	More than 21 years	30	13.76%
Job title	Staff	133	61.01%
	General director	52	23.85%
	Mid-level director	22	10.09%
	Senior director	11	5.05%
Scale of company	Below 20 people	0	0.00%
	21-50 people	8	3.67%
	51-100 people	11	5.05%
	101-200 people	19	8.72%
	201-500 people	48	22.02%
	More than 500 people	132	60.55%
Frequency	Below 10 times a week	53	24.31%
	From11 to 20 times a week	67	30.73%
	From 21-50 times a week	49	22.48%
	More than 50 times a week	49	22.48%

4.3 SEM analysis

4.3.1 Measurement model analysis

As most sampling-related studies did, the reliability and validity of the returned samples have to be tested to ensure the representativeness of the measurement model. In this study, we used composite reliability (CR), average variance extracted (AVE), factor loadings and critical ration (cr) that are common evaluation indices as the measures to identify reliability and validity of the samples.

As Table 4 shows, the CR value of each construct is greater than 0.8, which exceeds the recommended level of 0.7 and the AVE value of each construct exceeds the recommended level of 0.5. In addition, all factor loadings exceed 0.59 and a value of cr is greater than 1.96, which ensures the desired convergent validity of this empirical study. Hence, we can confirm a sound convergence validity between the collected data and the measurement model in this study.

Table 4: Factor loading, Construct reliability and Average variance extracted

Measures	Factor loading	Construct reliability [b] (CR)	Average variance extracted (AVE)
Service quality		0.839	0.5143
TAN RES REL ASS CAR	0.543 0.766 0.693 0.793 0.762		
Customer satisfaction		0.825	0.6146
CSA1 CSA 2 CSA3	0.827 0.647 0.861		
Customer loyalty		0.8046	0.5074
CUL1 CUL2 CUL3 CUL4	0.708 0.705 0.712 0.724		
Switching barrier		0.8377	0.5726
SWA1 SWA2 SWA3 SWA4	0.570 0.642 0.824 0.935		
Brand reputation		0.8845	0.6578
BRP1 BRP2 BRP3 BRP4	0.747 0.873 0.766 0.851		

TAN=tangibility，Res= Responsiveness，Rel= Reliability，ASS＝assurance，CAR=care，CSA=customer satisfaction CUL=customer loyalty，SWA=switching barrier，BRP= brand reputation

4.3.2 Discriminant validity

In addition, discriminant validity is used to evaluate whether there is a significant difference between different latent variables. The first χ2 value was obtained by setting the correlation between the construct pairs to 1.0. The second χ2 value was then calculated by estimating the correlation freely .If the difference between these two χ2 values is significant (larger than 3.84), a significant discriminant validity exists between this construct pairs. The greater the difference is, the lower relationship between the latent variables is. That is, the latent variables in this study are representative. Table 5 lists the result of the χ2 difference tests between all construct pairs. It is obvious that this study has great discriminant validity as all χ2 differences were significant.

Table 5: Result of the χ2 difference tests between latent construct pairs

Construct pair		Unconstrained model [a]		Constrained model [b]		$\Delta\chi^2$
		χ^2	df	χ^2	df	
Service quality	Customer satisfaction	53.077	19	145.538	20	92.461
Service quality	Customer loyalty	106.978	26	224.249	27	117.271
Service quality	Switching barrier	170.651	26	517.275	27	346.624
Service quality	Brand reputation	56.972	26	486.980	27	430.008
Customer satisfaction	Customer loyalty	74.622	13	100.003	14	25.381
Customer satisfaction	Switching barrier	124.118	13	346.635	14	222.517
Customer satisfaction	Brand reputation	17.211	13	222.790	14	205.579
Customer loyalty	Switching barrier	157.663	19	330.579	20	172.916
Customer loyalty	Brand reputation	65.608	19	241.939	20	176.331
Switching barrier	Brand reputation	129.064	19	479.495	20	350.431

[a] Unconstrained model means that the correlation between the construct pair was freely estimated.
[b] Constrained model means that the correlation between the construct pair was fixed to one.
*significant at the P<0.05, **significant at the P<0.01, ***significant at the P<0.001 level.

4.3.3 Goodness-of-fit measures of CFA

Table 6 lists main fitness measures outputted from AMOS and their acceptance thresholds, respectively. The normalized χ^2 value was 1.689, which was acceptable as it is less than 3. Five other measures, goodness-of-fit index (GFI) (value of 0.905), adjusted GFI (AGFI) (value of 0.864), normed fit index (NFI) (value of 0.902), comparative fit index (CFI) (value of 0.957) and root mean square residual (RMR) (value of 0.022) all achieve their acceptance thresholds (Bagozzi and Yi, 1988; Koufteros, 1999).Therefore, there is a sound fitness between the data and the measurement model.

Table 6: Goodness-of-fit measures of CFA

Goodness-of-fit measure	Recommended value	Value of this study
Ratio of χ^2 to degrees of freedom (χ^2/d.f.)	≤3.00	1.644
Goodness of Fit Index (GFI)	≥0.8	0.902
Adjusted Goodness of Fit Index (AGFI)	≥0.8	0.863
Comparative Fit Index (CFI)	≥0.9	0.958
Normed fit index (NFI)	≥0.9	0.902
Root Mean Square Residual (RMR)	≤0.05	0.032

4.3.4 Goodness-of-fit measures of the structural model

As table 7 illustrates, there are six goodness-of-fit indexes tested and overall fitness between the returned samples and the structural model achieve their acceptance thresholds. Hence, these measures demonstrate sound fitness between collected data and the structure model.

Table 7: Goodness-of-fit measures of the structural model

Goodness-of-fit measure	Recommended value	Value of this study
Ratio of χ^2 to degrees of freedom (χ^2/d.f.)	≤3.00	1.689
Goodness of Fit Index (GFI)	≥0.8	0.905
Adjusted Goodness of Fit Index (AGFI)	≥0.8	0.864
Comparative Fit Index (CFI)	≥0.9	0.902
Normed fit index (NFI)	≥0.9	0.957
Root Mean Square Residual (RMR)	≤0.05	0.022

Table 8: Test results of the hypotheses

Hypothesis	Variables	Estimates	S.E.[a]	C.R.[b]
H_1	Service quality→customer satisfaction	0.655***	0.112	8.094
H_2	Customer satisfaction→customer loyalty	0.800***	0.094	7.584
H_3	Service quality→customer loyalty	-0.121	0.115	-1.293
H_4	Brand reputation→customer satisfaction	0.148*	0.050	2.349
H_5	Brand reputation→customer loyalty	0.137*	0.039	2.427
H_6	Brand reputation→service quality	0.211**	0.043	2.785
H_7	Switching barrier→ customer loyalty	0.409*	0.039	4.888

[a] SE is an estimate of the standard error of the covariance.
[b] CR is the critical ratio obtained by dividing the covariance estimate by its standard error.
[c] Underlined value is the critical ratio that did not exceed 1.96, at the 0.05 level of significance.

We used the values of squared multiple correlations (R2) to examine the amount of variance of each specific construct accounted for by other constructs. With a range from 0 to 1, a high value of R2 shows that the amount of variance of a specific construct is well accounted for by other constructs. The result of structural model analysis is showed by Figure 2 indicates that CL has a R2 value of 0.853 indicating that it was well accounted by SQ, CS, BR and SB. Notably, because of the rejection of H3, the direct impact of SQ on CL was not significant. However, the indirect impact or so-called meditation effect transmitted the impact from SQ to CL through CS, BR and SCs because of the acceptance of all other hypotheses.

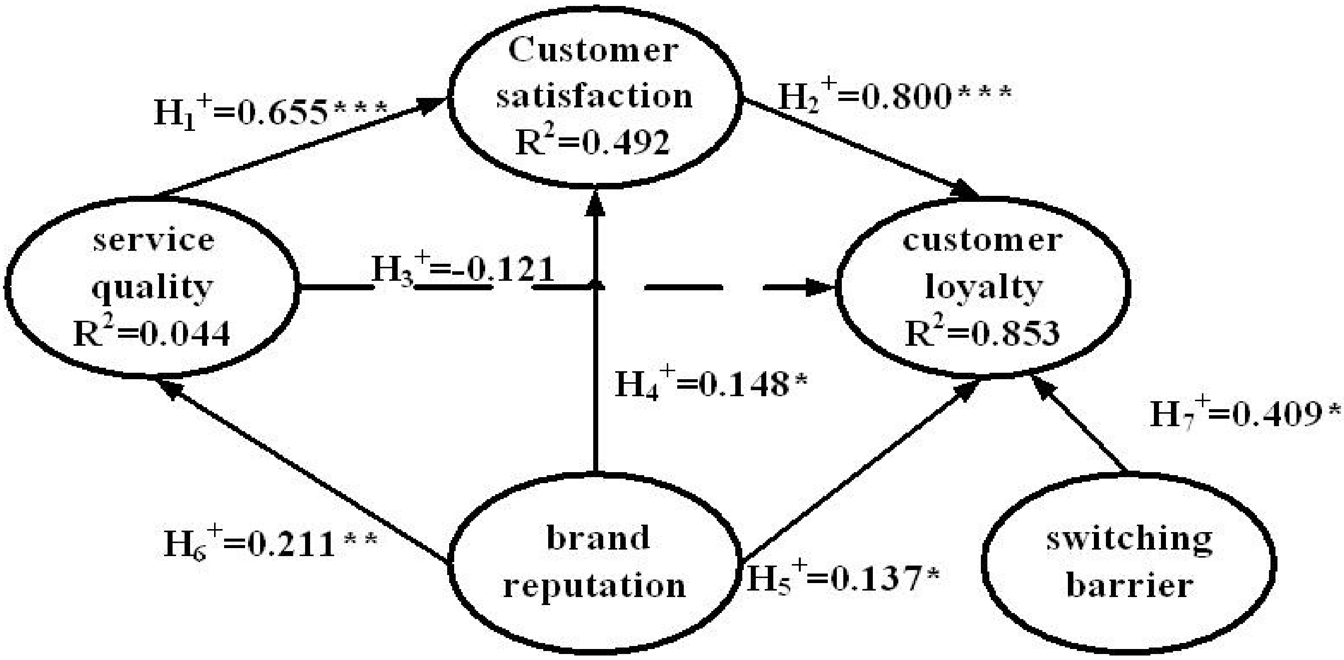

Figure 2: The result of structural model analysis

4.4 Research hypothesis test

All proposed hypotheses were tested and the result is presented and discuss in this section showed by table 8. The path coefficient of service quality toward customer satisfaction is 0.655 that exceeds the recommended level means shippers thought service quality provided by an international express carrier can directly impact its customer satisfaction. Therefore, the H_1 proposed in this study was supported. The path coefficient of customer satisfaction toward customer loyalty is 0.8 that exceeds the recommended level means that shippers thought their satisfaction can affect their loyalty. Therefore, the H_2 proposed in this study was supported. The path coefficient of service quality toward customer loyalty is -0.121 that lower than the recommended level means international express carrier’s service quality can’t directly impact customer loyalty. Therefore, the H_3 was rejected.

The path coefficient of brand reputation toward customer satisfaction is 0.148 that exceeds the recommended level means that brand reputation of international express carriers has positive impact on customer satisfaction. Therefore, the H_4 proposed in this study was supported. The path coefficient of brand reputation toward customer loyalty 0.137 that exceeds the recommended level means brand reputation of international express carrier has positive impact on customer loyalty. Therefore, the H_5 proposed in this study was supported. Because related literatures about this relationship are few, this is the most important founding in this study. The path coefficient of brand reputation toward customer loyalty is 0.137 that exceeds the recommended level means brand reputation of international express carrier has positive impact on customer loyalty. Therefore, the H_6 proposed in this study was supported. Finally, the path coefficient of switching barrier toward customer loyalty is 0.409 that exceeds the recommended level means switching barrier for international express carrier has positive impact on customer loyalty. Therefore, H_7 proposed in this study was supported.

5. Conclusions

The empirical result shows customer satisfaction and brand reputation has positive impact on customer loyalty in the international express industry .In other words, customers think if an international express carrier can increase the customer satisfaction or be trusted in the international express market, it will intensify customer loyalty. In addition, there were many studies focusing on the relationship between service quality, customer satisfaction and customer loyalty. However, this study found that brand reputation has positive impact on quality, customer satisfaction and customer loyalty. It means that an international express carrier can let their customers have high cognition of service quality and customer satisfaction/loyalty through building good brand reputation. Finally, although the result didn't support the positive relationship between service quality and customer loyalty, the indirect impact or so-called meditation effect transmitted the impact from service quality to customer loyalty via customer satisfaction because H1 and H2 were supported. In terms of switching barrier, it has positive impact on and plays an important role in the international express market. The higher switching barrier is, the higher customer loyalty is. Therefore, the international express carriers may use some strategies to raise their customer loyalty by increase switching barriers.

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Ferry Services and the British Colonial Governance in Hong Kong

Yui Yip Lau[1], Ka-chai Tam[2] and Adolf K.Y.Ng[3]

[1]Division of Business, Hong Kong Community College, The Hong Kong Polytechnic University, Hong Kong
[2]Department of History, Hong Kong Baptist University, Hong Kong
[3]Department of Supply Chain Management, I.H. Asper School of Business, University of Manitoba, Manitoba, Canada

Abstract

The history of Hong Kong ferry services began with the establishment of the colony of the British Empire in the Hong Kong Island since the Treaty of Nanking (29 August 1842). When the colony extended to the Kowloon Peninsular (located at the opposite side of the Victoria Harbour) and the New Territories, ferry services connecting different parts of Hong Kong became an essential part of the colonial government to maintain effective control over the scattered areas separated by the waters. Indeed, before the emergence of the metro systems and the establishment of harbor-crossing tunnel in the 1970s that led to its dramatic decline, the ferry system was the foundation of public transport in Hong Kong; other land transportation means were all supplementary to the passenger boats. Hitherto, only a handful of historical research, however, touches upon some factual developments of this important element of transportation. Many important issues related to the ferry services, such as colonial governance, micro-politics of the outlying islands, the self-identity of the island dwellers and the colonial government's experiences of controlling the local inhabitants of the outlying islands were never seriously addressed. Understanding such deficiency, in this study, we adopt the concept of centre-periphery theory to explain how ferry services facilitate regional integration in Hong Kong, notably outskirt islands, and describe how people are interconnected through ferry services. Through an intensive documental review, the paper undertakes a historical review study on the evolution of the Hong Kong ferry services throughout the colonial period (1842-1997). Based on that, we investigate the significance of ferry services in the government regime maintenance, economic development and social welfare. Even though Hong Kong ferry slowly declined since the 1970s, we addressed how and why ferry services in Hong Kong was still important to keep the city intact, and also enhance the identity of the Hong Kong residents as 'Hongkongese'.

Keywords: Hong Kong ferry services, Self-identity, Island dwellers, Centre-periphery theory, Outskirt islands, Hongkongese

1. Introduction

Ferry services in Hong Kong began developing during the Qing dynasty (1644-1911). During the Yongzheng (1723-35) and Qianlong (1736-95) eras, the court implemented immigration measures that encouraged the Hakka minority to relocate to the south-eastern coast of China, including all of modern Hong Kong. Following relocation, the demand for ferry services in Hong Kong was derived from the island-dwellers' essential need for sea transportation. Ferry history began when the British Empire established a colony on the Hong Kong Island after the signing of the Treaty of Nanking (29 August 1842) and then extended this to the Kowloon Peninsula (on the opposite side of Victoria Harbour) and the New Territories. Ferry services that connected different parts of Hong Kong became an essential part of the colonial government's ability to maintain effective control over the scattered areas of the colony, separated as they were by water. In the past, the ferry was the sole mode of transport within Hong Kong territory. Since the late 1970s, however, the role of the ferry in Hong Kong has diminished significantly, stemming from the government's implementation of a series of large-scale reclamation works, a continuous redistribution of the population, a significant change in travelling patterns, rapid expansion in land transit system networks, the development of a public cargo-handling area and the development of extensive supporting infrastructure such as new bridges, strategic highways and tunnels. The ferry system demonstrates a representative life-cycle and is the earliest ancestor of public transport. The key finding of ferry development from the 1870s to the late 1990s has been shown in Appendix 1. The urban development is diminishing ferry development in terms of routings, ferry terminal utility rate, service frequency and fleet management.

Ferry services play a key role in providing relief services during crises or emergencies, such as disruptions to the MTR and road closures. In addition, ferry services cater for demand that does not justify enfranchising certain routes, for example non-essential services, excursion services (e.g. the ferry taxi connecting Disneyland to Ping Chau and Discovery Bay; ferry services connecting the Kai Tak cruise terminal to other locations) and special services (e.g. vehicular services for dangerous goods vehicles). The Hong Kong ferry system is thus able to benefit both regular commuters and the utility of the public transport network. The introduction of outlying districts ferry services could further open up these islands to recreational demand and facilitate tourism there. For visitors, ferry services are probably the most recognised symbol of Hong Kong, and ferry images have been used extensively by the Hong Kong Special Administrative Region (HKSAR) government in its overseas promotions. We have noted the support provided by the ferry system's continued operation to maintain Hong Kong's culture and heritage. In the long term, the disappearance of ferry services would adversely affect social network connectivity and governance, especially for sparse populations.

The long history of ferry services in Hong Kong's public transport sector is important in terms of the sustainable development of inter-island water transport (Choi et al., 1999; Cullinane, 2002). Sustainability is defined by the Brundtland Commission (World Commission on Environment and Development, 1987) as meeting the needs of today's citizens without prejudicing the ability of future generations to meet their needs. Hong Kong's ferry services both provide essential links to outlying islands and offer ancillary services between the inner harbour and the new towns. For many small outlying islands, for example Peng Chau, Cheung Chau, Lamma Island and Mui Wo, there is no possibility of building either a direct link to the main transportation infrastructure or a self-contained town–country type magnet as proposed by Ebenezer (1946).

Although nowadays the ferry has a complementary role in providing cross-harbour traffic, its major role lies in serving the outlying islands (Lai and Lo, 2004; Wang and Lo, 2008). Ferries offer convenient waterborne transportation both for people living in the outlying islands and potential ferry users who could travel a reasonable distance between ferry piers (Ceder, 2006; Wong and Lam, 2006). Of the popular modes of public transport, the ferry is considered to have a low service rate (Chan et al., 1999) and be the safest means of transportation (Ceder, 2006; Ceder and Sarvi, 2007), allowing Hong Kong residents to live, shop, work, go to school and enjoy recreation across all of the regions of Hong Kong (Meligrana, 1999; Wong and Lam, 2006). Despite recognising the benefits provided by the ferry system, however, the HKSAR government continues to offer barely minimal assistance and invests in ferry terminals at a relatively low level (Ceder, 2006). In the past few decades, government publications such as 'Transport in Hong Kong: a paper for public information and discussion' (1974), the 'Second Comprehensive Transport Study' (CTS-2) published in 1989, the 'White Paper on Transport Policy' published in 1990, and the 'Consultation Document on the Third Comprehensive Transport Study' (CTS-3) published in 1997 have all demonstrated the Hong Kong government's lack of support of and complacent attitude towards ferry services. Additionally, the ferry industry itself has received little attention in the literature to date. The studies mentioned above also seem to suffer from a number of methodological shortcomings. Some researchers, such as Chan et al. (2002), Lai and Lo (2004), Tang and Lo (2008) and Wang and Lo (2008), investigate ferry scheduling, service offerings and network design in the area of operational research. Also, studies on the Hong Kong ferry system are often merely extensive descriptions and analyses of the changing needs of the contemporary business environment (Chan et al., 2012). It is clear that a number of important issues related to the ferry services, such as colonial governance, micro-politics of the outlying islands, the self-identity of the island dwellers and the colonial government's experiences of controlling the local inhabitants of the outlying islands were remain unanswered. Understanding such deficiency, in this study, we adopt the concept of centre-periphery theory to explain how ferry services facilitate regional integration in Hong Kong, notably outskirt islands, and describe how people are interconnected through ferry services. Even though Hong Kong ferry slowly declined since the 1970s, we addressed how and why ferry services in Hong Kong was still important to keep the city intact, and also enhance the identity of the Hong Kong residents as 'Hongkongese'. The remaining of this paper is as follows. After the introduction in Section 1, Section 2 provides an overview of Hong Kong ferry throughout the colonial period. Section 3 describes the methodological context. Section 4 presents the relationships between centre-periphery theory and Hong Kong ferry. Section 5 discusses the significance of ferry services in the government regime maintenance, economic development and social welfare. Section 6 concludes this paper.

2. Hong Kong Ferry

The ferry is regarded as an ancient Hong Kong transportation service. For more than 170 years, ferry services have contributed to various aspects of Hong Kong that pertain to social identity, transport network connectivity, political stability and the support of economic development. Since 1 April 1999, most of the ferry services are provided by licensed ferry operators. As at 1 July 2014, there are 11 ferry operators providing 18 licensed passenger ferry services to outlying islands and across the harbour. Ferry licences are used to provide for services whose patronage is lower or which serve localised communities, are granted by the Commissioner for Transport for a maximum period of 3 years, but could be extended for a further period of 3 years at any one time (Transport Department Hong Kong Government, 1997). Additionally, there are 2 franchised ferry services operated by Star Ferry operating between Tsim Sha Tsui and Wan Chai as well as Tsim Sha Tsui and Central. Ferry franchises generally cover a network of services and are granted by the Chief Executive in Council for 10-15 years (Transport Department Hong Kong Government, 1997). In order to serve remote coastal settlements, "kaitos" provides supplementary ferry service. According to Transport Department, HKSAR, we have summarized service details of franchised and licensed ferry services and regular kaito ferry services in Table 1-3.

Table 1: Franchised and licensed ferry services - inner harbor

Ferry Routings	Operator	Service Frequency							
		Mon	Tue	Wed	Thur	Fri	Sat	Sun	Public Holiday
North Point – Hung Hom	New World First Ferry Services Ltd.	√	√	√	√	√	√	√	√
North Point – Kowloon City	New World First Ferry Services Ltd.	√	√	√	√	√	√	√	√
North Point – Kwun Tong	Fortune Ferry Company Limited	√	√	√	√	√	√	√	√
Central – Tsim Sha Tsui	The "Star" Ferry Company, Limited	√	√	√	√	√	√	√	√
Wan Chai – Tsim Sha Tsui	The "Star" Ferry Company, Limited	√	√	√	√	√	√	√	√
Sai Wan Ho – Sam Ka Tsuen	Coral Sea Ferry Service Company Limited	√	√	√	√	√	√	√	√
Sai Wan Ho – Kwun Tong	Coral Sea Ferry Service Company Limited	√	√	√	√	√	√	√	√

Table 2: Franchised and licensed ferry services – outlying islands

Ferry Routings	Operator	Service Frequency							
		Mon	Tue	Wed	Thur	Fri	Sat	Sun	Public Holiday
Central – Cheung Chau	New World First Ferry Services Ltd.	√	√	√	√	√	√	√	√
Central – Mui Wo	New World First Ferry Services Ltd.	√	√	√	√	√	√	√	√
Central – Peng Chau	Hong Kong & Kowloon Ferry Ltd	√	√	√	√	√	√	√	√
Central – Yung Shue Wan	Islands Ferry Company Ltd.	√	√	√	√	√	√	√	√
Central – Sok Kwu Wan	Winnertex Ltd	√	√	√	√	√	√	√	√
Tuen Mun – Tung Chung – Sha Lo Wan – Tai O	Fortune Ferry Company Limited	√	√	√	√	√	√	√	√
Peng Chau – Mui Wo – Chi Ma Wan – Cheung Chau	New World First Ferry Services Ltd.	√	√	√	√	√	√	√	√
Aberdeen – Pak Kok Tsuen – Yung Shue Wan	Tsui Wah Ferry Service (H.K.) Limited	√	√	√	√	√	√	√	√
Aberdeen – Sok Kwu Wan (via Mo Tat)	Chuen Kee Ferry Ltd.	√	√	√	√	√	√	√	√
Central – Discovery Bay	Discovery Bay Transportation Services Limited	√	√	√	√	√	√	√	√
Discovery Bay – Mui Wo	Peng Chau Kaito Ltd.	√	√	√	√	√	√	√	√
Ma Wan – Central	Park Island Transport Company Ltd.	√	√	√	√	√	√	√	√
Ma Wan – Tsuen Wan	Park Island Transport Company Ltd.	√	√	√	√	√	√	√	√
North Point – Joss House Bay[i]	New World First Ferry Services Ltd.								

Table 3: Kaito ferry services

Ferry Routings	Operator	Service Frequency							
		Mon	Tue	Wed	Thur	Fri	Sat	Sun	Public Holiday
Sam Ka Tsuen – Tung Lung Island	Coral Sea Ferry Service Company Ltd						√	√	√
Ma Liu Shui – Tung Ping Chau	Tsui Wah Ferry Service Company Ltd						√	√	√
Tap Mun – Wong Shek Pier	Tsui Wah Ferry Service Company Ltd	√	√	√	√	√	√	√	√
Ma Liu Shui – Tap Mun	Tsui Wah Ferry Service Company Ltd	√	√	√	√	√	√	√	√
Sha Tau Kok – Kat O	Kat O Kaito	√	√	√	√	√	√	√	√
Wong Shek Pier – Wan Tsui (Nam Fung Wan)/Chek Keng	Tsui Wah Ferry Service Company Ltd						√	√	√
Aberdeen – Mo Tat	Chuen Kee Ferry Ltd.	√	√	√	√	√	√	√	√
Mo Tat – Sok Kwu Wan	Chuen Kee Ferry Ltd.	√	√	√	√	√	√	√	√
Aberdeen/Stanley – Po Toi Island	Tsui Wah Ferry Service Company Ltd		√		√		√	√	√
Peng Chau/Trappist Monastery – Discovery Bay	Peng Chau Kaito	√	√	√	√	√	√	√	√
Cheung Chau Pier – Sai Wan	Wah Shing Kaito	√	√	√	√	√	√	√	√
Aberdeen – Ap Lei Chau	Eastern Ferry Company Limited	√	√	√	√	√	√	√	√
Sai Wan Ho – Tung Lung Island	Lam Kei Kaito						√	√	√

3. Research Materials and Issues of Discussion

To date, only a handful of historical works have touched upon the development of ferry, one of the key elements of public transportation. Some research studies have been discussed about ferry in different regions, for instance, Scotland and the United Kingdom (Roueche, 1981; Baird, 2012; Cowie, 2012; Laird, 2012); Japan (Baird, 1999); USA (Benenati et al., 1998; Lawson and Weisbrod, 2005); Ireland (Mangan et al., 2002); and New Zealand (Lohmann and Pearce, 2012). To the degree that these research papers discuss Hong Kong ferry, the focus is a narrow perspective of ferry operational efficiency and ferry economic performance (e.g., Chan et al., 2002; Cullinance; 2002; Lai and Lo, 2004; Ceder, 2006; Ceder and Sarvi, 2007; Wang and Lo, 2008). Given the historical nature and the objectives of this research, we have carried out a comprehensive review of the governmental documents collected in the Government Records Service of Hong Kong (www.grs.gov.hk), *Cheung Chau Magazine* and 301 legislative council papers (www.legco.gov.hk) published since 1986, dealing with the planning, transportation, economic development and social control of colonial Hong Kong from the early stages to the contemporary times. We also have conducted an extensive review of the leading international transport journals and the professional ferry magazines (i.e. the *Starstruck Ferry*). A case study on the Cheung Chau island is carried out as follows to demonstrate the proposed research methodology. A discussion of the results and the implications of the findings are also provided.

4. Centre-Place Theory and Studies on the Hong Kong Ferry

This paper employing the Centre-Place, or the Centre-Periphery theory, to examine the roles of the ferry in connecting a territory with natural barriers such as mountains and waters. Broadly speaking, the centre is defined as the core areas and the periphery as the dependent and subordinated areas. The centre and the periphery refers to various levels of spatial organizations ranging from the global level of intercontinental relations to the local level of an internal structure of a given country's regions or other smaller territorial units (Zarycki, 2007). The centre designs the organization and controls the subsidiaries, the periphery (Forsgren, 1990). According to Galtung (1971), centre plays decisions models and provides ideas, norms, visions and ideals whereas periphery plays obedience models and provides imitation and adherence. The geographer Walter Christaller and the economist August Lösch had first applied centre place theory to urban geographical studies in the 1930s and 1940s. Christaller (1933) illustrated the centre place theory in agrarian societies, and the theory anticipated the emergence of a hierarchy of settlements, with each level of the hierarchy achieving corresponding levels of development and providing distinctive services. In the landscape, the economic activities of people to specific centre places at each hierarchical level in accordance with the services, including: to central towns for cooking utensils, to a nearby market town for items of daily use, to metropolises for specialized services (i.e., higher education), and to cities for fashionable garment. It establishes a significant starting point for an investigation of social patterns under a centre place analysis. In order to discover evidence for the 'market' and 'traffic' variants of Christaller's centre place theory, the anthropologist G. William Skinner applied the centre place analysis to demonstrating the spatial structure of rural Chinese society at the local level (Qi et al., 2004). He argues that the society should have a centre, and the centre zone has a definite location within the bounded territory in which the society lives. Some people will be a bit closer to the centre, while some will be more distant from it (Shils, 1961). In the structure of a society, the centre is geographically more centrally located in the interaction networks than the periphery (Lehtonen, 2011). The literature of centre-place theory appears widely in the fields of urban studies (e.g., Wallerstein 1991; Krugman 1991; Chase-Dunn and Hall, 1991; McLoughlin, 1994; Copus, 2011), tourism studies (e.g., Keller, 1980; Getz, 1994), or in the economic, political or cultural dimensions of spatial relationships (e.g., Forsgren, 1990; Krugman, 1991; Wagner and Leydesdorff, 2005; Zarycki, 2007; Lehtonen, 2011).

The centre-place theory is a tool good for our study on the outskirt areas of Hong Kong, as we may see the urban area as centre and the rural the periphery (Lehtonen, 2011). The former British colony of Hong Kong is a political region consists of the Hong Kong Island, the Kowloon Peninsula, the New Territories, the Lantau Island, as well as other 262 outlying islands. It is located at 22° 15' 0" N / 114° 10' 0" E, covers an area of 1,104 km^2. Between the Kowloon Peninsula and the Hong Kong Island lies the Victoria Harbour, Hong Kong has been recognized one of the world's most renowned deep-water harbours. Since Hong Kong is situated at the south of the Tropic of Cancer, it has a humid subtropical climate with temperatures dropping below 10^{o}C in winter, so that the port never frozen, and exceeding 31°C in summer. It is in general warm, sunny and dry in autumn, cool and dry in winter, and hot, humid and rainy from spring to summer (source: http://www.gov.hk/en/about/abouthk/).

The beginning of the history of Hong Kong could be found by the human presence in the Chek Lap Kok area from 35,000 to 39,000 years ago or on the Sai Kung Peninsula in the mainland from 6,000 years ago. In the Han Dynasty (206 BC), there were inhabitants in Ma Wan Island and Punti (i.e. local) settlement. China's fleeing imperial court found refuge in the Silvermine Bay on the Lantau Island during the Battle of Yamen in the Song Dynasty (1075). At the Ming Dynasty (1513), the Western adventurer Jorge Álvares arrives in Tuen Mun. In 1661, the Qing court ordered the Great Clearance, which required the evacuation of the coastal areas of Guangdong. Then, Hong Kong had become largely waster land (Steve, 1995; Chan et al., 2012). At this period, the region has a low population so that there was small demand for transport of any kind. Prior to 1842, the majority of people were living in the North Western region of the New Territories, the areas of Stanley, Aberdeen and Shau Kei Wan of the Hong Kong Island. There were only 7,450 people lived in the Hong Kong Island according to the first colonial census. Started from 1842, Hong Kong had been a crown colony of the British Empire governed by a governor sent from London.

As the British government has conducted a large scale of urban construction, the new colony attracted a large number of people to work and settle down in Hong Kong. Until 1914, the population of Hong Kong reached 501,304. Thereafter the population steadily increased, except during the years under Japanese occupation in the 1940s (Tsai, 2000). After the Japanese occupation, the British retook Hong Kong for strategic reasons; most significantly, Central is proximity to Victoria Harbour, has served as the house major military facilities and an administrative centre from the first day of the British colonial era in 1841. Meanwhile, Civil War broke out in China. This development stimulated the Chinese from the mainland fled and relocated to Hong Kong. The population significantly increased from 6,000,000 in 1946 to 17,500,000 in 1948 (Chan et al., 2012). Since then, Hong Kong had experienced rapid economic boom and urbanization. The population in 2014 was 7.26 million, which was more than a double of that of 3.13 million in 1961. In the next 20 years, the population would continue to increase at a fast pace (Census and Statistics Department, 2015).

The outskirt islands of Hong Kong formed a geographically peripheral and disadvantaged region (Keller, 1980). Although in some outlying islands such as Cheung Chau there are magnificent towns and flourished villages, many of the other islands are sparsely inhabited and remain largely rural. To a large extent, people living in the outlying islands of Hong Kong have no daily contact with the central urban area. They rarely travel to the centre and their social status is rather low. Lower social classes tend to ignore the symbolic world of the centre (Zarycki, 2007). In this sense, the Hong Kong ferry services are significant to keep the city intact between centre and periphery, and help improving the islanders' economic and social conditions.

5. Cheung Chau: A Case Study

Cheung Chau is the longest continuously existed inhabited part of Hong Kong. It has undergone different types of government control since the Ming dynasty (1368-1644) of China. Geographically, Cheung Chau is a small island located just over 5 miles west-south-west of Green Island at the western end of the Victoria harbor (Hayes, 1962). It is located among the south-east Lantau Island, the north side of Hei Ling Chau and the southwest side of Shek Kwu Chau. The island is dumbbell-shaped, with hills at the northern and southern ends. Since Cheung Chau is located at a relative remote sea, it is difficult for the Qing dynasty of China to govern it effectively. In 1898, the Qing dynasty and the United Kingdom signed the *Extension of Hong Kong Boundary Special Section*. Since then, the New Territories and more than 200 islands (including Cheung Chau) were leased to the British colony of Hong Kong for 99 years. In order to establish sound British colonial governance in Hong Kong, the Governor of Hong Kong, Stewart Lockhart mentioned that land surveying made land owners more positive in registering land titles with British Colonial Government in view of determination shown by the authority in land administration in Outlying Islands (including Cheung Chau). Hong Kong Colonial Government then issued a single land lease covering many land lots belonging to same family for easy management purpose (Cheung Chau Magazine, 2015). The population of Hong Kong had increased by 172% from 1876 to 1905 (Tsai, 2000), but her residents were separated by natural barriers. Although Cheung Chau has recognized as a village, the island was indeed most densely populated among the outskirt islands. The Chinese Imperial Maritime Customs remarked that Cheung Chau population has reached 5,000 in 1898 (Cheung Chau Magazine, 2015). The census of 1911 has recorded that Cheung Chau consisted a land population of 3,244 and a floating population of 4,442 (Hayes, 1962). During the outbreak of the Pacific War in 1941, the Japanese army set up Cheung Chau Residents Association to manage local affairs and to establish communication channels for Cheung Chau residents. Later, the British Colonial Government restored its rule to Hong Kong and established the Cheung Chau Rural Committee to replace the Cheung Chau Residents Association in 1960 (Cheung Chau Magazine, 2015). At the early period of the development of the New Territories, there were no land based transport and infrastructure in this densely populated island. To tackle this problem, the British Colonial Government could only rely on the ferry services to maintain effective control over Cheung Chau and other islands separated by the waters.

The sources of all non-original data/information must be quoted. Articles which have been co-authored by two authors must be fully quoted, while articles which have been co-authored by three or more authors should be quoted as "(first author) et al." For example:

According to the records of archaeological excavations, we have found that the Chinese migrants reached the Cheung Chau Island no less than 3,000 years ago. The deep anchorage of Cheung Chau provides excellent shelter, notably easterly gale (Cheung Chau Magazine, 2015). Cheung Chau has become a home port for fishing vessels since the Ming dynasty (1368-1644). During the Qing period (1644-1911), Emperor Qianlong (re. 1735-95) developed Cheung Chau as the "Bazaars" and the settlements concentrated there. Since the Tongzhi era (1856-75), Cheung Chau demonstrated its potential as an active player in business activities. At that time, Cheung Chau was a flourishing commercial centre (Hayes, 1962). Although the general infrastructure of Cheung Chau is desirable, the ferry is the sole transportation mode connecting the island with the central areas of Hong Kong. In the late 19th century, the island of Cheung Chau is a busy place where there were many of the steamers, launches and junks operating among Hong Kong, the West River and Macau (Hayes, 1962; Cheung Chau Magazine, 2015). Qing Dynasty set up a station of the Chinese Imperial Maritime Customs in Cheung Chau to control maritime traffic, carry out customs clearance, collect taxation and implement cargo inspection. Cheung Chau was a strategic point to connect the Hong Kong with surrounding areas. Thus, the maintenance of the ferry service was a fundamental concern of Cheung Chau's sustainable development.

In 1910, Walter Schofield, Assistant District Officer for New Territories South mentioned that the ferry serving Cheung Chau was single-decked, operated by Cheung Chau Kai Fong Wui. These are cargo vessels managed and operated by prominent persons of the island for a group of financially interested local parties to assist the public by providing a regular, safe and reliable means of conveying cargo and passengers between the islands. These *kai to* have mainly found in the Fong Pin Hospital and Tin Hau Temple. *Kai to* have been created propitious names like Tung On, Kung Cheong, Yee Tai On, Kung Yik and On Shun (Hayes, 1962). In order to enhance passenger safety and meet with passenger demand, Ferry Ordinance required ferry operators use 2nd hand Star Ferry boats to operate the ferry routings between Yaumatei, Kowloon City and Cheung Chau in 1917. In 1928, new ferry operator issued new ferry time schedule designed to fit the schedule of passenger from the Hong Kong Island. Europeans started constructing weekend bungalows on Cheung Chau Peak area facing the Hong Kong Island in the 1920s (Cheung Chau Magazine, 2015). Because of rapidly increasing passenger demand for travelling to Cheung Chau, the British Colonial Government decided to grant a franchise ferry operations. The Hongkong and Yaumatei Ferry Company Limited had then operated ferry services among Central, Cheung Chau, Peng Chau, Mui Wo and Lantau Island since 7 November 1938. People living in Cheung Chau started to create daily contact with the central urban area of Hong Kong under this regular ferry service. According to Foster (1975), we can identify the following major groups who benefited from the Cheung Chau ferry services: (1) users of the ferry, who pay directly; (2) those who pay for the by-products of the ferry system, such as shop owners on the islands who use the ferries to transport freight; and (3) those who own property on the islands. Cheung Chau is the small landmass, so that it has the possibility of either developing to be a self-contained Town-Country type magnet as suggested by Ebenezer (1946), or building a direct link to the main transport infrastructure (Wong, 2007). But the latter does not exist at all. In other words, the ferry services become the sole transport mode available to residents. Ferry indeed gives the Cheung Chau dwellers the opportunity to access services, goods and activities, which provide personal mobility (Wong, 2007). People are interconnected between Cheung Chau and different parts of Hong Kong through ferry services.

Traditionally, Cheung Chau was a fishing village, so that the originally fishermen population could provide their fishing boats as transportation means. But since the post Second World War era Cheung Chau has become a major tourist attraction of Hong Kong. Cheung Chau has a rich treasure of valuable antiques in the historical and folk culture like a big sword made in the Song Dynasty and the Pak Tai Temple established in the Qing Dynasty. Also, Cheung Chau has a large-scale religious event in the community, commonly known as "*Tai Ping Qing Jiao*" (sacrificial ceremony of peace and purity) ceremony organized by the local residents of the Island for over 200 years (Chew, 2009; Legislative Council Paper, 2011). Started from 2004, the "*Tai Ping Qing Jiao*" festival has been attracting between 40,000 and 50,000 of international and domestic tourists to visit the Cheung Chau Island each year. In the 1980s, Cheung Chau has started to develop into a holiday resort for the lower-middle class and young people. Cheung Chau has demonstrated demographic changes from traditional fishing village to a small influx of new non-local residents and out-migration of young natives accordingly (Chew, 2009). Therefore, development of a peripheral tourism industry undoubtedly has brought significant potential of development, and many people from other parts of Hong Kong have moved to this vibrant island. From an economic point of view, there are new opportunities for jobs. The inflow investment of capital is perceived as a means of increasing the overall welfare of the Cheung Chau population (Keller, 1980). In the same time, the frequency of ferry sailing of Cheung Chau has continuously increased. For instance, Tsui Wah Ferry's Maris Ferry provided a new ferry itinerary between Aberdeen and Cheung Chau on 8 August 2015. This routing could be more direct access to the Southern District of Hong Kong. In short, without the ferry services, it is impossible to develop large scale tourism in this relatively remote area and the non-fishing residents of the island could hardly settle in the island conveniently. Ferry provides supports cto the development of tourism and promotes intangible cultural heritage in Cheung Chau. Although the ferry operators have been facing severe deficits in their operations recently, the HKSAR government has decided to provide HKD 3.52 million subsidiary to New World Ferry for the Cheung Chau and Central route, mainly to support the children concession fare (Cheung Chau Magazine, 2015). It is clear that the government needs the ferry services to connect such populous yet peripheral island with the centre.

6. Conclusion

Ferry is the oldest public transportation means of Hong Kong which has developed for over 170 years. It connecting different parts of Hong Kong, and therefore became an essential part of the British colonial government to maintain effective control over the scattered areas of Hong Kong which are separated by the waters. Before the 1970s, the ferry system is the foundation of public transport and the sole transport mode in Hong Kong. The establishment of harbour-crossing tunnel and railway, however, were watersheds in ferry development. Indeed, the ferry has then reduced to be a supplementary means to land transport after the 1970s.

Even though the Hong Kong ferry services slowly declined since the 1970s, they still play significant roles to keep the city intact notwithstanding the hardships of deficits. The ferry also enhances the identity of the outskirt Hong Kong residents as a member of the 'Hongkongese', notably in Cheung Chau. Cheung Chau is a typical example of the transformation from a traditional fishing village to a small influx of new non-local residents and out-migration of young natives. And local identity is dually strengthened by the heightened attention of the outsiders flowing to the island on vacations and also the symbolic ferry connection between Cheung Chau and the urban centre area (Chew, 2009).

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[i] The service is only operated on the day preceding to Tin Hau Festival and on Tin Hau Festival.

Joint Scheduling of Container Berth-Quay Crane Based on Berthing Priority and Fair Principle

Lixian Fan[1], *Xingyuan Wang*[1] *and Jingbo Yin*[*2]

[1]School of Management, Shanghai University, 599 Shangda Rd., Shanghai 200444, China
[2]State Key Laboratory of Ocean Engineering, School of Naval Architecture, Ocean and Civil Engineering, Shanghai Jiao Tong University, 800 Dongchuan Rd., Shanghai 200240, China

[*]*Corresponding Author*

Abstract

As an important node in the shipping transportation, the container terminal plays a significant role in international logistics and national economies. The operation of container terminals mainly includes the processes of berth and yard allocation as well as the quay crane and container truck scheduling, in which berths and quay cranes are two interrelated scarce resources along the dockside. As a result, a reasonable scheduling can improve resource utilization and customer satisfaction and which is crucial for the productivity and service level of container terminals. In reality, the most important index to measure the performance of a container terminal is the time of the vessel waiting at port.

So, in this study, we develop a model for the optimization of the container berth-quay crane allocation based on different berthing priorities. Theses priorities are provided according to different vessel sizes and the time of arrival in the processes of berth allocation. The purpose is to minimize the total time of the vessels' waiting at port. To solve this problem, a mixed integer programming model is suggested. In solving this model, the genetic algorithm is employed in the berth allocation. The processes of mutation and crossover in genetic algorithm are based on serving orders which are determined by berthing priorities. Further, in quay crane allocation and scheduling, the fair allocation principle of Q value method is proposed.

To assess the feasibility of the model, a series of numerical experiments are performed in this paper. By solving the numerical examples, different priorities for vessels, the optimal berthing location and the optimal number of quay cranes for arrived ships are obtained. The experimental result shows that, by considering the combination of loading and unloading volume and arriving time, along with the proposed Q value of fair quay crane allocation algorism the Berth-Quay crane scheduling is significantly improved. Finally, sufficient quay crane re-scheduling can effectively shorten the time of the ships in port.

Keywords: Priority, Mixed integer programming model, Genetic algorithm, Numerical experiment

1. Introduction

Along with the development of economic globalization, great changes have taken place in the role and status of the ports since they are the key links in the international logistics supply chain. Actually, it is an important symbol of modern ports in providing fast, reliable and flexible integrated logistics management service. However, there are great challenge sin loading and unloading capacity and management level of the port in recent years because of the ever-growing scale of container ships, the growing port throughput and the port congestion. Therefore, many world-class ports have adopted the Multi-user container terminal management system to save operating costs and improve port resources utilization and efficiency, in which the optimization of berth allocation, quay crane scheduling and the joint operation are the key points to improve the efficiency of port operations.

Berth allocation is the arrangement of berth and berthing order after the arrival of ships or according to the constraints of the idle and physical conditions in various berths. Currently, FCFS (First Come First Service) method is commonly adopted in practice. However, to compete with other terminal operators, many operators have singed some strategic contracts with some big shipping companies to provide priority services for their vessels. This to some extent is an import reason for the port congestion. Therefore, how to improve the utilization rate of the berth, shorten the time of the ship in port, and reduce the cost of terminal operation is imperative in the shoreline with limited resources.

Alongside the berth allocation problem, the schedule of the loading and unloading quay cranes along the coast behind berths is another important issue whose scale and quantity are determined by the terminal operation object. Since the quay cranes can move along the dock shoreline, the utilization rate of quay cranes can be improved and the operation costs can be reduced by optimized operation. Consequently, the customer satisfaction and the calls for port will be improved.

As a transfer point of sea and land transport in the container terminal, the berth and the quay crane are the most important resources to restrict the scale and efficiency of container terminals, which are also the input of other operations. In addition, they are inter-dependent to each other. The berth allocation determines the allocation and scheduling of quay cranes, meanwhile the number of quay cranes assigned to a ship affects the docked time of the ship, which affects the subsequent berth planning. Therefore, the joint scheduling of berth-quay crane is an important measure to improve the competitiveness of container ports.

In this study, the berthing priority and service order of the ship in port, and the principle of fair quay crane allocation are introduced firstly. Next, the dynamic berth allocation problem is studied based on the integration of genetic algorithm and berthing priority. Finally, the allocation and scheduling of quay cranes are discussed according to the fair allocation principle. The goal is to minimize the total time of all ships in port considering the priority of ships.

The outline of this paper is arranged as follows: Section 2 reviews the related studies. Section 3 explains the joint scheduling model of container berth-quay crane. Section 4 designs a program to solve the problem. Section 5 is a numerical case and the main conclusions.

2. Literature Review

There are important progresses in the optimization of the berth allocation by considering various factors on the basis of a simple berth allocation. Imai et al. (2001) studied the dynamic berth allocation problem in which to the arrangement of the ship berth and berth sequence are designed according to the estimated arrival time and other relevant information. In order to reduce the cost of the port, they proposed to reduce the number of rental berths and increase the number of public berths, which has certain feasibility. Imai et al. (2003) proposed the concept of multi-user container terminal and explained the importance of ship service priority in the multi-user container terminal. They pointed out that both the size of the ship and the ship's actual loading and unloading activity are the influencing factors of the service priority. In addition, they also put forward a dynamic priority weight and added it to the mathematical model of berth allocation. Cordeau et al. (2005) studied the situation of discrete berths and proposed two different formulations: the dynamic berth-allocation model and the multi-depot vehicle routing model with time windows. Their models could solve various features of real-life problems, such as a weighted sum of service time and windows on berthing time.

The above studies all considered dynamic berth allocation according to ship size or loading, unloading activity, service time, or time windows. However, in reality the final arrival time of a ship is usually different from the planned arrival time. If the late ship first served the customers' satisfaction will be reduced. So, in considering the factors affecting ship service priority, the arrival time of the ship is also indispensable.

In addition, both the number of quay cranes and the service time of the quay crane had important influence on the berth allocation problem (Giallombardo et al., 2010). There are lots of studies focused on the optimization of berth allocation and quay crane scheduling. Bierwirth and Meisel (2010; 2015) investigated the research results of joint scheduling of berth-quay crane over past 20 years. They argued that methods of solving the joint scheduling problem of berth-quay crane were more concentrated in genetic algorithm and evolutionary algorithm, and other methods needed to be expanded. They also pointed out that some new features could be considered, such as indented berths, crane double cycling, double spreader cranes, etc. Han et al. (2010) proposed a proactive approach for robust scheduling problem with stochastic vessel arrival and container handling time. In the joint scheduling of berth-quay crane with uncertainties, a quay crane could be terminated and transferred to serving other ships during its operation. Imai et al. (2008) presented an effective joint scheduling plan of berth-quay crane in a multi-user container terminal. They relaxed some restrictions on quay crane transfer, and a ship could only be served by a certain number of quay cranes. Liang et al. (2009) considered the dynamic scheduling scheme of berth-quay crane in the case of discrete berths. Since the more quay cranes are allocated to a ship, the less time the ship is docked in the berth, berth and quay crane are closely linked. Therefore, the authors added some factors such as time, berth allocation, the number of quay crane etc. in the construction of the mathematical model.

All of the above studies are focusing on joint operation of berth-quay crane, and the objective of the optimization is to minimize the total time of all the ships in port. Considering the diversity in quay crane scheduling and its significance in time determination, in this study, the quay crane distribution is divided into two types: the initial allocation and the final allocation, and a fair principle is designed which should be followed in the quay crane scheduling.

From the perspective of methodology used in previous studies, genetic algorithm is an popular and effective means to solve the problem since the joint scheduling model of berth-quay crane is a mixed integer nonlinear programming model. Imai et al. (2003), Imai et al. (2008), Liang et al. (2009), Han et al. (2010), and Chang et al. (2010) all used the improved genetic algorithm to obtain the approximate optimal solution of their models. Of course, there are also some other methods used in solving this kind of problem. Meisel and Bierwirth (2009) proposed the construction heuristic, the local optimization procedure and two modern heuristic algorithms; Park and Kim(2003) developed two stage search procedures, which can also get the ideal solution; Giallombardo et al. (2010) combined the tabu search and the mathematical programming to solve the berth-quay crane scheduling problem. In this study, the genetic algorithm is also adopted and the mutation and crossover rules are improved. In addition, the fair allocation principle of quay cranes is added to make the algorithm selection process dynamic. Finally, it is quiet fast to get the optimal solution using the proposed model.

3. Joint Scheduling Model of Container Berth-quay Crane

Before the arrival of the ship, the berths and quay cranes will be arranged according to the arrival time and other relevant information. Since berth allocation and quay crane scheduling are closely related, the decision of berth allocation will affects the distribution of quay cranes, and both of them will directly affect the ship's time in port. So, in this study the joint scheduling of berth-quay crane not only considers the berth idle condition, but also the state of available quay cranes in the berth. By calculating the loading and unloading time of quay cranes, choose the berth that can minimize the ship's time in port.

3.1. Berthing priority

In the actual operation of the port, there are some inevitable factors, such as weather and handling delay of the former port etc., disrupt the berth allocation plan. To consider this in model development, Imai et al (2003) introduced the concept of ship priority. They proposed the priority right as a function of the ship's cargo handling capacity, and put forward 5 forms of priority weights, which are all associated with the volume of container loading and unloading.

Whereas, for the sake of providing customers with better service, the modern port not only considers the amount of container handling, but also pays attention to the ship size and the arrival time of the ship, and so on. In this study, the problem is analyzed using discrete dynamic berth allocation. In addition to volume of container handling, the arrival time of the ship is also a key factor of berthing priority.

3.2. Standardization

Before the ship reaches the port, the planning arrival time of the ship, the delay time, the volume of container handling, etc, can be informed in advance. The allocation and scheduling scheme of berth-quay cranes based on the data information is arranged by managers in port. In this program, the service priority of the ship is no longer followed by the manual allocation of FCFS. The service order of the ships is determined by the volume of ship handling and the arrival time of the ship in advance. Since these two factors are different in dimensions, they are standardized by the following equation to guarantee the reliability of the result.

$$X^* = \frac{X - min}{max - min} \tag{1}$$

Where max and min are the maximum and minimum values of the sample data.

It is worth to note that the arrival time of the ship is limited to a scheduling plan period in this study (such as one day or one week). As bigger ships have higher priority for service, the handling volume of each ship is positively correlated to its service priority.

In contrast, the shorter the arrival times the higher the priority for service. So the standardization of arrival times is designed as follows:

$$T^j_{time} = \frac{\frac{1}{T_j} - \frac{1}{T_{max}}}{\frac{1}{T_{min}} - \frac{1}{T_{max}}} \tag{2}$$

Where T^j_{time} represents the standardized arrival time of the ship j, and $\frac{1}{T_j}$ is the reciprocal of the actual arrival time of ship j; $\frac{1}{T_{min}}$ indicates the reciprocal of the earliest arrival time of all ships in port; $\frac{1}{T_{max}}$ shows the reciprocal of the latest arrival time of all ships; $j \in V = \{1, \cdots, J\}$, V is a set of all the vessels in port.

3.2.1. Determination of berthing order

In this study, the value of berthing priority determines the service order of the ship in port, that is, the ship with the greater berthing priority is served earlier. The volume of the ship handling and the arrival time are integrated to determine the berthing priority of the ship, but their influences are different. Some ports pay attention to the volume of the ship loading and unloading which suggests that the greater the volume of the ship handling, the earlier the ship's service is.

However, in order to show the principle of fairness, the arrival time is considered into the priority. The earlier the ship arrives, the earlier the ship is served. In summary, the berthing priority is calculated as:

$$S^j_{priority} = aX^j_{volume} + bT^j_{time} \tag{3}$$

Where $S^j_{priority}$ expresses the berthing priority of ship j; X^j_{volume} is the standardized handling volume of ship j; a and b are their weights which could be determined by the terminal companies according to the actual situation.

3.2.2. Fair quay crane allocation

Since the container port has a limited amount of quay cranes and each ship can only be assigned a specific number of them. If the terminal operator allocates quay cranes for berthing ships randomly or according to the experience, it could have some unfair distribution. For instance in Table 1, suppose there are 3 ships which are docked at 3 berths respectively. According to their proportions of handling volume, the allocated quay cranes are 10, 6 and 4 separately.

If the port has an additional quay crane, the allocation based on the proportion and convention will assign 11, 7 and 3 cranes to each ship now. Apparently, this result is not fair to ship 3, because the total number of quay cranes has been increased by 1, while the number being allocated to ship 3 is decreased from 4 to 3.

Table 1: Quay crane allocation based on the proportion and convention

Ship	Handling volume/TEU	Proportion (%)	Allocation of 20 quay cranes		Allocation of 21 quay cranes	
			Based on proportion	Based on convention	Based on proportion	Based on convention
ship1	103	51.5	10.3	10	10.815	11
ship2	63	31.5	6.3	6	6.615	7
ship3	34	17	3.4	4	3.57	3
Total	200	100	20	20	21	21

In order to avoid the occurrence of the above situation, fair quay crane allocation method is put forward.

3.2.3. Establishment of quantitative index

Assume the loading and unloading volumes of ship A and ship Barep_1 and p_2 respectively. The numbers of quay cranes being assigned to ship A and ship B are $n_1$and n_2.Then the volumes of each quay crane handling are $p_1/n_1$and p_2/n_2. Clearly, only when $p_1/n_1 = p_2/n_2$, the quay crane allocation is fair. Because both the volume of loading and unloading and the number of quay cranes are integers, usually $p_1/n_1 \neq p_2/n_2$. So in this situation, the ship with the larger value of $p_i/n_i (i = 1,2)$ suffers loss or it is not fair to it.

Suppose $p_1/n_1 > p_2/n_2$, and the unfair degree can be measured by the value of $p_1/n_1 - p_2/n_2$. The degree of relative unfairness for ship A is denoted as:

$$r_A(n_1, n_2) = \frac{p_1/n_1 - p_2/n_2}{p_2/n_2} \tag{4}$$

Similarly, if $p_2/n_2 > p_1/n_1$, the degree of relative unfairness for ship B is:

$$r_B(n_1, n_2) = \frac{p_2/n_2 - p_1/n_1}{p_1/n_1} \tag{5}$$

3.2.4. Determination of allocation scheme

Suppose the total number of quay cranes is increased by 1, which ship should be assigned to? By calculating $r_A(n_1 + 1, n_2)$, $r_A(n_1, n_2 + 1)$, $r_B(n_1 + 1, n_2)$, and $r_B(n_1, n_2 + 1)$ and comparison, it is not difficult to prove that: when Equation (6) is confirmed, the additional quay crane should be assigned to ship A and assigned to ship B otherwise.

$$\frac{p_2^2}{n_2(n_2+1)} < \frac{p_1^2}{n_1(n_1+1)} \tag{6}$$

Denote$Q_j = p_j^2/n_j(n_j + 1), j = 1,2,\cdots$, then the increased quay crane should be assigned to the ship with larger Q value and it is called quay crane allocation for Q value method in this study.

3.3. Mathematical model

The joint scheduling mathematical model of berth-quay crane is established on the premise of berthing priority. So, the fair allocation principle of quay crane in 3.2. is one of the constrains in the quay crane allocation and scheduling model.

3.3.1. Model assumptions

1) The requirements of ship draft and length can be satisfied by all the berths.
2) Each ship must berth only once, and the ship cannot move from a berth to another.
3) A berth can serve one ship at a time.
4) A ship can only be served after its arrival.
5) After the start of operation, a ship will not break off until the end of operation.
6) A crane cannot move across other quay cranes.

7) It is not necessary for the quay cranes to start work for the same ship at the same time, but they should stop at the same time.

8) Each berth has a maximum number of quay cranes that can be allocated.

Assumption 1) is the basic requirement of ship berthing in port. Assumption 2) and 3) are actual restrictions of port operation. Similarly, assumption 4) is the time requirement of ship in port. Assumption 5) ensures the continuity of quay crane service. Usually quay cranes are installed along the coast, and quay cranes transfer along a guide rail. So assumption 6) ensures that adjacent cranes cannot cross each other. Further, during quay crane operation, if adjustment quay cranes are adjusted they will interfere with each other, which reduce the operation efficiency of quay cranes. So in order to ensure the high efficiency of quay cranes, assumption 7) is indispensable. Lastly, berth size is generally set up according to port space and quay cranes cannot crowded in one berth which is illustrated in assumption 8).

3.3.2. Parameters

$i \in B = \{1, \cdots, I\}$ set of berths
$j \in V = \{1, \cdots, J\}$ set of ships
$k \in O = \{1, \cdots, J\}$ set of ship berthing orders in each berth
$m \in N = \{1, \cdots, M\}$ set of quay cranes
A_j arrival time of ship$j$
$y_i$the maximum number of quay cranes that can be allocated at berth i
$d \in D = \{1, \cdots, y_i\}$set of the amounts of quay cranes served for each ship
U_j the volume of loading and unloading for ship j
P the volume of handling by one quay crane in unit time
$e$adjustment time of quay cranes when a ship is docked
R a number of large enough

3.3.3. Variables

1) Decision variables

$x_{ijk}$is 1 if ship j is served at berth i as the kth ship; 0 otherwise
t_{ijk}start time of ship j at berth i as the kth ship
C_{jm}operation time of quay crane m serving ship j
$QC_j$the longest operation time of all quay cranes serving ship j
S_{jm}operation start time of quay crane m serving ship j
$QS_j$the earliest operation time of all quay cranes serving ship j
Z_j the initial allocated number of cranes for ship j
$Q_{ijkd}$$Q$ value of ship j served by d quay cranes at berth i as the kth ship

2) Auxiliary variables

α_{imn} is 1 if the ship at berth i is only served by quay cranes from the mth to the nth $(m \leq n)$,0 otherwise.
$r_{im}$is 1 if the ship at berth i is served by quay crane m,0 otherwise.
β_{mn} is 1if quay cranes from the mth to the nth $(m \leq n)$ are all working,0 otherwise.
σ_{ikd} is 1 if a ship is going to be served at berth i as the kth ship and d quay cranes are in a state to be allocated, 0 otherwise.
$\eta_{i(i+1)j}$ is 1 if quay cranes are needed to be transferred to ship j at berth $(i+1)$ from berth i,0 otherwise.
$\xi_{i(i-1)j}$ is 1 if quay cranes are needed to be transferred to ship j at berth $(i-1)(i \neq 1)$ from berth i,0 otherwise.

3.3.4. Formulation

$$\text{Minimize} \quad \sum_{i\in B}\sum_{j\in V}\sum_{k\in O} x_{ijk}\left(t_{ijk} + QC_j - A_j\right) \tag{7}$$

$$\sum_{i\in B}\sum_{k\in O} x_{ijk} = 1 \quad \forall j \in V \tag{8}$$

$$\sum_{j\in V} x_{ijk} \le 1 \quad \forall i \in B, k \in O, \tag{9}$$

$$\sum_{j\in V} x_{ijk} \le \sum_{j\in V} x_{ij(k-1)} \quad \forall k \ge 2, i \in B, \tag{10}$$

$$t_{ijk} \le R x_{ijk} \quad \forall i \in B, j \in V, k \in O, \tag{11}$$

$$\sum_{i\in B}\sum_{k\in O} t_{ijk} \ge A_j \quad \forall j \in V, \tag{12}$$

$$\sum_{j'\in V} x_{ij(k-1)}\left(t_{ij'(k-1)} + QC_{j'} + e\right) \le \sum_{j\in V} t_{ijk} \quad \forall i \in B, k \in O, j \ne j' \in V, \tag{13}$$

$$R\left(x_{ijk} - 1\right) \le x_{ijk}\left(QC_j - C_{jm}\right) \quad \forall m \in N, i \in B, j \in V, k \in O, \tag{14}$$

$$R\left(x_{ijk} - 1\right) \le x_{ijk}\left(S_{jm} - QS_j\right) \quad \forall m \in N, i \in B, j \in V, k \in O, \tag{15}$$

$$\sum_{i\in B}\sum_{k\in O} t_{ijk} = QS_j \quad \forall j \in V, \tag{16}$$

$$\left(C_{jm} + S_{jm} - S_{j'm}\right)\left(C_{j'm} + S_{j'm} - S_{jm}\right) \le 0 \quad \forall m \in N, j \ne j' \in V, \tag{17}$$

$$C_{jm} + S_{jm} - \left(C_{jm'} + S_{jm'}\right) = 0, \quad \forall m \in N, j \ne j' \in V, \tag{18}$$

$$x_{ijk} Z_j - y_i \le 0 \quad \forall i \in B, j \in V, k \in O, \tag{19}$$

$$U_j/(Z_j P) - QC_j \ge 0 \quad \forall j \in V, \tag{20}$$

$$\beta_{(m-1)n}\alpha_{imn} r_{(i-1)(m-1)} = \{0,1\}, \quad \forall m(\ne 1), n \in N, i(\ne 1) \in B, \tag{21}$$

$$\beta_{(m-1)n}\alpha_{imn} r_{(i+1)(m-1)} = \{0\}, \quad \forall m(\ne 1), n \in N, i \in B, \tag{22}$$

$$\beta_{m(n+1)}\alpha_{imn} r_{(i+1)(n+1)} = \{0,1\}, \quad \forall m, n \in N, i \in B, \tag{23}$$

$$\beta_{m(n+1)}\alpha_{imn} r_{(i-1)(n+1)} = \{0\}, \quad \forall m, n \in N, i(\ne 1) \in B, \tag{24}$$

$$\sigma_{ikd}\eta_{i(i+1)j}\left(Q_{ij'k(d-1)} - Q_{(i+1)jk'd'}\right) < 0,$$
$$\forall i \in B, j \ne j' \in V, k, k' \in O, d, d' \in D \tag{25}$$

$$\sigma_{ikd}\xi_{(i-1)ij}\left(Q_{ij'k(d-1)} - Q_{(i-1)jk'd'}\right) < 0,$$
$$\forall i(\ne 1) \in B, j \ne j' \in V, k, k' \in O, d, d' \in D \tag{26}$$

$$x_{ijk} \in \{0,1\} \quad \forall i \in B, j \in V, k \in O, \tag{27}$$

$$t_{ijk} \ge 0 \quad \forall i \in B, j \in V, k \in O, \tag{28}$$

$$C_{jm}, QC_j, S_{jm}, QS_j, Z_j \ge 0 \quad \forall m \in N, j \in V, \tag{29}$$

$$Q_{ijkd} > 0 \quad \forall i \in B, j \in V, k \in O, d \in D \tag{30}$$

$$\alpha_{imn} \in \{0,1\} \quad \forall i \in B, m, n(m \le n) \in N, \tag{31}$$

$$r_{im} \in \{0,1\} \quad \forall i \in B, m \in N, \tag{32}$$

$$\beta_{mn} \in \{0,1\} \quad \forall m, n(m \le n) \in N, \tag{33}$$

$$\sigma_{ikd} \in \{0,1\} \quad \forall i \in B, k \in O, d \in D, \tag{34}$$

$$\eta_{i(i+1)j} \in \{0,1\} \quad \forall i \in B, j \in V, \tag{35}$$

$$\xi_{i(i-1)j} \in \{0,1\} \quad \forall i(\ne 1) \in B, j \in V, \tag{36}$$

The objective function (7) is to minimize the total time of all ships in port. Constraints (8)~(10) ensure that one berth must be assigned to each ship, every ship is only docked once, and all berthing ships at each berth are served in sequence. Constraints (11) indicates that processing starting time of ship, which is 0 in the case of nonsense, has an upper bound. In addition, constraint (12) is also time constraint, and the processing starting time of each ship must be greater than its arrival time. Constraint (13) shows that the processing starting time of a ship must be greater than processing ending time of previous ship for two adjacent ships docked to the same berth. Constraint (14) expresses that when a ship is served by many quay cranes at the same time, there must exist the longest serving time of quay cranes which is greater than or equal to the serving times of any quay cranes. Similarly, constraint (15) represents that when a ship is served by many quay cranes, the processing starting time of each quay crane may be different, and the earliest processing starting time must be less than or equal to processing starting time of any other quay cranes. Constraint (16) shows that the earliest processing starting time of the quay crane is also the processing starting time of the ship. Constraint (17) ensures that two ships cannot be served by a quay crane at the same time. Constraint (18) indicates that the end time of all quay cranes serving the same ship is the same. Constraint (19) represents the number of quay cranes allocated to a ship cannot exceed the maximum number of quay cranes allowed by a berth. Constraint (20) expresses that for any ship, the initial allocation number of quay cranes is not necessarily the final allocation number of quay cranes. Because other quay cranes can be transferred to serve the ship during its serving time, the initial allocation number of quay cranes must be less than or equal to the final allocation number of quay cranes. So, the serving time of initially allocated quay cranes must be greater than or equal to the serving time of final allocated quay cranes.

Constraints (21)~(24) show that a crane cannot move across other quay cranes as shown in Figure 1 below:

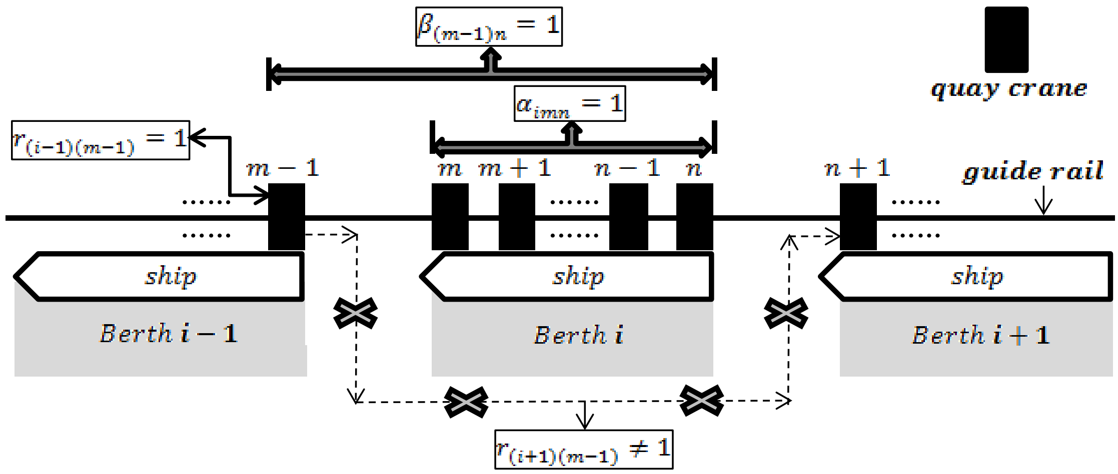

Figure 1: Schematic diagram of not crossing of quay cranes

Figure 1 illustrates that quay crane $(m-1), m, \cdots, (n-1), n$ are all working ($\beta_{(m-1)n} = 1$), and the ship at berth i is only served by quay cranes from the mth to the nth ($\alpha_{imn} = 1$); the ship at berth $(i-1)$ is served by quay crane $(m-1)$ ($r_{(i-1)(m-1)} = 1$), and the ship at berth $(i+1)$ cannot directly served by quay crane$(m-1)$, which means that crane m-1 cannot move across cranes$m$~n ($r_{(i+1)(m-1)} \neq 1$). The above is the rules in which quay crane $(m-1)$ cannot cross to right shown by constraints (21) and (22). Constraints (23) and (24) explain quay crane $(n+1)$ cannot cross to the left.

Constraints (25)~(26) show that the scheduling of quay cranes should follow the fair allocation principle of quay cranes in section 3.2 as shown in Figure 2 below:

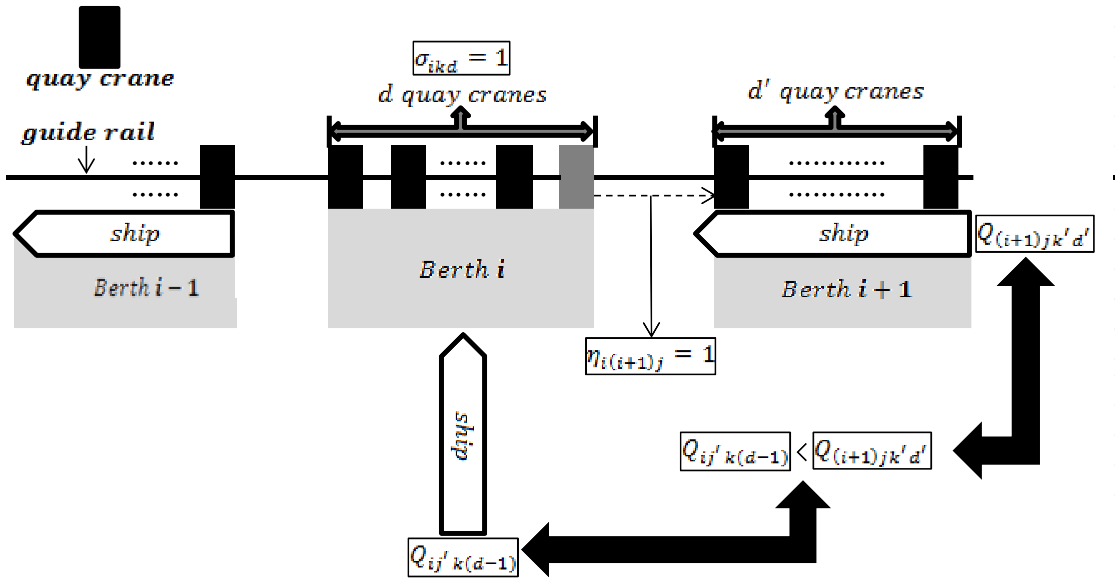

Figure 2: Schematic diagram of quay crane scheduling based on Q value

Figure 2 suggests that d quay cranes are in a state to be allocated at berth i, so $\sigma_{ikd} = 1$. Correspondingly, one ship at berth $(i + 1)$ is served by d' quay cranes. The Q value of ship j'(to be served at berth i) allocated with$(d - 1)$ quay cranes is$Q_{ij'k(d-1)}$, and the Q value of ship j(to be served at berth i+1) allocated with d' quay cranes is $Q_{(i+1)jk'd'}$. If $Q_{ij'k(d-1)} < Q_{(i+1)jk'd'}$, i.e. allocation of quay cranes is unfair, quay cranes should be transferred to ship j at berth $(i + 1)$ from berth i, i.e.$\eta_{i(i+1)j} = 1$.This is the rules of Constraint (25). Similarly, constraint (26) explains quay cranes should bet transferred from berth i to berth $(i - 1)$.

4. Solution Procedure based on priority and Q value

The model in this study is a nonlinear mixed integer programming model and the solution procedure is complex. Bierwirth and Meisel (2015)ascertained that genetic algorithm had the inherent heuristic feature of random search, which can effectively solve the random problem of berth-quay crane joint scheduling. However, considering the dynamic arrival of ships and the fair principle of quay crane allocation and scheduling, the solution of the model has some uncertainty. Just like Imai et al. (2008), this study weakens the genetic algorithm in solving the joint scheduling model of berth-quay crane.

The genetic algorithm is only employed in the berth allocation. The processes of mutation and crossover in genetic algorithm are based on serving orders determined by berthing priorities in section 3.1. Further, in quay crane allocation and scheduling, the fair allocation principle of Q value method is employed. The concrete solving processes are shown in Figure 3 below.

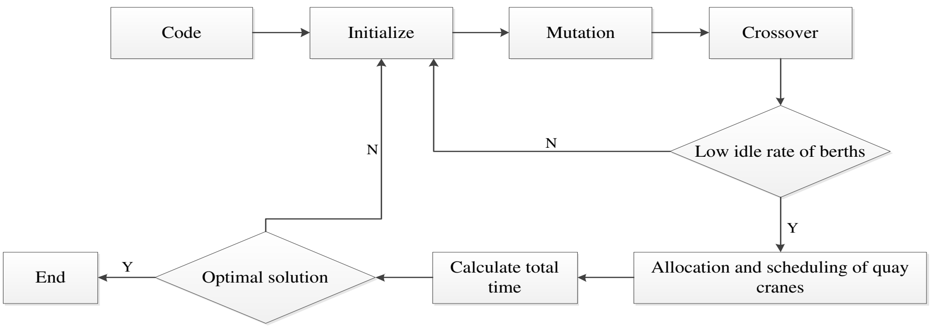

Figure 3: Solution procedure

4.1. Chromosome coding

The natural number coding is used in this study. Each chromosome represents a berthing plan, which includes berths, ship serving orders based on berthing priorities, and berthing orders of ships at each berth. In a chromosome, each gene indicates serving orders of ships except 0, by which each berth is separated, and berthing orders of ships at each berth are the orders from left to right in the chromosome. In addition, the sum of the numbers of berths and ships minus 1equals the length of a chromosome. Fig.4 shows 7 ships arriving at port corresponding to serving orders that are based on berthing priorities. Fig. 5 represents an example of chromosome coding with 7 arriving ships docked at 3 berths. Table 2 illustrates the berthing situation of ships based on Fig.4 and Fig.5.

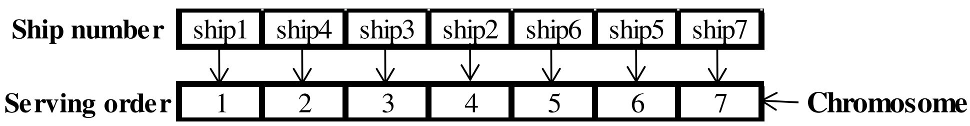

Figure 4: Serving orders of ships arriving port

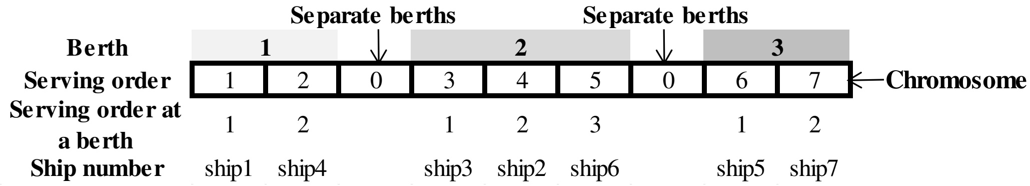

Figure 5: Chromosome coding

Table 2: Berthing situation of ship

Ship arriving order	Serving order	Berthing place	Serving order at berth
ship1	1	1	1
ship2	4	2	2
ship3	3	2	1
ship4	2	1	2
ship5	6	3	1
ship6	5	2	3
ship7	7	3	2

4.2. Initial population

Suppose there are J ships arriving at a port, the serving orders corresponding to the ships are 1, 2…J. If there are I berths, (I-1) points (location) are randomly selected among 1, 2… (J-1)(location) and the "0" is inserted after the (I-1) points. This generates one chromosome encoding berth allocation plan. It is repeated until the established size of initial population is met.

4.3. Mutation

Under established orders of ship serving, the purpose of mutation is to expand the diversity of ship berthing plan. Similar to previous studies it randomly selects two genes from a chromosome and then swaps the positions of the two genes.

4.4. Crossover

The aim of the crossover operation is to adjust the berthing plans in the chromosomes in a large magnitude. The specific procedure includes:

Step.1: Randomly select two genes from chromosome1, and the positions of the two genes are respectively noted down b_1' and b_1''. Gene segment $b_1' \sim b_1''$ corresponds to berths $I_1', I_1' + 1, \cdots, I_1''$.Where, I_1'' is the maximum berth number in chromosome1.

Step.2: Seek the positions of b_2' and b_2'' corresponding to chromosome1 from chromosome2. I_2'' is the maximum berth number in chromosome2.

Step.3: Exchange the gene segments in chromosome1 and chromosome2.

Step.4: Search the 0 items in chromosome1 and go to Step 5. There are 3 situations in the searching results:

1) Number of 0s equals to$(I_1'' - 1)$. If repeated 0 items are searched in Step5, then do not note down 0 items, that is $0 \notin B_1$.
2) Number of 0s is larger than$(I_1'' - 1)$.If repeated 0 items are searched in Step5, then note down 0 items that is $0 \in B_1$.
3) Number of 0s is less than$(I_1'' - 1)$. If repeated 0 items are searched in Step5, then do not note down 0 items, that is $0 \notin B_1$.
4) The process is then repeated for chromosome2.

Step.5: Search repeated genes compared to gene segment $b_1' \sim b_1''$ from left to right for chromosome1. The set of repeated genes is B_1, and the set of berths corresponding to repeated genes is I_{B_1}.Similarly, search repeated genes compared to gene segment $b_2' \sim b_2''$ for chromosome2.The set of repeated genes is B_2, and the set of berths corresponding to repeated genes is I_{B_2}.

Step.6: Randomly exchange all genes in B_1 and B_2.

Step.7: Determine berths in chromosome1 and chromosome2 respectively, which belong to $\{I_1', I_1' + 1, \cdots, I_1''\} \cup I_{B_1}$ and $\{I_2', I_2' + 1, \cdots, I_2''\} \cup I_{B_2}$. Finally, rearrange genes at these berths from small to large.

Fig. 6 shows 8 ships arriving port correspond to serving orders based on berthing priority. Fig. 7~ Fig. 9 demonstrate the procedure in crossover process with 8 ships docked at 4 berths. Table 3lists the berthing situation of ships before and after crossover.

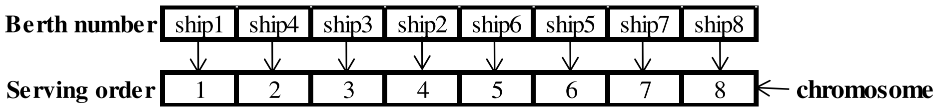

Figure 6: Serving orders of ships arriving port

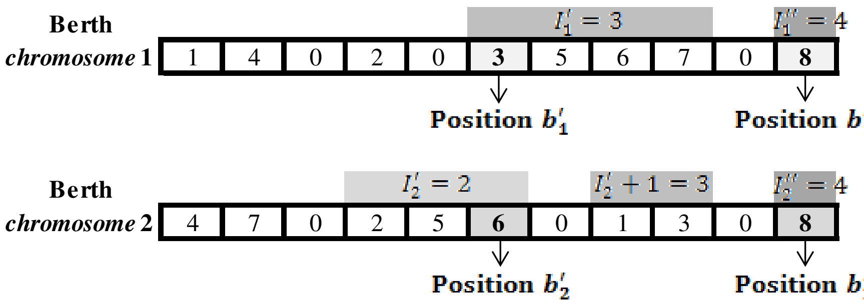

Figure 7: Step1 and Step2 in crossover process

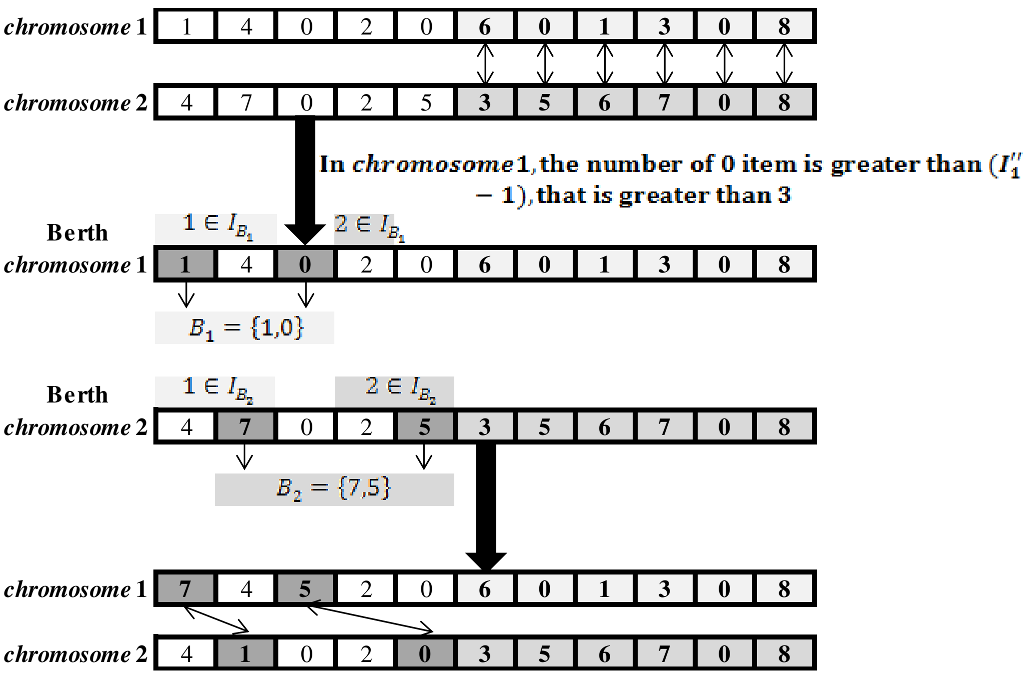

Figure 8: Step3~Step6 in crossover process

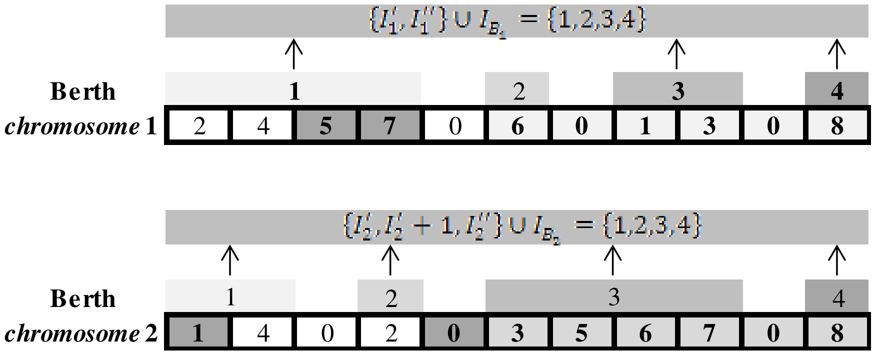

Figure 9: Step7 in crossover process

Table 3: Berthing situation of ships before and after crossover

		*chromosome*1		*chromosome*2	
Arriving number	Serving number	Berthing position and serving order before crossover	Berthing position and serving order after crossover	Berthing position and serving order before crossover	Berthing position and serving order after crossover
ship1	1	1(1)	3(1)	3(1)	1(1)
ship2	4	1(2)	1(2)	1(1)	1(2)
ship3	3	3(1)	3(2)	3(2)	3(1)
ship4	2	2(1)	1(1)	2(1)	2(1)
ship5	6	3(3)	2(1)	2(3)	3(3)
ship6	5	3(2)	1(3)	2(2)	3(2)
ship7	7	3(4)	1(4)	1(2)	3(4)
ship8	8	4(1)	4(1)	4(1)	4(1)

Note: numbers in parentheses indicate serving orders at berth.

4.5. *Low idle rate of berths for the first I ships*

In reality, if the first several ships adjacent in arriving are served by one berth, it will lead to high berth idle rate, such as Fig. 10 (1-4 are serving by berth 1). Because each ship has a priority order and in order to improve the model's searching efficiency, only the chromosomes with the first I (number of berths in a port) ships assigned to different berths are classed as feasible solutions.

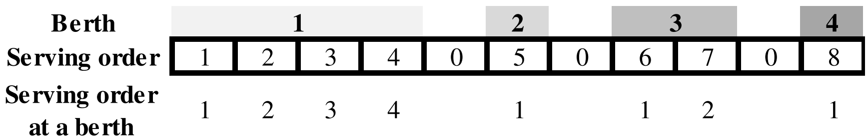

Figure 10: Schematic diagram of high idle rate

It is worth to note that there is no such restriction for the allocation of the following ships. Before berthing in a port, the allocation of quay cranes has already assigned to the ship by its Q value, which is called a preliminary plan. During the servicing time, it is possible that some adjacent cranes may be transferred to it, which is the final allocation plan.

4.6. *Allocation and scheduling of quay cranes*

In this study, the allocation and scheduling of quay cranes are based on a dynamic allocation mechanism using fairness principle. It is originally assigned a certain number of quay cranes to a ship before berthing according to its Q value and this is called an initial allocation. During the serving time of a ship, the number of quay cranes can rise due to the scheduling of the adjacent quay cranes which is called the final allocation in this study. The specific processes of the allocation and scheduling are as follows.

4.6.1. Initial allocation of quay cranes about the first I ships

Where
$U = \{U^1, U^2, \cdots, U^{I-1}, U^I\}$ is the set of handling volumes of ships corresponding to the genes 1 ~ I.
M is the total numbers of quay cranes at port.
$C = \{C^1, C^2, \cdots, C^{I-1}, C^I\}$ is the set of the allocation numbers of quay cranes.
y_{i_i} is the maximum number of quay cranes that can be allocated at berth i_i.
$Q' = \{Q^1, Q^2, \cdots, Q^I\}$ is the set of all Q values.

Step.1: Allocate quay cranes by rounding down

While$i \leq I$ do
if $[\frac{U^i}{U^1+U^2+\cdots+U^I} * M] \geq y_{i_i}$ // the notation "[]" indicates the integer notation
when set $C^i = y_{i_i}$ else then set $C^i = [\frac{U^i}{U^1+U^2+\cdots+U^I} * M]$;

Step.2: Reallocation of quay cranes based on the Q value

Step 2.1: Calculate the Q values of the ships corresponding to the genes $1 \sim I$ separately using the formula $Q^i = \frac{(U^i)^2}{C^i*(C^i+1)}$

Step 2.2: Calculate the rest of quay cranes using the formula $M - (C^1 + C^2 + \cdots + C^I)$ after allocation of cranes using rouding down operation

Step 2.3: The final allocation procedure

while $M - (C^1 + C^2 + \cdots + C^I) - 1 \neq 0$ do seek the maximum value among the Q values $(Q^1, Q^2, \cdots, Q^I)$, assume the maximum value Q^i, if $C^i = y_{i_i}$ then seek the maximum value except the Q^i
else then let $C^i \leftarrow C^i + 1$ and recalculate the Q^i value using the formula $Q^i = \frac{(U^i)^2}{C^i*(C^i+1)}$;

4.6.2. Final allocation of the quay cranes for the following ships

There are some additional principles for the final allocation of the quay cranes for the following.
1) The ship with the highest priority has to be served firstly.
2) During the servicing time of a ship, the rescheduling of quay cranes need to be considered at the beginning of serving for a ship to be served at adjacent berths.
3) The allocation and scheduling number of quay cranes at each berth cannot exceed the maximum restrict of the berth.

Where
$A = \{A^1, A^2, \cdots, A^I, \cdots, A^J\}$ is the set of the arrival time of the ships corresponding to the genes 1 ~ J.
$t' = \{t^1, t^2, \cdots, t^I, \cdots, t^J\}$ is the set of the service start time of the ships corresponding to the genes 1 ~ J.
$t'_C = \{t_C^1, t_C^2, \cdots, t_C^I, \cdots, t_C^J\}$ is the set of the service time of quay cranes corresponding to the genes 1 ~ J,

where $t_C^1 = \left[\frac{U^1}{P*C^1}\right], t_C^2 = \left[\frac{U^2}{P*C^2}\right], \cdots, t_C^J = \left[\frac{U^J}{P*C^J}\right]$.
$t'_E = \{t_E^1, t_E^2, \cdots, t_E^I, \cdots, t_E^J\}$ is the set of the service end time of the ships corresponding to the genes 1 ~ J,

where $t_E^1 = e + t_C^1, t_E^2 = e + t_C^2, \cdots, t_E^J = e + t_C^J$.

In a scheduling plan of ships, the number of the adjacent berth is 1 or 2 for one ship. Since, the scheduling of quay cranes is based on the Q value method and the total time is calculated by the two sets A andt_E', so, only the situation of one adjacent berth is discussed. Next, gene $J'$is searched, where$J' \in \{I+1, I+2, \cdots, J-1, J\}$.

Where
$i_{J'}$ is the berth corresponding to the gene J'.
I' is the gene prior to the gene J' at the berth $i_{J'}$.
I'' is the gene nearest to the gene J' at the adjacent berth.

If $t_E^{I'} > t_E^{I''}$then set $C^{J'} = C^{I'}$ and compare the size of $t^{J'-1}$ and $t_E^{I'}$

{ situation1:
if $t^{J'-1} > t_E^{I'}$ then calculate the time parameters of the first situation:
$t^{J'} = t_E^{J'-1} + e$ and $t_C^{J'} = \left[\frac{U^{J'}}{P*C^{J'}}\right]$ and $t_E^{J'} = t^{J'} + t_C^{J'}$
else then

situation2:
calculate the time parameters of the second situation:
$t^{J'} = t_E^{I'} + e$ and $t_C^{J'} = \left[\frac{U^{J'}}{P*C^{J'}}\right]$ and $t_E^{J'} = t^{J'} + t_C^{J'}$
}Else then compare the values of $t_E^{I''}$ and $t_E^{J'-1}$

{ situation3:
if $t_E^{J'-1} > t_E^{I''}$ then set $C^{J'} = C^{I'}$ and calculate the time parameters of the third situation
else then compare the values of $t_E^{I'}$and $t^{J'-1}$
{if $t_E^{I'} > t_E^{J'-1}$ then set $U_{surplus}^{I''} = U^{I''} - P * C^{I''} * (t_E^{I'} - t^{I''})$ and $Q^{I''} = \frac{(U_{surplus}^{I''})^2}{C^{I''}(C^{I''}+1)}$ and $Q^{J'} = \frac{(U^{J'})^2}{(C^{I'}-1)*C^{I'}}$

situation4:
if $Q^{J'} > Q^{I''}$ then set $C^{J'} = C^{I'}$ and calculate the time parameters of the fourth situation
else then set $C^{J'} = C^{I'} - 1$ and let $C^{I''} \leftarrow (C^{I''} + 1)$

situation5:
if $C^{I''} = y_{i_{I''}} = y_{2_{I''}}$ then calculate the time parameters of the fifth situation
$t^{J'} = t_E^{I'} + e$ and $t_C^{J'} = \left[\frac{U^{J'}}{P*C^{J'}}\right]$ and $t_E^{J'} = t^{J'} + t_C^{J'}$ and $t_E^{I''} = t_E^{I'} + \left[\frac{U_{surplus}^{I''}}{P*C^{I''}}\right]$
while $C^{I''} \neq y_{i_{I''}} = y_{2_{I''}}$ do set $Q^{I''} = \frac{(U_{surplus}^{I''})^2}{C^{I''}(C^{I''}+1)}$ and $Q^{J'} = \frac{(U^{J'})^2}{(C^{I'}-1)*C^{I'}}$

situation6:
if $Q^{J'} > Q^{I''}$ then calculate the time parameters of the third kind

situation7:
else then set $C^{J'} = C^{I'} - 1$ and let $C^{I''} \leftarrow (C^{I''} + 1)$ and calculate the time parameters of the seventh situation

situation8:
if $t_E^{J'-1} > t_E^{I'}$ then set $U_{surplus}^{I''} = U^{I''} - P * C^{I''} * (t_E^{J'-1} - t^{I''})$ and $Q^{I''} = \frac{(U_{surplus}^{I''})^2}{C^{I''}(C^{I''}+1)}$ and $Q^{J'} = \frac{(U^{J'})^2}{(C^{I'}-1)*C^{I'}}$

The allocation of quay cranes and the time corresponding to the gene J' are similar to situation6 and situation7, but the start time of the ship is set to $t^{J'} = t_E^{J'-1} + e$.

As mentioned above, the service end time of each ship can be obtained. So, the time of each ship at port can also be calculated by the difference between the end time and the arrival time.

4.7. Fitness function

The objective function of the model is to minimize the total time of all ships in port. This study adopts the exponential transformation method and the fitness function is shown below:

$$f(x) = 1/(1 + \exp(y(x)/1000)) \tag{42}$$

Where $y(x)$ is the original objective function.

5. Numerical Experiment

5.1. Data

The data used in this part is collected by an international container port in Ningbo, China. The port has 4 discrete berths and 15 quay cranes. In addition, the maximum number of quay cranes is 6 at each berth, the loading and unloading efficiency of each quay crane is 40TEU/ (60min), and the adjustment time of each quay crane is 30min. The port is relatively busy and there are a large number of ships waiting to be served each day. As ships need to wait for a long time in the anchorage, unfair phenomenon of quay crane allocation often occurs. In order to solve the above problems, we randomly select the arriving data of ships in one day. It should be noted that the arrival time of ships is the actual arrival time, which includes the delay time of ship. Specifically, the data are shown in Table 4 below.

Table 4: Arriving data of ships

Ship arriving order	Container handling volume(TEU)	Arrival time(min)	Arrival time(h)	Standardization of the volume of container handling	Reciprocal of arrival time (min)	Standardization of reciprocal of arrival time (min)	FCFS
ship1	486	300	5:00	0.2461	0.00333	1.0000	1
ship2	838	310	5:10	0.4747	0.00323	0.9319	2
ship3	454	315	5:15	0.2253	0.00317	0.8995	3
ship4	840	345	5:45	0.4760	0.00290	0.7246	4
ship5	1647	360	6:00	1.0000	0.00278	0.6481	5
ship6	477	363	6:03	0.2403	0.00275	0.6336	6
ship7	405	385	6:25	0.1935	0.00260	0.5339	7
ship8	594	387	6:27	0.3162	0.00258	0.5254	8
ship9	1080	396	6:36	0.6318	0.00253	0.4882	9
ship10	738	423	7:03	0.4097	0.00236	0.3861	10
ship11	401	450	7:30	0.1909	0.00222	0.2963	11
ship12	294	450	7:30	0.1214	0.00222	0.2963	12
ship13	476	462	7:42	0.2396	0.00216	0.2597	13
ship14	1105	480	8:00	0.6481	0.00208	0.2083	14
ship15	107	484	8:04	0.0000	0.00207	0.1974	15
ship16	437	485	8:05	0.2143	0.00206	0.1947	16
ship17	267	497	8:17	0.1039	0.00201	0.1632	17
ship18	412	523	8:43	0.1981	0.00191	0.0999	18
ship19	567	541	9:01	0.2987	0.00185	0.0596	19
ship20	348	570	9:30	0.1565	0.00175	0.0000	20

The traditional and common method for service is FCFS which is listed in the last column in Table 4. However, both handling volume and arrival time impact the berthing priority of each ship. Table 5 provides 5 different sets of berthing priorities of serving orders with different weights on handling volume and arrival time.

Table 5: Serving orders with different weights on handling volume and arrival time

Ship number	Berthing priority (0.5, 0.5)	Order based on priority	Berthing priority (0.4, 0.6)	Order based on priority	Berthing priority (0.3, 0.7)	Order based on priority	Berthing priority (0.2, 0.8)	Order based on priority	Berthing priority (0.1, 0.9)	Order based on priority
ship1	0.6231	3	0.6984	3	0.7738	2	0.8492	1	0.9246	1
ship2	0.7033	2	0.7490	2	0.7947	1	0.8405	2	0.8862	2
ship3	0.5624	5	0.6298	4	0.6972	4	0.7646	3	0.8321	3
ship4	0.6003	4	0.6252	5	0.6500	5	0.6749	5	0.6998	4
ship5	0.8241	1	0.7889	1	0.7537	3	0.7185	4	0.6833	5
ship6	0.4369	7	0.4763	7	0.5156	7	0.5549	6	0.5943	6
ship7	0.3637	11	0.3977	9	0.4318	9	0.4658	9	0.4999	9
ship8	0.4208	9	0.4417	8	0.4627	8	0.4836	8	0.5045	7
ship9	0.5600	6	0.5457	6	0.5313	6	0.5169	7	0.5026	8
ship10	0.3979	10	0.3956	10	0.3932	10	0.3909	10	0.3885	10
ship11	0.2436	13	0.2541	12	0.2647	12	0.2752	12	0.2858	11
ship12	0.2089	14	0.2263	14	0.2438	14	0.2613	13	0.2788	12
ship13	0.2497	12	0.2517	13	0.2537	13	0.2557	14	0.2577	13
ship14	0.4282	8	0.3842	11	0.3402	11	0.2963	11	0.2523	14
ship15	0.0987	19	0.1185	19	0.1382	17	0.1579	16	0.1777	16
ship16	0.2045	15	0.2026	15	0.2006	15	0.1986	15	0.1967	15
ship17	0.1335	18	0.1395	17	0.1454	16	0.1513	17	0.1573	17
ship18	0.1490	17	0.1391	18	0.1293	19	0.1195	18	0.1097	18
ship19	0.1791	16	0.1552	16	0.1313	18	0.1074	19	0.0835	19
ship20	0.0782	20	0.0626	20	0.0469	20	0.0313	20	0.0156	20

Note: The decimals in parentheses represent the weights of handling volume and arrival time separately.

5.2. *Result and Comparison*

5.2.1. *FCFS*

In the Ningbo port, the arriving ships dock in the berths from left to right. Then, the operators allocate quay cranes according to the handling volumes of the ships according to a hierarchical classification in Table 6.Moreover, one ship has to dock in anchorage if there are not enough quay cranes according to the standard rules in Table 6.

Using this operation mechanism, the total time in port for the 20 ships in Table 4 is 19358 minutes.

Table 6: FCFS allocation of quay cranes

Volume of handling	≤ 200	201～500	501～800	801～1000	1001～1500	＞1500
Number of quay cranes	1	2	3	4	5	6

5.2.2. *Optimal solution*

In genetic algorithm, we set parameters of mutation rate = 0.5, crossover rate = 0.8, the number of initial population =100, and the number of generations =100.

To prevent the convergence of parameters in the genetic algorithm, thegenetic algorithm is conducted 100 times under every set of ship serving orders. Lastly, we also compare the optimal solution in each genetic algorithm, and finally find the optimal solution of the algorithm. Fig. 11~Fig. 15 and Table 7 are the results of the algorithm running.

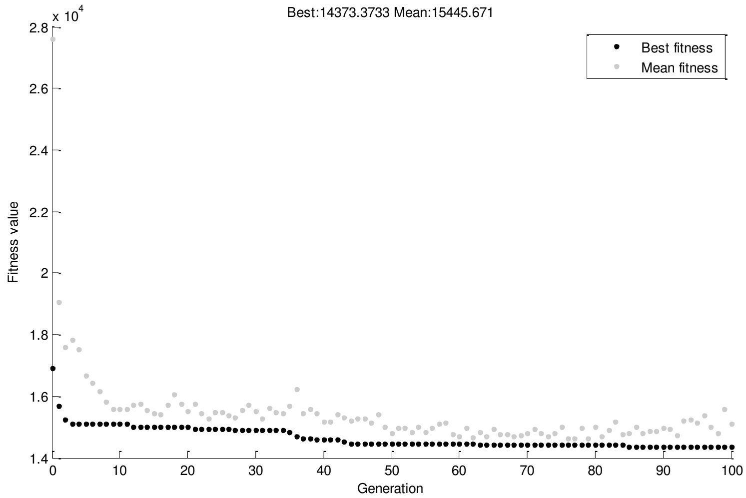

Figure 11: Optimal solution under weight of berthing priority (0.1, 0.9)

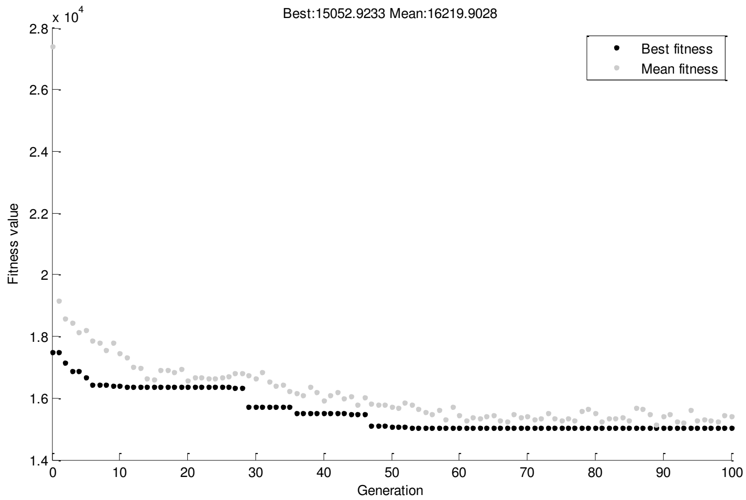

Figure 12: Optimal solution under weight of berthing priority (0.2, 0.8)

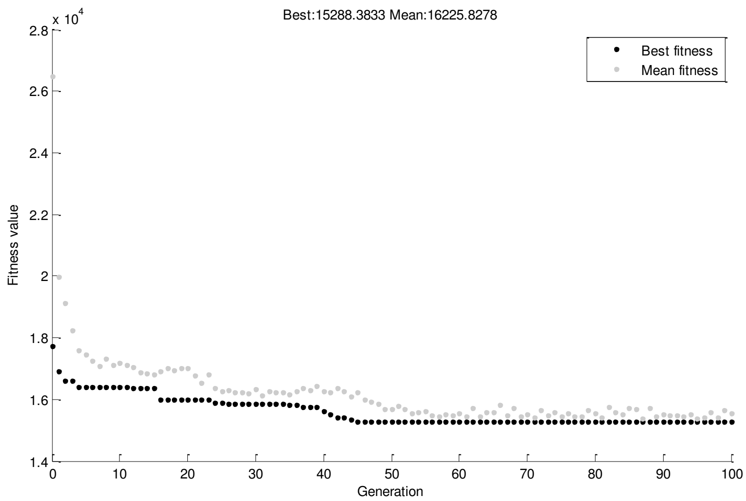

Figure 13: Optimal solution under weight of berthing priority (0.3, 0.7)

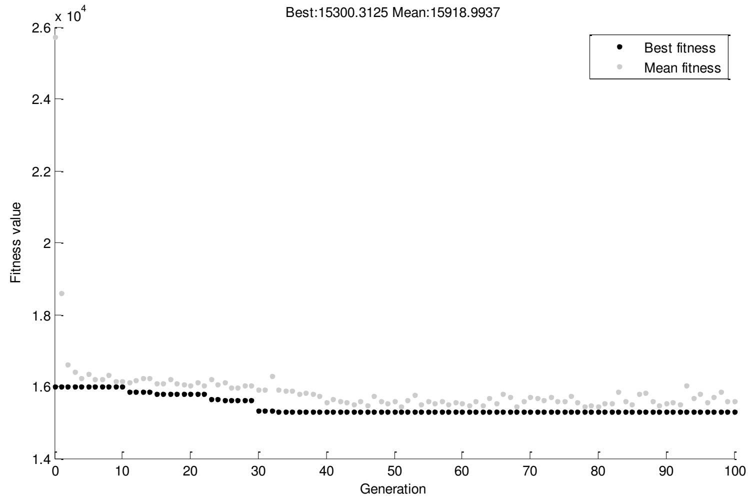

Figure 14: Optimal solution under weight of berthing priority (0.4, 0.6)

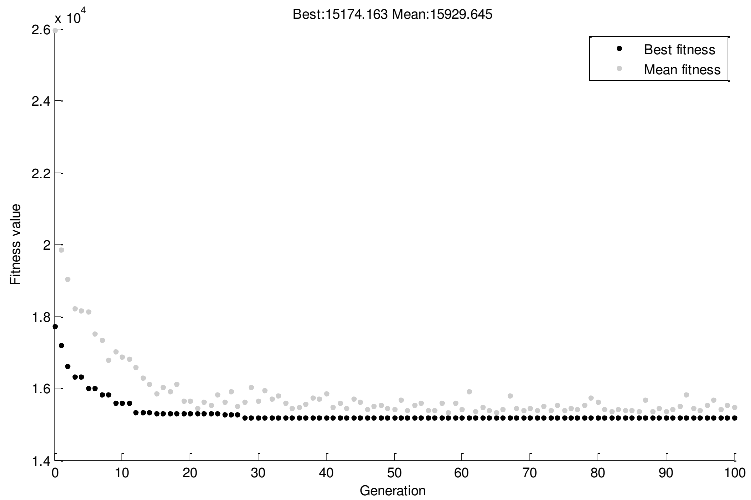

Figure 15: Optimal solution under weight of berthing priority (0.5, 0.5)

Table 3: Comparison of optimal solutions

Different proportions of priority	Times and generations	Optimal solution (min)	Compared with FCFS (min)	Percentage
(0.1, 0.9)	19-85	14373	-4985	-25.75%
(0.2, 0.8)	87-53	15053	-4305	-22.24%
(0.3, 0.7)	67-45	15288	-4070	-21.02%
(0.4, 0.6)	63-33	15300	-4058	-20.96%
(0.5, 0.5)	6-28	15174	-4184	-21.61%

Note: The second column is the originality of the optimal solution. For example, 19-85 means that in the 100 times, the optimal solution is obtained at the 85th generation in the 19th time.

Fig. 11 ~Fig. 15 illustrate the evolve process of the optimal solutions at certain generations. The optimal solutions are the minimum total time in port. Table 7 provides a detailed comparison according to the different weight compositions. Compared with the total time used in FCFS, the total times used under different priorities have been reduced by more than 20%.In addition, the best solution from the (0.1, 0.9) weight composition is the best with a lower total time in port. However, with the increase of the weight for handling volume, the total time in port maintains near15000 min. This indicates that by considering the handling volume as one part of the priority, the Berth-Quay crane scheduling is significantly improved.

5.2.3. *Allocation and scheduling results of each weight composition*

Each optimal solution represents an integrated Berth-Quay crane arrangement, and the corresponding chromosome represents the optimal scheduling plan of the ships. So, Table 8 reports the final arrangement of berths and their serving orders for different weigh compositions of handling volume and arrival time. Besides, the final allocations of quay cranes are also shown in Table 8.

Table 8: Joint scheduling of different priorities

	Berthing priority (0.1, 0.9)		Berthing priority (0.2, 0.8)		Berthing priority (0.3, 0.7)		Berthing priority (0.4, 0.6)		Berthing priority (0.5, 0.5)	
Ship	Berthing place and serving order	Final allocation	Berthing place and serving order	Final allocation	Berthing place and serving order	Final allocation	Berthing place and serving order	Final allocation	Berthing place and serving order	Final allocation
ship1	3(1)	3	4(1)	3	3(1)	2	1(1)	3	1(1)	6
ship2	4(1)	5	1(1)	5	4(1)	3	3(1)	4	1(4)	5
ship3	2(1)	3	2(1)	2	2(1)	6	4(1)	6	2(2)	4
ship4	1(1)	4	4(2)	4	1(2)	4	3(2)	4	2(1)	4
ship5	2(2)	5	3(1)	5	1(1)	4	2(1)	2	3(1)	2
ship6	4(2)	5	1(2)	5	2(2)	6	4(2)	6	1(2)	5
ship7	4(3)	5	3(2)	3	1(3)	6	3(3)	5	2(3)	4
ship8	1(2)	2	2(2)	4	4(2)	3	1(2)	3	4(3)	5
ship9	3(2)	3	1(3)	5	3(2)	2	2(2)	2	4(2)	4
ship10	3(3)	5	4(3)	10	1(4)	5	2(3)	4	1(3)	5
ship11	4(4)	3	3(3)	3	4(3)	3	1(3)	4	2(4)	2
ship12	3(4)	4	2(4)	6	1(5)	4	4(4)	5	1(4)	5
ship13	2(3)	6	1(4)	5	2(4)	6	3(4)	3	4(4)	4
ship14	2(4)	6	2(3)	3	2(3)	4	4(3)	6	3(2)	5
ship15	3(5)	4	1(5)	3	2(6)	4	4(6)	4	2(5)	4
ship16	4(5)	5	4(4)	4	2(5)	6	4(5)	5	3(3)	4
ship17	3(6)	2	3(4)	2	1(6)	4	3(6)	4	1(7)	3
ship18	4(6)	5	2(5)	4	3(3)	4	3(7)	4	1(6)	3
ship19	2(5)	6	1(6)	5	2(7)	4	3(5)	4	1(5)	5
ship20	4(7)	5	4(5)	4	1(7)	4	2(4)	3	4(5)	4

Note: 1) The numbers in the columns of "Berthing place and serving order" represent the ships' berthing places (in parentheses) and their serving orders. 2) The numbers in the columns of "Final allocation" indicate the numbers of quay cranes allocated for each ship.

In addition to the results above, the algorithms in this study can also be used to calculate the specific starting and ending time of each quay crane serving for each ship. For space restriction, Table 9 only reports the specific joint scheduling for each ship with initial and final crane allocations including their starting and ending times for the priority (0.1, 0.9).

Table 9: Specific joint scheduling under the priority (0.1, 0.9)

Ship	Berthing place and Serving order	Quay crane numbers 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
ship1	3(1)								330 / 615	330 / 615	330 / 615					
ship2	4(1)											340 / 624	340 / 624	340 / 624	340 / 624	340 / 624
ship3	2(1)					345 / 602	345 / 602	345 / 602								
ship4	1(1)	375 / 690	375 / 690	375 / 690	375 / 690											
ship5	2(2)			720 / 1161	720 / 1161	632 / 1161	632 / 1161	632 / 1161								
ship6	4(2)											654 / 798	654 / 798	654 / 798	654 / 798	654 / 798
ship7	4(3)											828 / 1006	828 / 1006	828 / 1006	828 / 1006	828 / 1006
ship8	1(2)	720 / 1530	720 / 1530													
ship9	3(2)								720 / 923	720 / 923	720 / 923					
ship10	3(3)								953 / 1196	953 / 1196	953 / 1196	1036 / 1196	1036 / 1196			
ship11	4(4)													1036 / 1237	1036 / 1237	1036 / 1237
ship12	3(4)									1226 / 1336	1226 / 1336	1226 / 1336	1226 / 1336			
ship13	2(3)			1226 / 1344	1226 / 1344	1226 / 1344	1226 / 1344	1226 / 1344	1226 / 1344							
ship14	2(4)			1375 / 1651	1375 / 1651	1375 / 1651	1375 / 1651	1375 / 1651	1375 / 1651							
ship15	3(5)									1375 / 1415	1375 / 1415	1375 / 1415	1375 / 1415			
ship16	4(5)											1445 / 1522	1445 / 1522	1375 / 1522	1375 / 1522	1375 / 1522
ship17	3(6)									1445 / 1645	1445 / 1645					
ship18	4(6)											1552 / 1675	1552 / 1675	1552 / 1675	1552 / 1675	1552 / 1675
ship19	2(5)			1681 / 1823	1681 / 1823	1681 / 1823	1681 / 1823	1681 / 1823	1681 / 1823							
ship20	4(7)											1711 / 1835	1711 / 1835	1711 / 1835	1711 / 1835	1711 / 1835

In Table 9, each quay crane has a specific number from 1 to 15. Each square represents the certain quay crane in a column. Those black squares are allocated to serve for ships. The gray squares indicate that those cranes are reallocated to the adjacent ships during the operation of that ship. Moreover, the numbers in black or gray squares indicate the start time of the quay cranes while the numbers below black or gray squares denote the end time of the quay cranes.

It is worth to note that the unit of the start and end time is minutes. For example, forship1, the 8th, 9th and 10th are allocate to serve it. The start time and the end time are the 330th minute and the 615th minute respectively. For the ship5, the 5th, 6th and 7th quay cranes are allocated to serve at the 632th minute. At the 720th minute, the 3th and 4th quay cranes are scheduled to serve for the ship5 by the *Q* value method. The end time of the quay cranes is the 1161th minute. Lastly, the service time of each quay for each ship can be gained by the difference between the end time and the start time.

6. Conclusions

Generally speaking, the management of the port or terminal usually arranges the serving order of ships based on their arrival time. However, in reality some ships have certain priorities. The service order of the ships is not necessarily only dependent on the arrival time. Some late ships may be served first and this could be one of the reasons for port congestion. To resolve this problem, this study proposes a Berth-Quay crane scheduling model considering service priority.

In the scheduling of cranes, a fair allocation principle based on Q value is proposed. As the scheduling of quay cranes are dynamic, the initial schedule of quay cranes will be changed based on the principle of fair allocation principle.

The genetic algorithm is used to solve the problem of joint operation of berth and quay cranes. In the genetic algorithm, the genes on chromosomes represent the ships' service order. After mutation and crossover, the position of some gene in a chromosome is changed, but the service orders are remained. In order to reduce the search space of the algorithm, the concept of low idle rate is proposed, so that those chromosomes do not satisfy with the low idle rate are deleted.

The decoding process of the chromosomes is the allocation and scheduling process of the Berth-Quay cranes. The total time of the ships in port is used to express the fitness value of the genetic algorithm. By comparing the size of the fitness value, the optimal solution is obtained.

The proposed Berth-Quay crane schedule has certain practical significance. The terminal companies can change the weights of loading and unloading volume and the arrival time to get an optimal arrangement in port. In addition, the proposed fair allocation principle can greatly improve the customer satisfaction and the efficiency of the terminals.

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Compensation for Pirates: Justice or Topsy-Turvy World?

Klaas Willaert

Department of European, Public and International Law, Faculty of Law, Ghent University, Belgium

Abstract

In December 2014, the European Court of Human Rights decided in *Ali Samatar and Others v. France* and *Hassan and Others v. France* that France had violated the rights of pirate suspects and needed to pay a compensation to these 'victims'. Both cases concerned similar situations, where Somali pirate suspects were held in custody for too long before they were formally charged or brought before a judge. According to some, the judgments are completely in line with the European practice of human rights protection, yet others consider them to be totally incomprehensible and disastrous for the global fight against piracy. It indeed needs to be stressed that prosecution and punishment of piracy is already a difficult story, so additional impediments should be avoided.

The European Court of Human Rights needs to look at the bigger picture and has to be conscious of the negative effects of rigorous jurisprudence in piracy cases. Profound awareness of the damaging impact of the judgments on the shipping industry and the global fight against piracy would be appropriate and this should lead to a more favorable approach of the Court towards states that engage in prosecuting arrested pirate suspects themselves, despite the costs and risks. After all, the stern attitude of the Court may not only cause more difficulties in the fight against piracy, but can also lead to bigger excesses with regard to human rights.

Keywords: Piracy, Law of the Sea, Human Rights, ECHR, Detention

1. Introduction and Facts

In December 2014, the European Court of Human Rights decided in *Ali Samatar and Others v. France* and *Hassan and Others v. France* that France had violated the rights of pirate suspects and needed to pay a compensation to these 'victims'. [i]Both cases concerned similar situations, where Somali pirate suspects were held in custody for too long before they were formally charged or brought before a judge.

In the first case before the Court, the claimants were six Somalis (*Ali Samatar and Others v. France*)[ii] who were prosecuted in France for acts of piracy. The crimes were committed in April 2008, when a French cruise liner (*Le Ponant*), on its way from the Seychelles to the Mediterranean, was attacked and captured off the coast of Somalia. [iii]There were no passengers on board during the hijacking, but thirty crew members, including twenty French citizens, were taken hostage for a week and were only released after payment of a ransom. France put everything in place to arrest the suspects and a special intervention unit of the French police (*GIGN*) succeeded to apprehend them on the day of the ransom payment. [iv]They were placed under military supervision and four days later, when the Somali authorities gave permission, they were flown to France, where they appeared before an investigative judge two days later and were indicted.

The six Somali suspects appealed the decision at the French national level, primarily claiming that their apprehension on Somali soil and their detention before the transfer to France was illegal, but those requests were denied. [v]The French courts stated that the arrests were carried out within the context of the ad hoc cooperation with the Somali authorities, allowing access to Somali territorial waters and authorizing all necessary measures (including the proportional use of force) to combat piracy. [vi]Taking into account the specific circumstances of the case, they also concluded that the actions of France complied with the 'promptness'-requirement, stipulated in article 5 §3 ECHR. According to the French courts, insurmountable conditions, characterized by the waiting period between the arrests and the permission granted by the Somali authorities to transfer the suspects to France, justified the detention. On the merits of the case, four suspects were convicted and two of them were acquitted.[vii]

The second case before the European Court of Human Rights (*Hassan and Others v. France*)[viii] concerned three Somali citizens who were also prosecuted in France for acts of piracy. They were suspected of hijacking the French yacht *Carréd'As* in September 2008, robbing the people on board (a French couple) and taking them hostage. An operation to free the hostages was set up in line with the then already adopted Resolution 1816 of the United Nations Security Council[ix], enabling willing states to access Somali territorial waters and deploy all necessary means to combat piracy. French troops were able to capture the suspects in Somali waters two weeks later and managed to free the hostages. During the operation, one of the suspects was killed and six Somalis, including the three plaintiffs, were arrested. [x]After six days on a French war vessel, the suspects were transferred to a military base in Djibouti, from where they were flown to France a day later. The waiting period can again be explained by the required permission of the Somali authorities, that was only granted after five days. Once the suspects arrived in France, they were brought before an investigating judge two days later and were indicted. The three claimants lodged an appeal against the decision, but the French courts confirmed the ruling, stating that the actions of the French troops corresponded with the goal of Resolution 1816 (in particular with respect to the detention of the suspects) and judging that the arrest and detention of the suspects before their transfer to France did not constitute a breach of article 5 ECHR, considering the 'wholly exceptional circumstances'.[xi]

2. Judgment of the European Court of Human Rights

In both cases, the Somali suspects did not accept the decisions of the French courts and, respectively in March and August 2010, turned to the European Court of Human Rights. Different arguments were raised:

- Article 5 §1 ECHR[xii]: In *Hassan and Others v. France*, the plaintiffs put forward that there was no legal basis for their long detention (six days and 16 hours) by the French military authorities.

- Article 5 §3 ECHR: In both *Ali Samatar and Others v. France* and *Hassan and Others v. France*, the claimants raised that their right to liberty and security was violated, as they were not 'promptly' brought before a judge.

- Article 5 §4 ECHR: In both cases, the plaintiffs also relied on the argument that they did not have access to a court to challenge the lawfulness of their arrest in Somalia or their detention until they were taken into police custody in France.

Regarding article 5 §1 ECHR, the European Court of Human Rights decided that the arrest and detention, for the purpose of bringing them before the competent legal authority, was lawful. The Court noted in particular that there were plausible reasons to suspect them of committing offences against a French vessel and French citizens. The actions were in line with the rules of international law and were deemed 'foreseeable', but the Court however found that the applicable law at the relevant time did not meet the quality standards laid down by its case-law. The main reason that led to this decision was the fact that the law applicable to the situation of individuals arrested by French forces for acts of piracy did not include any rule defining the conditions of deprivation of liberty that would subsequently be imposed on them pending appearance before a judge. The Court thus concluded that the legal system in force at the relevant time did not provide sufficient protection against arbitrary interference with the right to liberty and that there had therefore been a violation of article 5 §1 ECHR.

With respect to article 5 §3 ECHR, the Court started off by stating that the length of the applicants' detention before their arrival in France was caused by 'wholly exceptional circumstances' and could therefore be justified, referring to its case-law. [xiii]The French authorities intervened off the coast of Somalia, 6.000 kilometers from mainland France. As the Somali authorities lacked the capacity to deal with the widespread problem and to ensure that the applicants stood trial, it was decided to take them back to France. There was no evidence to suggest that the transfers had taken longer than necessary, taking into account the difficulties related to the organization of such an operation from a sensitive area like the Horn of Africa, and given that the flights to France had been arranged as soon as the Somali authorities had given their permission.

The Court however noted that the applicants were held in police custody for another 48 hours after their arrival in France, rather than being brought immediately before an investigating judge. The additional delay in both cases could not be justified in any way, according to the Court. The European Court of Human Rights was of the opinion that the French authorities had ample time to prepare everything and should have made sure that the Somali plaintiffs were brought 'promptly' before the competent legal authority: eleven days in the case of *Ali Samatar and Others v. France* and at least eighteen days in *Hassan and Others v. France* had passed between the decision to intervene and the arrival of the claimants in France. Summarized: the long detention pending the transfer of the applicants to France did not constitute a breach of the 'promptness'-requirement because of 'wholly exceptional circumstances', but the additional delay on French soil was not tolerable and violated article 5 §3 ECHR.

Concerning article 5 §4 ECHR, the Court observed that it had already examined the deprivation of liberty sustained by the applicants before being brought before the investigating judge under article 5 §3 ECHR. Pointing out that the provisions of paragraph 3 were stricter than those of paragraph 4 with regard to the criterion of 'promptness', the Court decided that it did not need to examine the facts under article 5 §4 ECHR.[xiv]

Based on article 41 ECHR, the Court awarded the applicants just satisfaction for the reported violations: France had to pay respectively 2.000 and 5.000 euros in respect of non-pecuniary damage in *Ali Samatar and Others v. France* and *Hassan and Others v. France*; for costs and expenses, the compensations varied between 1.200 and 9.000 euros per claimant.

3. Impact of the Judgment and Criticism

Not surprisingly, the decisions of the Court immediately drew bitter criticism. [xv]After all, prosecuting states already have ample reasons for reluctance: high transport and procedural costs, problems with regard to evidence, difficulties concerning detention and penitentiary capacity, potential asylum claims, … [xvi]Needless to say, an additional obstacle, in the form of possible convictions of prosecuting states and compensations for pirate suspects, is absolutely undesirable. The commitment of western states to prosecute and try pirates is necessary to combat this global issue in an efficient and effective way, as exclusive prosecution by the local states would certainly cause capacity problems and would not always meet the desired standards in terms of arrest, custody, prosecution, trial and punishment. Article 105 of the United Nations Convention on the Law of the Sea certainly stipulates that the courts of the State which carried out the seizure should decide upon the penalties to be imposed. [xvii]An increasing presence of the 'catch and release' phenomenon, describing situations wherein piracy suspects are arrested, but are subsequently released because of the difficulties concerning prosecution, can be considered a huge risk. Finally, attention has to be paid to the risk-reward analysis that pirates are conducting: the odds of impunity, a long stay in a comfortable western prison or even political asylum are already taken into account, but now the possibility of being awarded a large compensation should also be added to the equation. [xviii]This can of course cause a downfall of the already declining deterrence of pirate arrests, leading to a complex string of worrying developments.

The discussed decisions of the European Court of Human Rights immediately served as examples in Denmark, where nine Somali piracy suspects, who tried to hijack a Danish ship in November 2013, were awarded a compensation by the Danish judge because they were detained for approximately 13 days before they appeared in front of a judge via video link. [xix]The suspects each received more than 2.500 euros and to make matters worse, the Danish authorities gave up on prosecuting them and transferred the alleged perpetrators to the Seychelles to stand trial. [xx]The compensation awards to piracy suspects seemed to have set the tone and introduced a detrimental trend for the commercial shipping industry.

The International Maritime Bureau expressed its concern over the decisions of the European Court of Human Rights and did not like them at all. [xxi]The IMB pointed out that there are practical difficulties with respect to the gathering of evidence and the transportation of the alleged perpetrators when a crime is committed at sea, thousands of miles from where the court proceedings take place. These complexities need to be fully appreciated, according to the IMB. The organization was worried about the message that the judgments might send out to other pirates and the implications it may have on shipping and seafarers' safety. They sincerely hoped that the decisions would not discourage European navies from taking appropriate action against widespread piracy along vital international trade routes.

Other associations and support groups also voiced their disapproval: according to Roy Paul, director of the Maritime Piracy Humanitarian Response Programme, the decisions are an insult to every seafarer that has been attacked or taken hostage by pirates, as surely this constitutes a true violation of their right to freedom and security. [xxii]He did not understand why the atrocities committed by these criminals were not duly considered and could not believe that these far-reaching rights, guaranteed by European states, were also applied to Somali pirate suspects. To fully appreciate the circumstances and the possible drawbacks of their decisions, the judges should be confronted with a number of piracy victims, who were deprived of all their human rights and never received any compensation. Roy Paul concluded that the judges appeared to be looking at the letter of the law, not the spirit: the provisions were installed to protect innocent people, not to reward criminals. In his opinion, the pirates gave up any of their rights when they set sail to attack innocent seafarers who were simply doing their work. On behalf of the seafarers, their families and the shipping industry in general, he requested the European states to take urgent actions against these 'crazy' judgments. Many people shared his opinion, labelling the verdict as 'ludicrous' and a 'farce'. Some claim that the decisions reached the height of absurdity and suggest that the Court's independence has transformed into irrationality and incomprehensible arrogance.[xxiii]

4. Evaluating the Judgment

Although the above statements are not at all nuanced, often oversimplified and do not always have a sound legal basis, there is a certain logic behind it and the concern and incomprehension is sincere and (partly) fair. Profound awareness of the negative impact of the judgments on the shipping industry and the global fight against piracy would be appropriate and this should lead to a more favorable approach of the Court towards states that engage in prosecuting and trying arrested pirate suspects themselves, despite the costs and risks. It needs no explanation that the local standards concerning trial and the conditions for detention cannot match the European requirements and the European Court of Human Rights needs to realize that, apart from an extremely robust approach by the European navies or the undesirable 'catch and release' phenomenon, this is the only alternative right now. After all, if the Court hampers prosecution and trial of pirates in Europe because of harsh decisions like these, this will only cause European countries to renounce and (at best) transfer these responsibilities to regional countries, resulting in even worse conditions for the pirate suspects and, taking into account the high standards of the Court, multiple human rights violations. A little bit more goodwill from the European Court of Human Rights would come a long way. My assessment of the judgments of the Court is however twofold.

With regard to the reported breach of article 5 §1 ECHR, I firmly oppose the opinion of the Court. It has to be noted that in *Medvedyev and Others v. France*[xxiv], an earlier case about a Cambodian freighter that was arrested on alleged charges of drug trafficking, the Court identified a difference between the provisions concerning arrest and detention in the field of overseas drug trafficking[xxv] on the one hand, and the same provisions within the framework of the fight against piracy[xxvi] on the other hand. It stated that article 108 of the United Nations Convention on the Law of the Sea, contrary to the piracy provisions of the same convention, did not constitute an exception to the principle of exclusive jurisdiction of the flag state and could therefore not be considered a 'sufficient legal basis' to board the ship and arrest the people on board. The Court thus clearly indicated that the piracy provisions in principle should pass the 'sufficient legal basis'-test. [xxvii]In *Medvedyev and Others v. France* it admittedly concerned a boarding and arrest on the high seas, but as UN resolutions created the possibility to act the same way in Somali territorial waters and the consent of the Somali authorities was given[xxviii], such cases should be treated the same way. Judgments to the contrary, like the assessment of the Court in *Hassan and Others v. France* that the applicable law did not include any rule defining the conditions of deprivation of liberty, despite the fact that the intervention and arrest by the French authorities in Somali territorial waters was deemed legal and 'foreseeable' on the basis of Resolution 1816, are otherwise hardly compatible with the earlier case-law of the Court. On this point I argue for a more consistent and gentle attitude of the European Court of Human Rights: pronouncing violations of article 5 §1 ECHR in piracy cases need to be avoided at all cost.

The abovementioned critical comments do however not mean that the prosecuting states do not have to adjust their behavior in any way. With respect to the reported violations of article 5 §3 ECHR, it must be noted that the decisions of the Court may seem unreasonable and out of touch with reality at first, but (after a proper analysis) cannot be deemed completely incorrect. Although a milder approach would have been better for the greater good of all, the responsibility of the prosecuting states should be stressed. The protest and indignation of the shipping industry was understandable, considering that there are already ample problems and difficulties hindering consistent prosecution and trial of pirates, but their arguments were not always justified. Many people view the compensations as an inconceivable reward for pirates, but it has to be clearly emphasized that the guaranteed rights of article 5 ECHR, protecting individuals against unlawful deprivation of freedom, are not only conferred to suspects who later turn out to be not guilty, but also to the ones who are convicted in the end. [xxix]By definition, they are at a stage when a court has not yet pronounced on guilt and it would be really odd to compensate acquitted individuals, while withholding any compensation from convicted suspects. Looking at it the other way around, the prospect that thoroughly undeserving individuals might collect a nice paycheck after brutal acts of piracy could be precisely the spur that is needed to ensure that states bring the suspects before a judge as soon as possible. Negligent states should act faster and in a more consistent way. Earlier case-law and the circumstances of the discussed cases have demonstrated that it was certainly possible to satisfy the 'promptness'-requirement, so every state that engages in prosecuting and trying arrested pirate suspects themselves, an attitude that needs to be commended and encouraged, should take all necessary measures to bring pirate suspects before a judge as soon as possible and make this an absolute priority. After all, the purpose of article 5 §3 ECHR is to facilitate the detection of any ill-treatment and to minimize any unjustified interference with individual liberty by means of an automatic initial review within a strict time-frame. France argued in both cases that the additional period in police custody was necessary for the purposes of the investigations, but this unfortunate custom of intensifying or finalizing the investigation once the alleged perpetrators reach European soil should be renounced. Targeted measures, enabling and obligating states to prepare the cases once the suspects are arrested abroad, can suffice to answer both needs, creating a vital mutual understanding between the prosecuting states and the Court. [xxx]By judging that the length of the overseas detention was justified because of 'wholly exceptional circumstances', the Court already showed some compliance, so an additional effort of the prosecuting states to bring the suspects before the competent legal authorities as soon as possible should be expected and is, in my opinion, not inappropriate.

5. Conclusion

By way of conclusion it should be clear that human rights issues play an important role in the fight against piracy and increasingly leave their mark on arrest, prosecution and trial of pirates. [xxxi]There wasn't enough attention paid to it in the past, but the recent judgments of the European Court of Human Rights prove that this must change soon, as the impact can be huge. The states will have to take action, irrespective of the oversimplified criticism of the decisions, that is however sincere and (partly) fair. The human rights violations the pirates are facing while being held in custody are indeed not at all comparable to the abuse, violence and terror that seafarers are suffering in case of a pirate attack. Everyone is aware that human rights serve a higher purpose and, in principle, they need to be complied with at any time and in any situation. However, a bit more understanding from the European Court of Human Rights, that admittedly judged in a nuanced way and took into account the wholly exceptional circumstances, is more than advisable.

Violations of both article 5 §1 ECHR (in *Hassan and Others v. France*) and article 5 §3 ECHR (in *Ali Samatar and Others v. France* and *Hassan and Others v. France*) were established by the Court, eventually leading to a conviction of France and the obligation to pay compensation to Somali pirate suspects. With respect to article 5 §3 ECHR, the Court judged that the 'promptness'-requirement was not met: the length of the detention abroad was justified because of 'wholly exceptional circumstances', but the additional 48 hours under police custody on French soil, before the alleged perpetrators appeared before a judge, was deemed excessive. This assessment of the Court may seem unreasonable and disconnected, but is not at all irrational or incorrect. After all, the prosecuting state itself is also at fault here. Despite the problems that inevitably rise during an investigation and trial held several thousand miles away from the crime scene, it should be perfectly possible to bring the pirate suspects before a judge as soon as they arrive in the country, considering the time the authorities had to prepare everything during the detention abroad. European states that engage in prosecuting and trying pirates themselves should adapt their policy in order to satisfy this requirement. Compliance with article 5 §3 ECHR is very important and by making an additional effort in that respect, a reasonable understanding with the European Court of Human Rights, which is crucial but seems a bit lost now, can be reached.

With regard to the reported breach of article 5 §1 ECHR, I do however not share the opinion of the European Court of Human Rights. Considering the fact that the Court made a lucid distinction between the piracy provisions of the United Nations Convention on the Law of the Sea and the provision about overseas drug trafficking in *Medvedyev and Others v. France*, it was clear that the piracy articles meet the 'sufficient legal basis'-test of the Court. Pronouncing a breach of article 5 §1 ECHR should thus absolutely be avoided. On that point I plead for a consistent attitude of the Court, paying attention to its case-law to guarantee legal certainty, and a more favorable approach towards states that engage in prosecuting and trying arrested pirate suspects themselves, despite the costs and risks. The European Court of Human Rights needs to look at the bigger picture and has to be conscious of the negative effects of rigorous jurisprudence in piracy cases. After all, this stern (and according to some unworldly) attitude of the Court may not only cause more difficulties in the fight against piracy, but can also lead to bigger excesses with regard to human rights.

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Appendix

Article 5 – Right to liberty and security

1. Everyone has the right to liberty and security of person. No one shall be deprived of his liberty save in the following cases and in accordance with a procedure prescribed by law:
(a) the lawful detention of a person after conviction by a competent court;
(b) the lawful arrest or detention of a person for non-compliance with the lawful order of a court or in order to secure the fulfilment of any obligation prescribed by law;
(c) the lawful arrest or detention of a person effected for the purpose of bringing him before the competent legal authority on reasonable suspicion of having committed an offence or when it is reasonably considered necessary to prevent his committing an offence or fleeing after having done so;
(d) the detention of a minor by lawful order for the purpose of educational supervision or his lawful detention for the purpose of bringing him before the competent legal authority;
(e) the lawful detention of persons for the prevention of the spreading of infectious diseases, of persons of unsound mind, alcoholics or drug addicts or vagrants;
(f) the lawful arrest or detention of a person to prevent his effecting an unauthorised entry into the country or of a person against whom action is being taken with a view to deportation or extradition.

2. Everyone who is arrested shall be informed promptly, in a language which he or she understands, of the reasons for his arrest and of any charge against him.

3. Everyone arrested or detained in accordance with the provisions of paragraph 1.c of this article shall be brought promptly before a judge or other officer authorised by law to exercise judicial power and shall be entitled to trial within a reasonable time or to release pending trial. Release may be conditioned by guarantees to appear for trial.

4. Everyone who is deprived of his liberty by arrest or detention shall be entitled to take proceedings by which the lawfulness of his detention shall be decided speedily by a court and his release ordered if the detention is not lawful.

5. Everyone who has been the victim of arrest or detention in contravention of the provisions of this article shall have an enforceable right to compensation.

[i] 'France must pay pirates damages', Maritime Security Review, 4 December 2014, http://www.marsecreview.com/2014/12/france-must-pay-pirates-damages/ (consulted on 12 January 2015); 'European Court of Human Rights Orders France to Pay Damages to Somali Pirates', Piracy Law – CommunisHostis Omnium, 7 January 2015, http://piracy-law.com/2015/01/07/european-court-of-human-rights-orders-france-to-pay-damages-to-somali-pirates/ (consulted on 12 January 2015).
[ii]ECHR, *Ali Samatar and Others v. France*, 2014.
[iii] 'Six Somali pirates on trial in Paris over capture of Le Ponant crew', RFI, 22 May 2012, http://www.english.rfi.fr/africa/20120522-six-somali-pirates-trial-paris-over-capture-le-ponant (consulted on 28 January 2015).
[iv]After release of the hostages, French helicopters tracked the suspects from a military base in Djibouti. When they tried to flee into the desert, special forces were deployed: a sniper disabled the engine of the get-away car and six suspects were arrested. Local officials claim that at least three people died and eight had been wounded in the raid, but French authorities denied that there had been any casualties ('France raid ship after crew freed', BBC News, 12 April 2008, http://news.bbc.co.uk/2/hi/africa/7342292.stm (consulted on 28 January 2015)).
[v]*Républiquefrançaise v. Ali X et al.*, Courd'appel de Paris 6 April 2009; *Républiquefrançaise v. Ali X et al.*, Cour de Cassation 16 September 2009, nr. 09-82777.
[vi]This was stated in a diplomatic letter from the *Transitional Federal Government* (*TFG*) to the French government of 5 April 2008.
[vii]*Républiquefrançaise v. Ali X et al.*, Courd'Assises de Paris 14 June 2012; 'Prised'otages du Ponant: Trois des 6 accusséspeuventsortir de prison', RTL, 15 June 2012, http://www.rtl.be/info/monde/france/prise-d-otages-du-ponant-trois-des-6-accuses-peuvent-sortir-de-prison-296098.aspx (consulted on 28 January 2015); 'La nouvelle vie parisienne des 'pirates' du Ponant', Direct Matin, 25 June 2012, http://www.directmatin.fr/france/2012-06-25/la-nouvelle-vie-parisienne-des-pirates-du-ponant-42699 (consulted on 28 January 2015).
[viii]ECHR, *Hassan and Others v. France*, 2014.
[ix]SC Res. 1816 (2008).
[x] 'French hostages freed in gunbattle with pirates', CNN International, 16 September 2008, http://edition.cnn.com/2008/WORLD/africa/09/16/somalia.pirates/index.html?iref=nextin (consulted on 12 January 2015).
[xi]*Républiquefrançaise v. X Yakoub et al.*, Courd'appel de Paris 6 October 2009; *Républiquefrançaise v. X Yakoub et al.*, Cour de Cassation 17 February 2010, nr. 09-87254.
[xii]For the text of article 5 ECHR, see Appendix.
[xiii]See for example ECHR, *Rigopoulis v. Spain*, 1999; ECHR, *Medvedyev and Others v. France*, 2010; ECHR, *Vassis and Others v. France*, 2013.
[xiv]It can thus be stated that the European Court of Human Rights interprets the 'promptness'-requirement in an even stricter sense if the detention period in the country where the suspects will be tried is preceded by a spell of actual deprivation of freedom, like the detention of individuals on the high seas (see for example ECHR, *Vassis and Others v. France*, 2013).
[xv]See for example 'A European Court Is Wrong about France', American Thinker, 22 December 2014, http://www.americanthinker.com/articles/2014/12/european_court_wrong_france.html (consulted on 28 January 2015); 'IMB concern over pirate payouts', Maritime Security Review, 29 December 2014, http://www.marsecreview.com/2014/12/imb-concern-over-pirate-payouts/ (consulted on 12 January 2015); 'Second case of pirate compensation draws bitter criticism', Oceanus Live, 11 December 2014, http://www.oceanuslive.org/main/viewnews.aspx?uid=00000944 (consulted on 20 January 2015).
[xvi]See for example A. Ademun-Odeke, 'Jurisdiction by Agreement over Foreign Pirates in Domestic Courts' (2011) 24 U.S.F. Mar. L.J. 35; R. P. Kelley, 'UNCLOS, but No Cigar: Overcoming Obstacles to the Prosecution of Maritime Piracy' (2011) 95 Minn. L. Rev. 2285; E. Kontorovich, ''Guantanamo on the sea': The difficulties of prosecuting pirates and terrorists' (2010) 98 Cal. L. Rev. 243;J. A. Roach, 'General problematic issues on exercise of jurisdiction over modern instances of piracy' in C. R. Symmons (ed.), *Selected contemporary issues in the law of the sea* (Leiden: Martinus Nijhoff Publishers, 2011), pp. 119.
[xvii]Article 105, United Nations Convention on the Law of the Sea, 1982, (1994) 1833 UNTS 3.
[xviii]Official data of the Central Bank of Somalia indicates that 43 percent of the population lives on less than one US dollar a day and 73 percent of the Somalis live on less than two US dollar a day. The magnitude of the

discussed compensations, paid out to Somali pirate suspects, should thus not be underestimated ('Somalia's economy at a glance', Central Bank of Somalia, http://www.somalbanca.org/economy_and_finance.html (consulted on 12 January 2015)).

[xix] 'Denmark compensates suspected pirates for overly long detention', Reuters, 8 December 2014, http://www.reuters.com/article/2014/12/08/us-denmark-piracy-idUSKBN0JM2A920141208 (consulted on 12 January 2015).

[xx] 'Suspected Torm pirates prosecuted', Maritime Security Review, 22 December 2014, http://www.marsecreview.com/2014/12/suspected-torm-pirates-prosecuted/ (consulted on 12 January 2015).

[xxi] 'IMB concern over pirate payouts', Maritime Security Review, 29 December 2014, http://www.marsecreview.com/2014/12/imb-concern-over-pirate-payouts/ (consulted on 12 January 2015).

[xxii] 'Second case of pirate compensation draws bitter criticism', OceanusLive, 11 December 2014, http://www.oceanuslive.org/main/viewnews.aspx?uid=00000944 (consulted on 20 January 2015).

[xxiii] 'A European Court Is Wrong about France', American Thinker, 22 December 2014, http://www.americanthinker.com/articles/2014/12/european_court_wrong_france.html (consulted on 28 January 2015).

[xxiv]ECHR, *Medvedyev and Others v. France*, 2010.

[xxv]Article 108, United Nations Convention on the Law of the Sea, 1982, (1994) 1833 UNTS 3.

[xxvi]Article 101-107 and 110, United Nations Convention on the Law of the Sea, 1982, (1994) 1833 UNTS 3.

[xxvii]S. P. Bodini, 'Fighting Maritime Piracy under the European Convention on Human Rights' (2011) 22 Eur. J. Int'l L. 829, 831-832.

[xxviii]In the case of *Hassan and Others v. France*, France relied on Security Council Resolution 1816 to combat piracy in Somali territorial waters (SC Res. 1816 (2008)).

[xxix] 'Why pirates received compensation', Maritime Security Review, 10 December 2014, http://www.marsecreview.com/2014/12/why-pirates-received-compensation/ (consulted on 15 January 2015).

[xxx]It is obvious that the length of the overseas detention, before the suspects are transferred to the country where they will be prosecuted and tried, should ideally also be kept to a minimum. On this front, it would be a good idea to streamline the procedure to obtain the consent of the Somali authorities concerning the transfer of their citizens. If this procedure runs more smoothly and efficiently, the period of overseas detention could be shortened significantly. A more comprehensive solution to the problem could be the facilitation of the first appearance before a judge by means of video link. If this would be arranged as soon as possible after an arrest of a pirate suspect, it should be able to solve all existing problems with regard to article 5 §3 ECHR and guarantee that the essential 'promptness'-requirement, that is not always easy to satisfy in such situations, is met at all time. After all, in this age of modern communication, it appears very devious to disregard these technological means and not turn them to good account.

[xxxi]See for example S. P. Bodini, 'Fighting Maritime Piracy under the European Convention on Human Rights' (2011) 22 Eur. J. Int'l L. 829; S. De Bont, 'Murky Waters: Prosecuting Pirates and upholding Human Rights Law' (2011) 7 J. Int'l L. & Int'l Rel. 104; D. Guilfoyle, 'Counter-Piracy Law Enforcement and Human Rights' (2010) 59 ICLQ 141; D. Osiro, 'Somali pirates have rights too. Judicial consequences and human rights concerns' (2011) 224 ISS Papers 1; M. H. Passman, 'Protections afforded to Captured Pirates under the Law of War and International Law' (2008) 33 Tul. Mar. L.J. 1.

An Empirical Analysis of Vessel Capacity Utilization

Roar Adland[1], Haiying Jia[2] and Siri P. Strandenes[1]

[1]Department of Economics, Norwegian School of Economics (NHH), 5045 Bergen, Norway
[2]Center for Applied Research (SNF), Norwegian School of Economics, 5045 Bergen, Norway

Abstract

The objective of this paper is to determine the drivers behind the utilization of a vessel's cargo-carrying capacity on individual voyages. Based on maritime economic theory we propose that a vessel's capacity utilization - here defined as the ratio of cargo size divided by DWT - should be positively correlated with freight rates, as poor market conditions will force vessels to compete for lower-than-optimal stem sizes. Furthermore, we propose that capacity utilization is dependent on the distance sailed and the value of the cargo. Using a unique data set sourced from port agent lineup reports and covering nearly 10,000 individual shipments of iron ore from Brazil between 2009 and 2014 we estimate a multiple regression model consisting of macroeconomic, route-specific and vessel-specific determinants. Our empirical results suggest that vessel-specific determinants (DWT) dominate the impact of general market conditions, with smaller vessels typically having lower capacity utilization. The impact of the freight market conforms to our a priori expectations. This line of research is crucial for improved modelling of real vessel earnings. Our results are also important for accurate estimation of tonne-mile demand based on observations of global ship movements from AIS data.

Keywords: bulk shipping, capacity utilization, trade flows

1. Introduction

Vessel capacity utilization, that is, the share of a vessel's carrying capacity occupied by paying cargo (Alizadeh & Talley, 2011a) is a key input in maritime economic models. In general, cargo carrying capacity is defined by the type of ship and may be measured in tonnes (tankers/bulkers), cubic meters (gas carriers), TEU (container vessels) or lane meters (RoRo vessels), among other units. At the macro level, capacity utilization is one of the determinants of overall fleet efficiency, or the ability of a fleet to produce transportation work (e.g. tonnemiles). The higher the utilization, the more transportation work a given fleet will produce per time unit. Conversely, a low average utilization implies there is substantial slack or spare capacity available in the supply side. The capacity utilization rate, much like real sailing speeds and ballast ratio, is therefore a key variable in classical freight market modelling (see e.g. Wergeland & Wijnolst, 1996). At the micro level – be it an individual voyage or an individual company – capacity utilization will have a large impact on the profitability and unit transport cost. This is because most costs of ship operation can be taken as fixed once a decision of accepting a fixture/voyage has been made or, in the case of liner shipping, a string of vessels have been employed with a defined route and service frequency.

While capacity utilization is a general concept that applies to all segments of shipping, our analysis focuses on the case of tramp shipping, specifically the drybulk freight market. To illustrate the importance of capacity utilization for bulk carriers, Figure 1 below shows the relationship between capacity utilization and timecharter-equivalent (TCE) vessel earnings and transportation cost, respectively. For the purpose of illustration we here use the Capesize voyage from Rotterdam via Tubarao to Qingdao, with fuel and freight market prices as of 26th June 2015 and Baltic Exchange (2015) route assumptions. The transport cost refers to the $/tonne breakeven rate when chartering the vessel at the prevailing trip charter terms. We have here ignored the second order effect caused by the dependency of fuel consumption on cargo size (i.e. vessel draught). From Figure 1 it is obvious that part loads – i.e. sailing with very low capacity utilization – is detrimental to profitability. Indeed, there will be a point of utilization below which accepting the cargo becomes uneconomic. It is also worth noting that a vessel generally cannot be loaded to 100% deadweight tonnage (DWT) utilization, as the deadweight measure also includes the weight of fuel, freshwater, supplies and crew that the vessel can carry for a particular draught (typically taken to be the assigned summer draught).

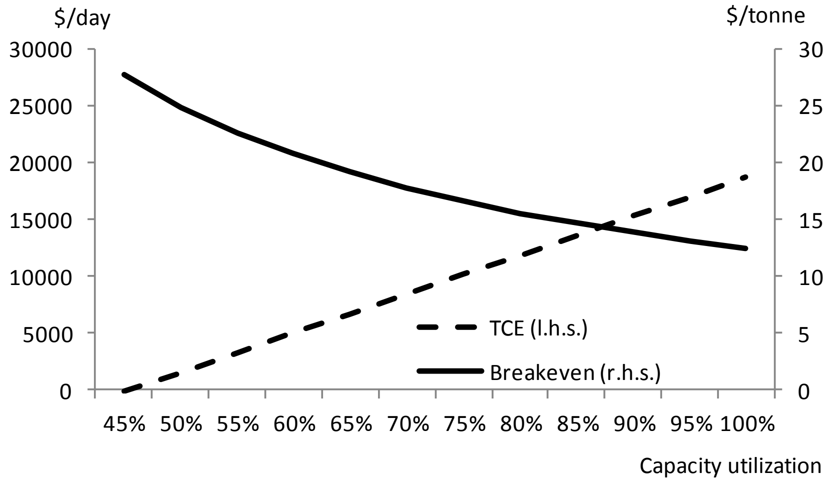

Figure 1: Profitability and breakeven rates as a function of vessel capacity utilization

Despite the relationships illustrated in Figure 1, it need not be the case that a vessel is always loaded to its maximum capacity in practice. Often this is related to prevailing commercial conditions – there may not be a sufficiently large cargo available on offer in the market, or the cargoes traded in the underlying commodity markets may have developed into fairly standard lot sizes (e.g. 150,000 tonnes of coal ex-Richards Bay). Smith et al (2013) point out that when the freight market is in a state of overcapacity, operators are forced to compete harder for cargoes, resulting in a willingness to accept a greater number of part-load cargoes. There may also be purely technical reasons for limiting the cargo size to be carried relative to the DWT of the ship, for instance:

- Maximum draught limits in the loading or discharge port
- Storage capacity limitations at the loading or discharge port
- Hold strength limitations (particularly for heavy cargo such as iron ore)
- Stricter international load line regulations for the intended voyage (e.g. North Atlantic winter)

In addition the type of charter party will influence whether the charterer is incentivised to optimize cargo intake. Under a time (trip) charter, the charterer is in commercial control of the vessel and pays a fixed daily hire irrespective of the cargo size (Stopford, 2009). Accordingly, the charterer will achieve the minimum unit transport cost by maximising capacity utilization. Conversely, under a voyage charter, the charterer pays a fixed $/tonne irrespective of the cargo size. For the shipowner the situation is the reverse, with no economic gain from an increased cargo intake under a time charter, and a proportional improvement in earnings as a function of the cargo size under the voyage charter. Unfortunately, public records of fixtures are too incomplete to make any further investigation of the relationship between contract type and vessel capacity utilization feasible.

While it is clear that capacity utilization is a key economic driver in the maritime supply chain, we do not yet have a good understanding of its determinants from an empirical point of view. While the utilization is an input in most standard supply/demand models, it is often assumed to be of a certain functional form based on industry "rules of thumb". For instance, Adland and Strandenes (2007) assume that a VLCC crude oil cargo is 260,000 tonnes or 95% of a vessel's DWT, whichever is lower. Alizadeh & Talley (2011a, b) include the capacity utilization ratio in a multiple linear regression model as one of several vessel and voyage-specific determinants (e.g. age, hull type and freight rate volatility) of tanker spot freight rates and contract lead times. Using a sample of fixture data for crude oil tankers between January 2006 and March 2009, they find that reported utilization is higher for the larger vessels (average 90.8% for VLCCs compared to 77% for Aframax tankers). They also find that an increase in the utilization ratio will result in a decline in spot freight rates.

Smith et al (2013) use reported vessel draughts from the Automated Identification System (AIS) as a basis for estimating capacity utilization across shipping segments and find it to be approximately 80% or less in the case of crude oil tankers, but does not investigate its determinants. So far there are no empirical studies of the determinants of the capacity utilization ratio itself. This may be partly related to the fact that actual cargo sizes are often unobservable. Public fixture data will only give a partial picture because not every voyage is fixed in the spot market (i.e. those performed under a timecharter, contract of affreightment or using in-house tonnage) and because many spot market fixtures are kept "off market". The use of AIS-reported draught data can give good approximations of cargo sizes, as reported in Jia et al (2015), but relies heavily on the geographical coverage of the data, the accuracy of the manual draught reports by the ship's crew and the naval architecture models used to convert between draught and displacement.

We contribute to the literature by providing the first empirical analysis of the micro- and macroeconomic determinants of the capacity utilization ratio. In doing so, we reverse the causal relationship proposed in Alizadeh & Talley (2011a, b) and suggest that the state of the freight market influences the utilization ratio and that the two should be positively correlated. The remainder of this paper is structured as follows: Section 2 details the methodology and variable choices in our multiple linear regression framework. Section 3 describes the data sources and presents descriptive statistics. Section 4 presents the empirical results and Section 5 concludes.

2. Methodology

To explain the determinants of the utilization rate Ui for voyagei, we estimate various specifications of the following general model using a pooled OLS regression:

$$U_i = \alpha_0 + \alpha_1 I_t + \alpha_2 F_t + \sum_j \theta_j R_{i,j} + \sum_j \omega_j S_{i,k} + \varepsilon_i \qquad (1)$$

where U is the observed capacity utilization of the ith voyage signed at date t. Two variables account for macroeconomic market conditions at date t: It is the iron ore spot price and Ft is the spot freight rate. Ri, j is the set of j voyage-specific variables and Si, k is the set of k ship-specific variables listed below. Finally, εi is a random perturbation such that E(εi) = 0 and Var(εi)=σ2. We note that pooled OLS is appropriate in this context because there are, on average, few observations along the individual vessel dimension in our panel data and so we care less about time-invariant effects. We apply robust regression estimation using Huber-White sandwich estimators to control for heteroscedasticity, lack of normality, and outlier observations that exhibit large residuals, leverage or influence (Huber 1967, White 1980). We also check for the presence of multicollinearity using the Variance Inflation Factor (VIF) diagnostic.

We can group the determinants of capacity utilization on an individual voyage broadly into macroeconomic, voyage- and ship-specific variables as detailed below:

Macroeconomic variables

- Spot freight rate. As per Smith et al (2013) we expect that freight market conditions, as proxied here by the $/tonne spot freight rate for a voyage charter, is positively correlated with capacity utilization. During a weak freight market, with a corresponding oversupply of vessels relative to the volume of available cargoes, it will be rational for operators to compete for low utilization (part cargoes) as long as the resulting TCE is positive and there is no alternative employment. Conversely, in strong freight markets where transport capacity is scarce, charterers have a strong incentive to maximize the cargo intake for every voyage they undertake, subject to technical constraints.

- Iron ore price. We include the iron ore spot price (landed basis, CIF China) as a proxy for the value of the cargo. Intuitively, the higher the value of the cargo, the stronger the incentive to maximize the cargo intake for each shipment.

Voyage-specific variables

- Distance. All else equal, longer distances require higher bunker intake at the start of a voyage and, correspondingly, lower capacity utilization as long as the cargo intake is maximized. However, there are secondary effects that may alter this relationship in practice. For instance, because of economies of scale, long voyages are typically served by large vessels and this interaction effect may bias our results. Similarly, long voyages in the drybulk market will typically serve the modern deep-water ports in North-East Asia which may have fewer draught restrictions than regional ports closer to the main export areas (Brazil in our empirical case). Accordingly, we risk that distance serves as a proxy for draught restrictions, resulting in a positive relationship between distance and capacity utilization.

- Seasonality (winter dummy). Stricter international load line restrictions during the winter months in certain areas of the world (winter seasonal zones) translate into reduced maximum draughts and capacity utilization for vessels sailing through these areas. We have here assigned a winter dummy variable to laden voyages commencing in Q4 and Q1 with reference to the North Atlantic and North Pacific winter seasonal zones.

Ship-specific variables

- DWT, DWT_Sq and DWT group dummies. In order to test for the presence of non-linear effects in the relationship between vessel size and capacity utilization we include three alternative variables: DWT, the DWT squared and dummy variables for size groups as detailed in Table 3 below.

3. Data

3.1. Cargo Size Data

We collected monthly summaries of vessels leaving the six main iron ore export terminals in Brazil from port agents LBH Group over the period November 1, 2008 to August 1, 2014. Table 1 below details the physical characteristics of the six terminals.

Table 1: Brazil iron ore terminal details

Terminal name	Pier	Shipper	Number of Berths	Latitude	Longtitude	Max DWT	Max LOA	Max draught	Berth length	DepTh alonside	Shiploaders	Load rate (MTPH)
Ponta da Maderia	Pier I	Cia Vale do Rio Doce	2	-2.57	-44.38	420,000	345 / 280	25	685	25	2	16,000
	Pier II					155,000						8,000
	Pier III					220,000						8,000
Ponta Ubu	Westside Pier	Samarco Mineracao	2	-20.78	-40.58	250,000	308	15.5	313	20	2	10,000
	Eastside Pier					150,000	240	16.8	313	16		7,000
CSN Terminal	Pier 401	Ferteco Mineracao	2	-22.87	-43.77		n/a	17.3	400	19	2	5,000
Tubarao	Pier 1 (North & South)	CVRD (Vale)	2	-20.28	-40.25	200,000	285 / 320	17	430	20	2	7,000
	Pier 2	CVRD (Vale)	2	-20.28	-40.25	365,000	350	20	430	24	2	16,000
Itaguai				-22.87	-43.77	230,000		18				
GIT				-23.00	-44.02	300,000		15.2				

Source: Compiled by authors

The port agent reports contain the following data fields:

- Report date
- Vessel name
- DWT
- Arrival time, ETA (Expected Time of Arrival)
- Berthing time, ETB (Expected Time of Berthing)
- Departure time, ETD (Expected Time of Departure)
- Destination
- Cargo quantity

The sample consists of 9,862 individual port calls by 3,954 vessels ranging from 24,000 DWT to 405,000 DWT with an average size of 152,000DWT. Table 2 shows the descriptive statistics for cargo size by port.

Table 2: Descriptive statistics for cargo size by port

	Obs	Mean	Std. Dev.	Min	Max
CSN	965	156,482	19,772	39,285	198,236
GIT	1,114	186,669	55,285	29,220	285,902
Itaguai	834	149,624	34,450	27,500	274,380
PDM	2,745	197,710	73,401	20,052	395,384
Tubarao	3,165	169,826	81,096	8,000	395,373
Ubu	992	119,638	54,189	29,998	204,350

Source: LBH Group, compiled by authors

Sailing distances for the laden trip are obtained from a standard marine distance calculator (axsmarine.com) under the assumption that vessels avoid pirate zones where applicable.

3.2. Macroeconomic Data

As China is by far the largest importer of Brazilian iron ore, we use the Baltic Capesize Index C3 for the route Tubarão to Qingdao as reference for the freight market. As per Baltic Exchange (2015) assumptions, vessels are assumed to be delivered for the trip in the Antwerp-Rotterdam-Amsterdam (ARA) area and then sail in ballast to Tubarão for loading. Accordingly, we match each laden voyage with the Baltic spot freight rate 21 days prior to the loading port ETA[i] to better reflect freight market conditions at the time of the fixture.

We base our proxy for the value of the cargo on the 62%Fe-content spot iron ore index as provided by The Steel Index (TSI) and obtained from Bloomberg. This is the benchmark iron ore price index underlying iron ore swaps and futures cleared or traded through the Singapore Exchange. We note that the TSI 62% spot iron ore price index, published every trading day, is defined as the price per tonne of iron ore delivered in Tianjin, China, on a Cost, Insurance and Freight (CIF) basis. Thus, in order to avoid accounting for variations in the freight component twice in our model, we calculate the FOB price by subtracting the freight rate from the CIF price and using the FOB price in our estimations. Similarly to the freight rate, we match each cargo with the iron ore price 21 days prior to the time of arrival at the load port (anchorage) in Brazil in order to better reflect market conditions at the time of sale[ii].

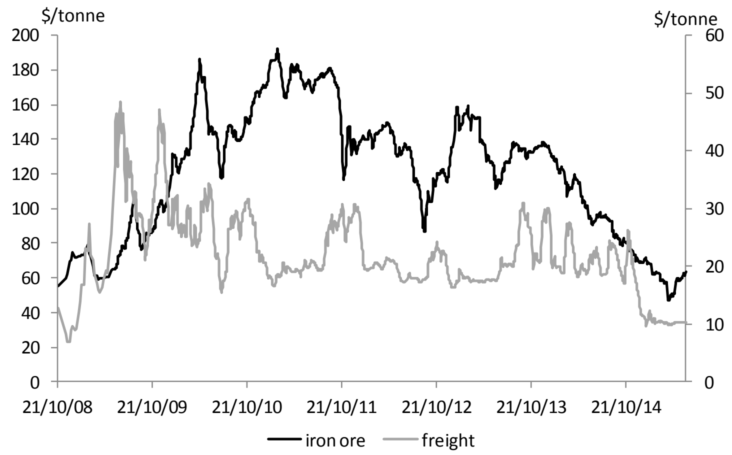

Figure 2: Freight rate and iron ore prices during sample period
Source: Clarksons, Bloomberg

3.3. Capacity utilization

The utilization rate is calculated as the ratio between the cargo quantity and a vessel's DWT. Figure 3 shows the kernel density of the utilization, using default bandwidth (0.007) and the Epanechnikov kernel function. We see that the majority of voyages are performed with fairly high capacity utilization (>85%), with a peak around 96%. Indeed, the average capacity utilization across the sample is 92%. The observations with very low capacity utilization may be either a result of vessels loading at multiple ports in Brazil, making it appear as if the cargo intake at each port is unusually low, or errors in the data entry process at the port agent. For instance, the cargo size or DWT may be wrongly entered, or a vessel name may not be unique to a certain size vessel.

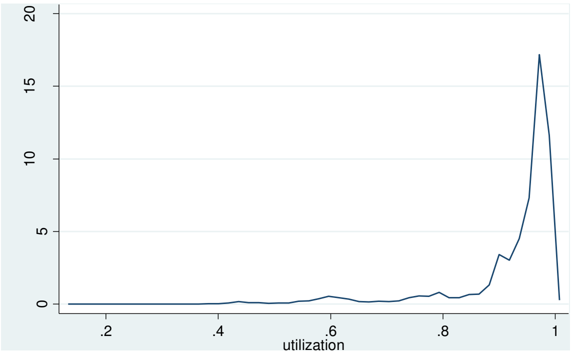

Figure 3: Kernel density of utilization

Figure 4 shows a scatter plot of vessel capacity utilization vs. DWT. We see a clustering of vessel sizes into roughly four main DWT groups: Panamax and smaller (<100,000DWT), Capesizes (<250,000 DWT), iron ore carriers and Valemaxes (> 400,000DWT). We note the presence of some “mini-Capes” around 115,000DWT size but choose to include these with their bigger Capesize cousins. Table 3 summarizes the utilization statistics by size group.

Table 3: Descriptive statistics for capacity utilization by size group and port

	Obs	Mean	Std. Dev.	Min	Max
0 - 99,999	1589	0.801	0.175	0.285	1.00
100,000 - 249,999	6405	0.944	0.069	0.153	1.00
250,000 - 399,999	1652	0.936	0.074	0.027	1.00
400,000 +	169	0.934	0.079	0.650	0.99

	Obs	Mean	Std. Dev.	Min	Max
CSN	965	0.916	0.081	0.230	1.00
GIT	1,114	0.954	0.058	0.388	1.00
Itaguai	834	0.924	0.075	0.153	1.00
PDM	2,745	0.945	0.080	0.140	1.00
Tubarao	3,165	0.904	0.131	0.027	1.00
Ubu	992	0.860	0.149	0.250	1.00

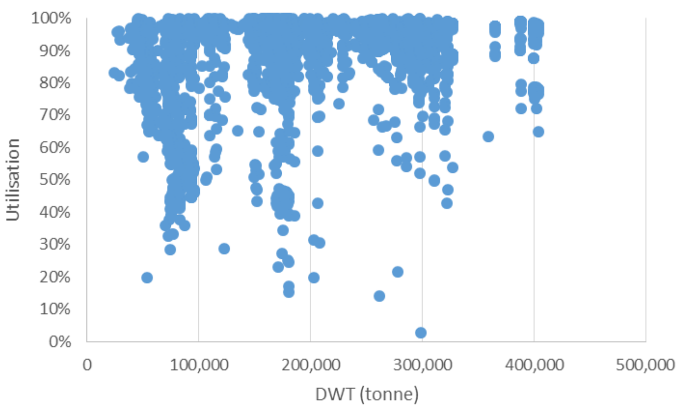

Figure 4: Scatter plot of utilization vs. DWT

We note that there is some non-linearity in the mean-utilization-DWT relationship, with particularly the sub-Capsize segment but also the very large vessels showing lower utilization than the standard Capesize segment (around 180,000 DWT).

4. Empirical Results

Table 4 below shows the results for the various specifications of our multiple regression model. Of the three different relationships between vessel size (DWT) and capacity utilization (specifications 1 to 3), the size group dummies perform the best. Our results are similar to those found for tankers in Smith et al. (2013) in the sense that smaller vessels operate with lower average capacity utilization. However, the relationship is non-linear, with vessel sizes above 100,000DWT showing only marginal changes. For the remainder of the specifications we use only the DWT group dummies as they have the highest explanatory power. In specification 4 we add the impact of the freight market. As expected, the spot freight rate loads positively and is highly statistically significant (as is most of our variables). From an economic point of view, a change in the spot freight rate from \$30/tonne observed at recent peaks down to the \$10/tonne at the cycle lows implies a reduction in the vessel capacity utilization of 2.2%-points, all else being equal. Given that the ship-specific variation in capacity utilization is relatively low (ref. the peaked distribution in Figure 3), this is economically meaningful. When we add the iron ore price as an explanatory variable (specification 5), this effect is reduced somewhat. Moreover, the commodity price loads negatively in the regression, contrary to our expectations, as it means that vessels have lower utilization in what is typically a high demand scenario.

When adding the voyage-specific variables (specification 6) we note that only distance is statistically significant. In economic terms, the increase in utilization between a short and long voyage, say Rotterdam (4965 nautical miles) vs Qingdao (11017 nautical miles), is approximately 3.6%-points. Seasonality, at least how we have defined it here, does not seem to make a difference to vessel capacity utilization.

Table 4: Regression results

Dependent variable: utilization %

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
adj. R-squared	0.104	0.042	0.232	0.236	0.238	0.256	0.261
VIF				1.39	1.380	1.54	1.44
Constant	0.84	0.89	0.80	0.77	0.80	0.77	0.77
	(201.780)	(399.220)	(182.940)	(132.300)	(108.300)	(175.890)	(104.920)
	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]
DWT	0.46						
(tonne)	(23.690)						
('000000)	[0.00]						
DWT^2		0.74					
(tonne)		(18.440)					
('000000)		[0.00]					
DWT_group_dummy (<100,000t benchmark)							
DWT_2			0.14	0.14	0.14	0.12	0.12
(tonne)			(32.170)	(32.470)	(32.260)	(23.610)	(23.810)
100,000-249,999t			[0.00]	[0.00]	[0.00]	[0.00]	[0.00]
DWT_3			0.14	0.14	0.14	0.11	0.11
(tonne)			(28.560)	(28.910)	(28.890)	(19.800)	(20.160)
250,000-399,999t			[0.00]	[0.00]	[0.00]	[0.00]	[0.00]
DWT_4			0.13	0.14	0.14	0.11	0.11
(tonne)			(17.910)	(18.400)	(18.270)	(13.780)	(14.160)
400,000+t			[0.00]	[0.00]	[0.00]	[0.00]	[0.00]
Freight rate				1.08	0.75		0.73
(C3 route \$/tonne)				(7.510)	(4.880)		(4.920)
('000)				[0.00]	[0.00]		[0.00]
Iron ore price					-0.17		-0.14
(62% FOB \$/tonne)					-(6.080)		-(4.960)
('000)					[0.00]		[0.00]
Distance						0.0060	0.0005
(nautical mile)						(13.460)	(13.030)
('000)						[0.00]	[0.00]
Winter_dummy						0.00	0.00
						(0.180)	(0.270)
						[0.85]	[0.79]

note: Figures in [ ] are the *p* - values of H_0: zero coeffecients; figures in ( ) are *t-stats*

5. Concluding Remarks

We have shown that several macro- and microeconomic determinants, notably freight market conditions, the commodity price, sailing distance and vessel size, influence the vessel capacity utilization of drybulk carriers. Most importantly, the findings support our hypothesis that utilization declines during poor freight markets, delivering a double blow to realised vessel earnings.

We acknowledge that there remains a large unexplained component in the observed vessel capacity utilization data. While some of this is likely due to measurement errors in the original dataset, future revisions of this work should try to further improve the explanatory power of the models herein. In particular, vessel age and hold structure should be considered. Older tonnage will expectedly have lower capacity utilization – both because it is less attractive on the spot market and therefore may have to bid for sub-optimal cargo sizes but also because of reduced structural strength. This is particularly a concern for heavy cargo such as iron ore, where the fatigue caused by numerous loading and discharge cycles over the life of the vessel can eventually cause a collapse of hull sections (Paik and Melchers, 2008). Similarly, specialised iron ore carriers and other bulk carrier vessels denoted as "strengthened for ore" will expectedly have a higher capacity utilization than vessels not built to this higher specification. This is in part to avoid failures in the ship structure, particularly during the loading process. However, ore carriers also have a different hold shape than standard bulk carriers, ensuring a higher centre of gravity and better sea keeping performance. It is also worth modeling the relationships between maximum vessel draughts and any draught restrictions in the loading or discharge port in detail, as this is known to often be a limiting factor. The challenge here is that the final port of discharge will not always be known.

6. Acknowledgements

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[i] This includes 17 days sailing in ballast from Rotterdam plus an assumed average of 4 days between fixture and delivery as per Baltic Exchange definitions.

[ii] Technically the sale of the cargo will probably have taken place even earlier than the fixture of the ship though this would be private information.

Simulation-based Evaluation of Container Location Dispersion for Convenience of Container Loading at Transshipment Terminals

Hang Yu[1], *Ying-En Ge*[2] *and Meilong Le*[3]

[1]School of Economics & Management, Shanghai Maritime University, Shanghai
[2]College of Transport & Communications, Shanghai Maritime University, Shanghai
[3]College of Civil Aviation, Nanjing University of Aeronautics and Astronautics, Nanjing

Abstract

The process of container operations at a transshipment terminal is often restricted by overloading in the container yard, as a consequence of high density container storage from the same service line in a small region. The container location dispersion refers to the degree of scattering of loading clusters onto the same ship at a transshipment terminal and indicates the container travel distance from yard to quay. This research aims to identify the relationship between the container location dispersion and long-run efficiency of quay crane. Also, implications of this measure are discussed in the context of the yard template design and improving the overall performance of a container transshipment terminal.

We build a discrete event driven simulation model for the container handling process at a transshipment terminal. First, we identify the influence of location dispersion on the container loading performance with scarce or adequate equipment allocation without interferences. Then, we investigate those scenarios with such interferences as retrieving containers from other loading lines and suddenly entering containers from different services in the same region. All data in our experiment are extracted from the terminal operations system (TOS) at a real-life container terminal. It is concluded that the container location dispersion measure well captures the overall performance of container terminal handling and can be used for yard template optimization.

Keywords: transshipment terminal, yard template, location dispersion, discrete event driven simulation

1. Introduction

Container terminals play a key role in the global supply chain or network. Generally, container handling performances, including loading, unloading, pre marshalling et al., are determined by the scheduling of yard storage. In order to organize container operations more efficiently in the terminal, it is necessary to categorize all kinds of containers. Some classification methods are shown in Figure 1, in which a container follows such classifications to find location range in yard storage when grounding into a yard and then follow an exact allocation strategy to get into a specific slot.

A proper allocation strategy always improves the performance of the following container handlings. A more precise classification of the containers for allocation optimization can be found in Zhang et al. (2003) , all the handling containers are classified into four different types based on their working features, which are Vessel discharge (VSDS) containers, Container yard pickup (CYPI) containers, Container yard grounding (CYGD) containers and Vessel loading (VSLD) containers shown as Figure 1. Generally speaking the allocation optimizations of VSDS and CYGD containers are always the primary objectives in most relative research, as CYPI and VSLD are transformed from VSDS and GYGD containers.

In a real container loading process, we find the retrieving sequence for the VSLD containers must coordinate with the stowage scheduling. The allocations of the CYGD containers often determine the retrieving points of VSLD containers. Thus, an optimal allocation schedule of CYGD containers makes a better terminal operation performance.

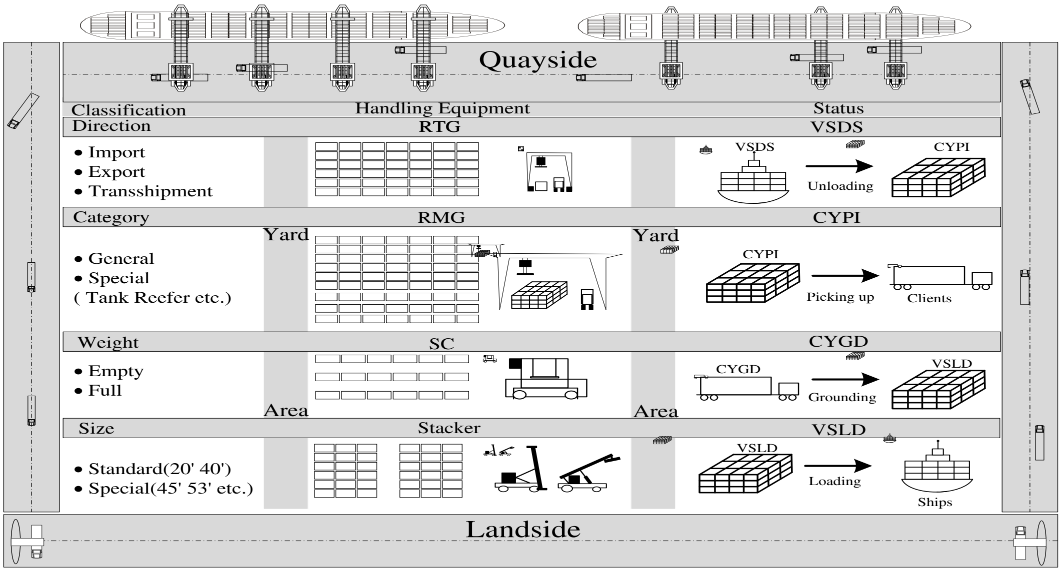

Figure 1: A classification of containers in the yard area

2. Problem Description

2.1. Allocation of export containers

Export containers are main parts of the CYGD containers. The allocation of the export containers directly affect the loading performance when ship berthing. For a land-scarcely yard with less equipment and more ships, the following pattern in Figure 2 is appreciated.

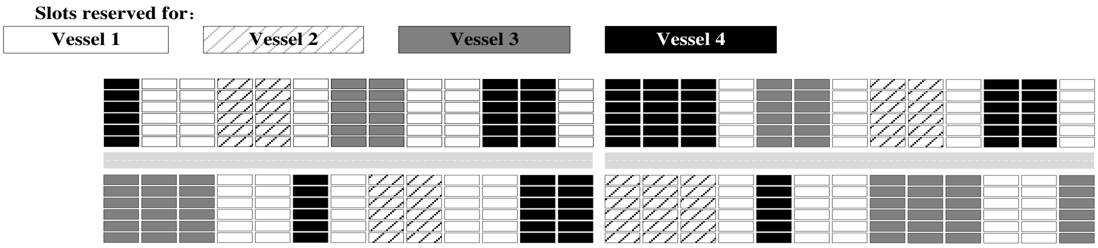

Figure 2: Template pattern of the yard

Under this pattern, the PSCW principle is a basic consignment strategy can help the export containers which belong to the same destination Port, same container Size, same classification Category and same Weight class to find same specific bays. The whole yard is separated to different templates based on the PSCW principles. More rules were developed by Zhang et al. (2003), Chen and Lu (2012), Sharif and Huynh (2013) to achieve two main objectives below, which are also the basic objectives of our research.

- Optimize the distance between yards and ships to reduce costs required for the yard trucks to transfer the containers from the yard to the berth for loading onto the ships.
- Balance the handling workload among blocks to mitigate congestion in the yard and to reduce rehandle during the future loading operations.

2.2. Loading cluster and location dispersion for export containers

All the export containers should enter in yard before their ships berth in the terminal. The terminal operations system will give a specific slot for the entering export container to ground. Considering the rehandle cost, the export containers are seldom moved again before loading for most terminals. Hence the first allocation slot is always the container retrieving point during loading. The continuous retrieving points constitute **loading**

clusters which consist of several export bays for the same service. As shown in the Figure 3, service 1 has 5 different loading clusters in area A and B while service 2 has 6. When loading begins, yard trucks will get orders to transport containers between these loading clusters and their dedicated service lines. In a resource scarcely terminal, a single YC has to handle containers for different service lines in the same block. Shown as area A1, area A3 and area A4, two clusters for different ships are being retrieving simultaneously, that means in these blocks at least one of these clusters has to wait for the YC. Apparently, allocation of the loading clusters directly influences the transportation process and the yard congestion. An optimal allocation of loading clusters can increase the loading efficiency and mitigate the congestion, and over retrieving load in a same block may bring delays.

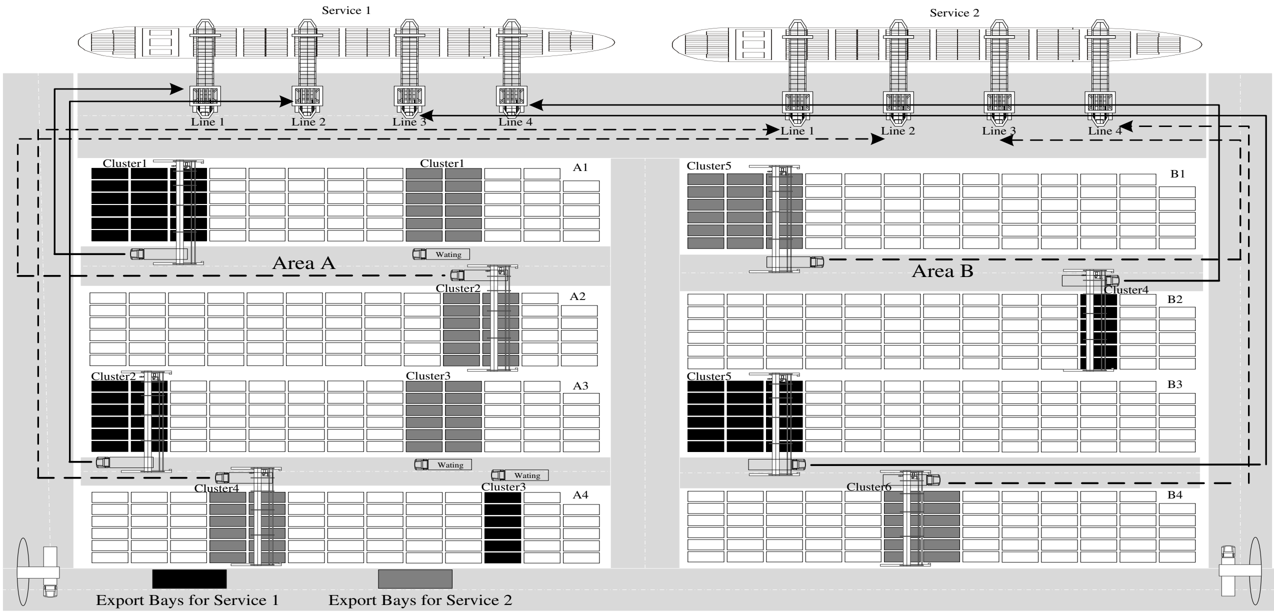

Figure 3: Loading cluster distribution in yard

In this research, we want to focus on the **location dispersion** of the **loading clusters**. Location dispersion is a basic index of allocation distributions touched in Petering et al. (2009). It leads export containers to locate into a certain yard range. As shown in the Figure 4, it's a typical location dispersion description for a 6 berths terminal. The dispersion levels indicate loading clusters location range of different berths. The location dispersion of the loading clusters closely affect the yard congestion and transportation distance. High level dispersion means spread storage, less congestion and long travel distance. Low level dispersion always indicates high density storage, more congestion and short travel distance.

Different from Petering et al. (2009), we make a basic evaluation of the effect of the location dispersion influence on single service under different scenarios. Two main studies are proposed:

- We identify the influence of location dispersion on the container loading performance with scarce and adequate equipment allocation without other interference under varying number of service lines.

- We investigate loading performance with such interferences as retrieving containers from other loading lines and suddenly entering containers from different services in the same portion.

We build a discrete event driven simulation model for the container handling process at a transshipment terminal to implement these two studies. Location dispersion in scheduling loading clusters shows crucial effects on the following loading efficiency from our studies. We identify and discuss these effects in the Section 5.

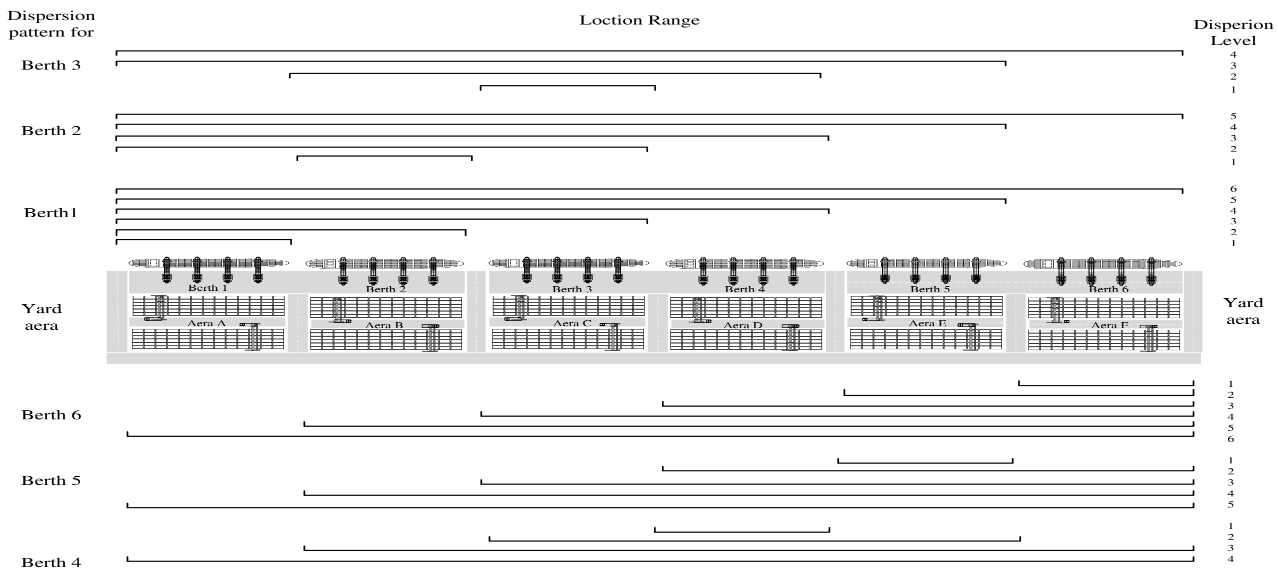

Figure 4: Location dispersion description for a 6-berth port

3. Literature Review

The literature relevant to this study includes papers on container terminals that discuss storage yard management and simulation. Storage allocation problem is a main topic in the research of yard management. Zhang et al. (2003) firstly define four kinds of terminal handling containers in an operational level and optimize the allocation problem of both the import and export containers in a limited storage yard. With the increasing computational complex of this problem due to large number of containers, Bazzazi et al. (2009) and Sharif and Huynh (2013) tried to solve this problem using intelligent algorithm. However, the number of containers is changing in real handling, thus, more flexible plans are needed.

Compared with the storage allocation problem, scheduling of yard template is more practical in real handling. Schedule of yard templates are often generated from allocating subblocks to containers belong to different ships. Lee et al. (2006) considered the handling interferences and equipment conflicts during container retrieving. A strategy that decreases the shift moves of YCs and avoids the yard congestion is developed by Lee et al. (2006) to generate a yard template considering the berthing date. Under this strategy, adjacent subblocks have the smallest chance to be retrieving simultaneously. Based on that, Zhen et al. (2011) combine yard templates problem with berth templates problem together. The integrated problem is closely related to the time of ship berthing and the container transportation distance in the yard, the result shows the improvement of the working efficiency following this method. Besides, Li and Li (2011) put forward the concept of continuous loading clusters, however, their objective – optimizing the utility of yard bays, is not the most important in benefit considered.. Apparently, research on the yard allocation shows the operational development trend, many new studies appear in considering the real handling demands.

Representatively, Jiang et al. (2013) propose a space-sharing strategy to allocate containers belong to different services into the same subblock based on the consignment strategy. The space-sharing strategy separates the service time window of containers allocated to the same block which improves the utilization of the yard space. Jin et al. (2014) integrate the space allocation and yard crane deployment decisions together with consideration of yard congestion. Five different types of YCs moves are introduced by Jin et al. (2014) to deploy and route YCs to perform all the grounding and retrieval activities during the handling. The storage allocation problem is optimized to balance the workload distribution among blocks in this research too. To satisfy the real management demand，the uncertain handling change is also discussed by Zhen (2014). Zhen (2014) considers the fluctuations of container handling in the container terminals and builds a yard template planning model considering random service composition.

All research listed above use programming model to represent the handling constraints and make an optimization. Aiming to give a more visualized solution, simulation method is generally applied in the storage yard management problem. Liu et al. (2002) and Kim et al. (2008) introduce the simulation method to evaluate the performance of different design in different container terminals in early study. Then, Petering and Murty (2009), Petering (2009) propose several simulation analysis on the yard management problem. Petering and Murty (2009), Petering (2009) discuss the effect of different block length and block width design on the long-run performance at a seaport container terminal. A fully-integrated, discrete vent simulation model can be found in Petering and Murty (2009), Petering (2009) which is firstly applied in the yard management research. It should be mentioned that a more particular research on container handling is conducted by Petering (2011). Numerical results on yard capacity, fleet composition, truck substitutability, and terminal scalability issues are obtained using a fully-integrated, discrete event simulation model of a vessel-to-vessel transshipment terminal. The fleet composition is discussed in the research but the effect of the service composition is never touched.

In General, many outstanding research have been conducted in the operational level, however, none of them discuss the effect of the service composition on the loading cluster distribution. The location dispersion is never be touched in scheduling the loading clusters too. In the following section, we present an integrated yard operations simulation model to explore the effect of loading cluster distribution.

4. Simulation of Container Loading

4.1. Simulation model based on FlexTerm

In this research, we want to evaluate the performance of different loading clusters dispersion strategies. Since the simulation method itself is not the most important part of our research, we choose FlexTerm as the basic software to build the simulation model. FlexTerm is built on Flexsim technology and designed for container terminal operations simulation and analysis. We build an integrated yard operations simulation model including main components of the loading process based on the FlexTerm. Main elements of the simulation model are shown in the Figure 5.

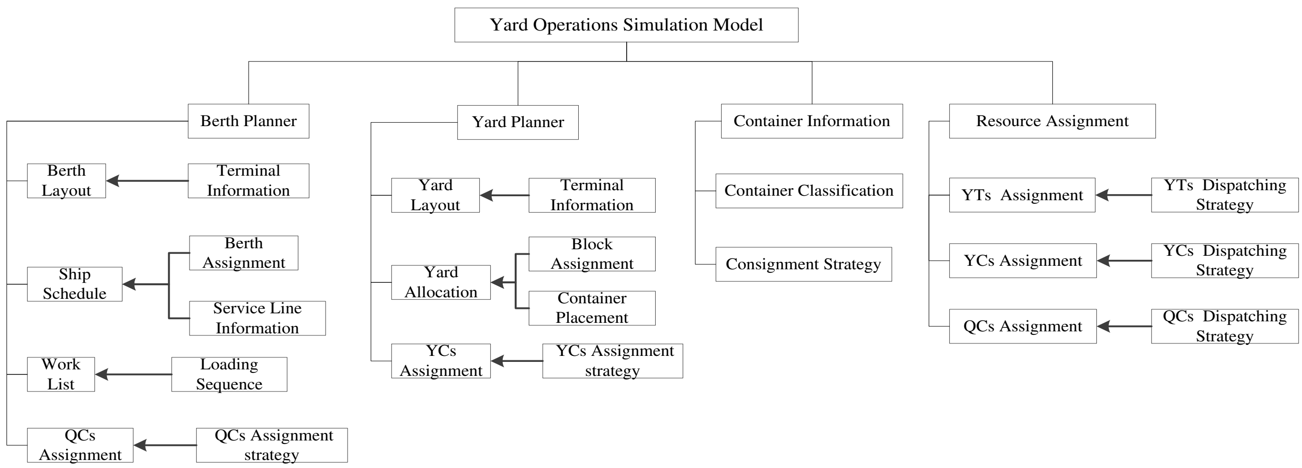

Figure 5: Elements of the simulation model

4.2. Main features and limitation of simulation model

The model integrates different handling process together to simulate the loading process in a container terminal. Berth Planner and Yard Planner are the two main plan modules in the FlexTerm. Berth Planner is applied to generate the basic environment of the experiment and the service group for export loading. The loading sequence should be confirmed in this planner and the Work List for every service is settled. QCs start from the beginning of the work list when ships finish berthing. Yard Planner is designed to apply different allocation strategies to the yard allocation management. To apply different location dispersion strategies to the loading clusters scheduling, we implant various location dispersion strategies to the block assignment strategies to restrict the location range of container placement. In the FlexTerm, a separately module is used to record the containers information called Container Types. We use the Container Types module to record all the experiment containers' information and apply the PSCW principle as the basic consignment strategy in the simulation. Besides, different dispatching algorithms can be chosen in the FlexTerm to deploy equipment timely.

In this research, we focus on the evaluation of the different allocation strategies using simulation. Two limitations of our model can be easily found. The first one is the inflexibility of our model. We build the yard operations simulation model based on the FlexTerm. Most basic modules and strategies designed by FlexTerm are difficult to change. So, we choose the basic strategies for handling equipment instead of designing more optional algorithms to optimize the dispatching strategies. As a result, the simulation model is less flexible and hard to be used in more evaluations except for yard management problems. The second limitation of our model is regardless of the uncertainty. We generate the experiment environment for a certain number of export containers and a decided loading sequence. However, the first limitations will not affect the evaluation of the loading clusters distribution and the second limitation is a further topic in the future research.

5. Experiments, Results and Discussion

5.1 General setup for experiments

Some basic simulation parameters can be found in Petering (2011).The main parameters in our research are listed in theTable1.The experiments focus on a specific berth in a 6-berth container terminal. As shown in Figure 6, we consider berth 1 GCR performance which has 6 different dispersion levels with scarce and adequate equipment size. In order to find the effect of the service workload, we design four loading sequence with different workload from low to high. We also propose a separate study recording the GCR changes with and without extra interference. Thus, a total of 96 independent experiments were conducted. Table 2 gives the major specifications of the basic scenarios of all the independent studies.

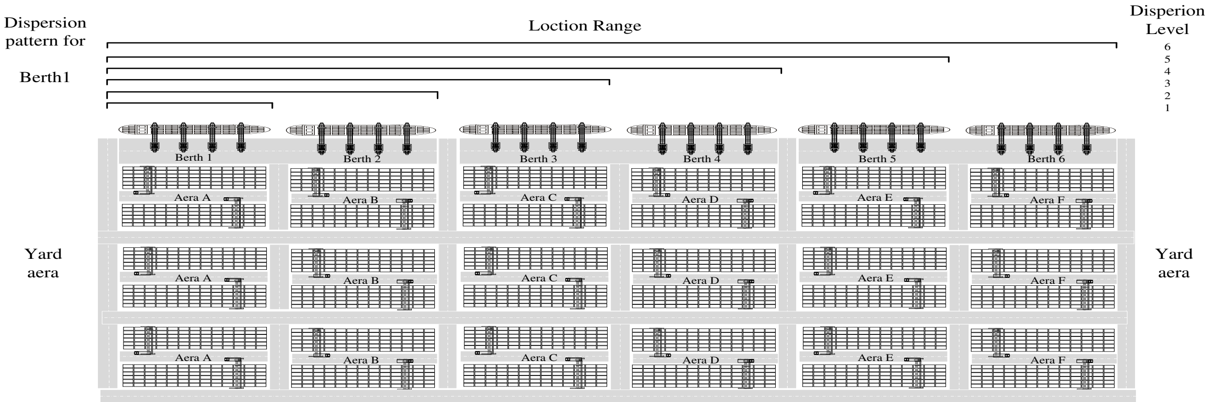

Figure 6: The location dispersion for Berth 1

Table 1: Default value of operational parameters

Parameter	Value	Parameter	Value
QC		**Ship Arrival**	
Handling time	Triangular(1.0,1.5,3.0)	Reliability percentage	100%
Maximum GCR	40move/h	**YC**	
Travel speed	7.2km/h	Handling time	Triangular(0.5,1.0,2.0)
Twin lift of QC		Maximum lifts	60move/h
Percentage of 20'	50%	Travel speed	18km/h
Percentage of 40'	0%	Minimum separation distance	4 bays of 20'
YT			
Travel speed	36km/h		

Table 2: Basic scenarios considered in the experiments

	Scarce equipment	Adequate equipment
Vessel calls for berth per week	7	
Yard length *yard width	6 blocks * 6 blocks	
Block length*Block width	24bays * 6rows	
Maximum stacking height	5 tires	
Grounding slots for each block	504 teu	
Grounding slots for whole yard	18144 teu	
Expected QC lifts for each ship	420teu-1680teu	
Expected QC lifts for berth 1 per week	2940 teu-11760teu	
Ratio of 20'-40' containers	2:3	
QCs assignment	1/Service line	1/Service line
YCs assignment	1/Block	2/Block
YTs assignment	4/QC	6/QC

As an important indicator for evaluating the long-run performance of container terminal, GCR (gross crane rate) is usually used in relative research (Petering and Murty 2009, Petering 2009, Petering 2011).We also use GCR as the major output to evaluate the long-run performance which can be measured as follows:

GCR= (total number of QC lifts) / (total number of QC hours beside a busy berth) (1)

5.2 Main studies and conclusion

Study 1: Effect of loading clusters distribution on the GCR performance with different service load

Different scenario settings with adequate and scarce equipment as table 4 were conducted in this study. Different services with 2, 4, 6, 8 service lines were applied to this study to test long-run GCR performance. As settings in the Table 4, every service line corresponds to a single quay crane. In our simulation model, we ignore the cooperation handling between adjacent cranes along the berth. The total loading works for each vessel are equally assigned to different cranes with 210teu/service line. All the service lines start to load simultaneously. We gather average GCR results under every dispersion level to draw Figure 7 and Figure 8.

The vertical axes represent average GCR and the horizon axes are changing of dispersion levels. The GCR performances with different service lines are represented by different kinds of lines. As the workload increasing, the GCR performance is falling both in Figure 7 and Figure 8. This falling is due to the increase of time delay during the loading in the whole yard. Most of these delay come from the trucks congestion causing by rehandling works, a service with 8 service lines often waste more time than service with 2 service lines. This waste time seldom increase in linear growth that will be another interesting topic in the further research.

The long-run GCR under different workloads perform real different with changing of dispersion levels. In an adequate equipment environment as Figure 7, the average GCR is around 30move/h. One important finding is that concentrate allocation is preferred in the adequate environment. The reasons are more YCs and YTs deployment can decrease the congestion delay causing by truck queueing and more export containers within less loading clusters can be transfer to the berth side continuously and timely. As a result, when the service lines' workload is capable with the assignment equipment, the concentrate allocation is appreciated. And highest GCR performances of services with 2, 4 and 6 lines can be more than 30move/h in the dispersion level 2. As services increasing to 8 lines, the highest GCR appears in dispersion level 4, that results from the capability limit of yard equipment. The spread allocations of loading clusters in high location dispersion level may mitigate the congestion in the yard and help export containers in 8 service lines to load continuously.

Another finding comes from the falling of GCR with the dispersion level increasing in Figure 7. The GCR falls quickly in dispersion level 6 with each kind of service lines shown as Figure 7. These GCR declines mainly due to the transportation distance increase. Considering the GCR estimation equation in section 5.1, as the total number of QC lifts is determined in our simulation, the total number of QC hours is key factor to affect the GCR performance. The total number of QC hours is also a comprehensive time value which can be influenced by two kinds of time cost, one is the congestion time delay from truck queueing, and the other is the travel time cost on road. The congestion time delay often results from the capability limit of yard equipment or randomly rehandling works. And the travel time cost is directly related to the distance from loading clusters to the corresponding service line. When the dispersion level increase to 6, all the export containers are allocated real scattered around the whole yard, the travel distance grow much longer than concentrate allocation do. While the dispersive allocation can avoid the congestion in the yard, the grown travel time is too long to make the GCR perform well. So, the GCR often get a big slide in a real high dispersion level.

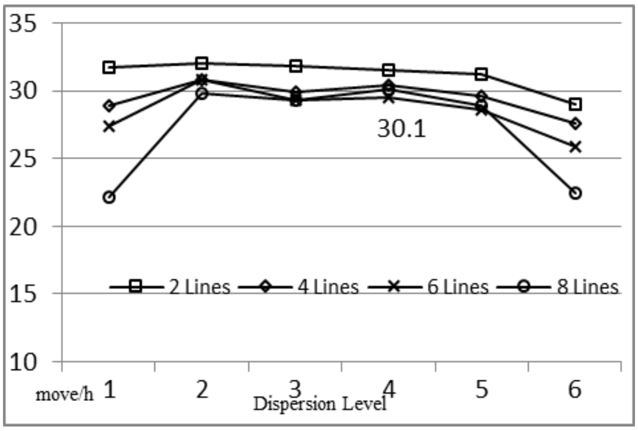

Figure 7: Average GCR with adequate equipment

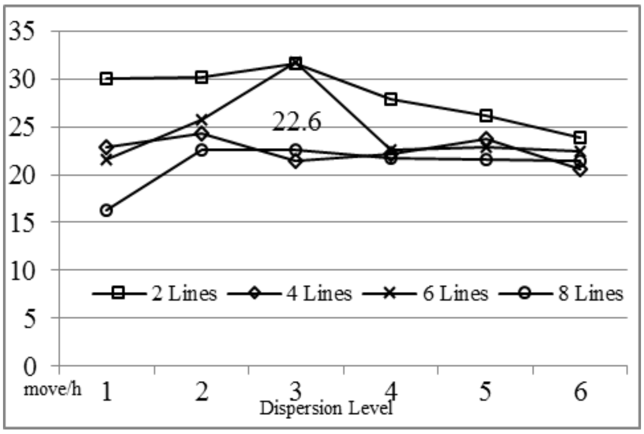

Figure 8: Average GCR with scarce equipment

After these two findings, we realize that the GCR performance is directly related to the time cost during containers loading in the terminal. The time cost by trucks' traveling on the road and the congestion delay time occurring in the yard are both related to the distribution of loading clusters. The optimal loading clusters distributions with highest GCR usually result from the best dispersion level choice for each vessel. As a result, the best allocation strategy with highest GCR often comes from the optimal choice of location dispersion for loading clusters distribution of each vessel. Consequently, the location dispersion is definitely an important index that terminal should consider during the yard allocation. We can confirm this conclusion from Figure 8 with scarce equipment too.

From the Figure 8, we can clearly see the different GCR performance with various service lines under different dispersion level. The average GCR is roughly 25move/h in the scarce equipment. As we all known, the GCR is a comprehensive value that indicating the performance of the whole loading procedure. Since we have decreased the max number of equipment deployment in the scarce environment, the GCR worse than Figure 7 is intelligible. Because the limit capability of yard equipment, most of the service lines (2 lines, 6lines and 8lines) get their highest GCR in dispersion level 3 to share more equipment. Since the lack of equipment in the yard, it's easily to be understand that service with 8 service lines prefer a lower dispersion level than the choice in the adequate environment before for avoiding longer distance increase but less congestion mitigation. Besides, service with 4 lines chooses dispersion level 2 to allocate the export containers, that's also a result of overall consideration between concentrate allocation and spread allocation. It's an optimal trade-off between long distance travels but less congestion and short distance travels but more congestion.

The study 1 finds some general conclusions about GCR performance and the effect of different location dispersion choices in an ideal environment without interference:

- The GCR is a useful comprehensive value which can be used to represent the long-run efficiency in the terminal. The time waste from trucks traveling and queueing directly affect the performance of GCR.

- The GCR performance is directly related to the equipment deployment, terminals with adequate equipment often have a better GCR performance.

- As the workloads increasing, the GCR is usually falling. The reason may due to the on-linear grown time from working delays.

The general relationship between location dispersion choice of loading clusters and GCR performance also can be concluded from this study as below.

- The GCR performance is closely related to the location dispersion choice of loading clusters.

- Allocation of export containers with concentrate allocation is preferred by equipment adequate terminals in an ideal environment without interference.

- The optimal choice of the location dispersion level often indicates the best trade-off between travel distance and yard congestions.

Study 2: Loading clusters distribution under interferences

In a real working environment, kinds of interferences of retrieving or grounding from other services often happen in the same block. In the study 2, we investigate the GCR performance with different loading clusters distribution under interferences. We allocate an 840Teu randomly handling containers from other services of retrieving or grounding to the same location range of berth 1. We want to better simulate the real productivity and talk about the meaning of location dispersion concept in an operational level. We gather the average GCR for each service shown in the Figure 9 and Figure 11.

The average GCR performances with adequate equipment deployment are shown as Figure 9. Most of the average GCR is around 30move/h in the adequate equipment considering interferences. The GCR performance with or without interferences are represented by different lines. One important finding is the GCR performance with interference sometimes better than that without interference under an adequate equipment environment. We draw a brief picture as Figure 10 to explain this phenomenon. The yard template schedules of blocks in area A are shown in the Figure 10. As following the Block Assignment Strategy in section 4, numbers of export bays allocated in the area A are the same. But numbers of the loading clusters are totally different after implication of Container Placement Logic. As the randomly interferential works sequence scanned, some bays may be assigned to them firstly. Then, the continuously loading clusters will be separated to more parts. With two yard cranes serving in the same block, more loading clusters may mitigate the congestion causing by high-density stacking in adjacent bays and improve the GCR performance. For example, Service with 2 lines in Figure 9.1 gets its best GCR with dispersion level 1 which indicates all the export containers stacking within area A. The interference works increase the number of loading clusters for service 1 as mentioned before. The GCR reach 32move/h with concentrating stacking for service 1. As service lines increase to 4 and 6, more equipment with spread location dispersion are needed, so dispersion level 3 is preferred. When the service lines increase to 8, even blocks far away from berth 1 can offer better equipment shared, the total travel distance is much bigger in high dispersion level. As the additional interference, the GCR is hard to be 30move/h, but roughly around 25move/h. After balancing between time delay of truck congestion and longer travel time, the best performance appear in dispersion level 2 with 30.6move/h. Also in Figure 9, with the increasing of dispersion level, the GCR performance is falling due to the increasing of travel distance.

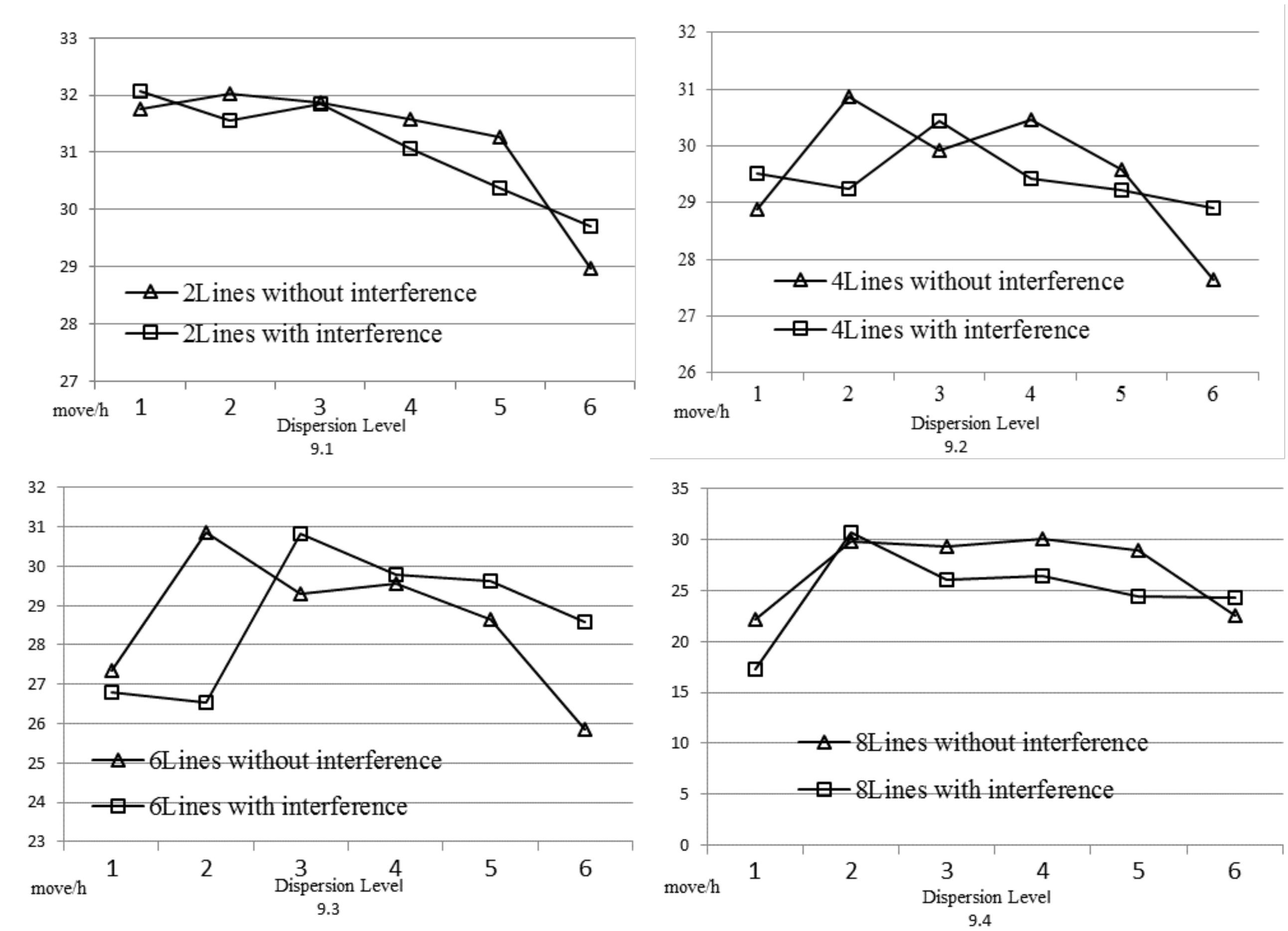

Figure 9: Average GCR with adequate equipment under interference

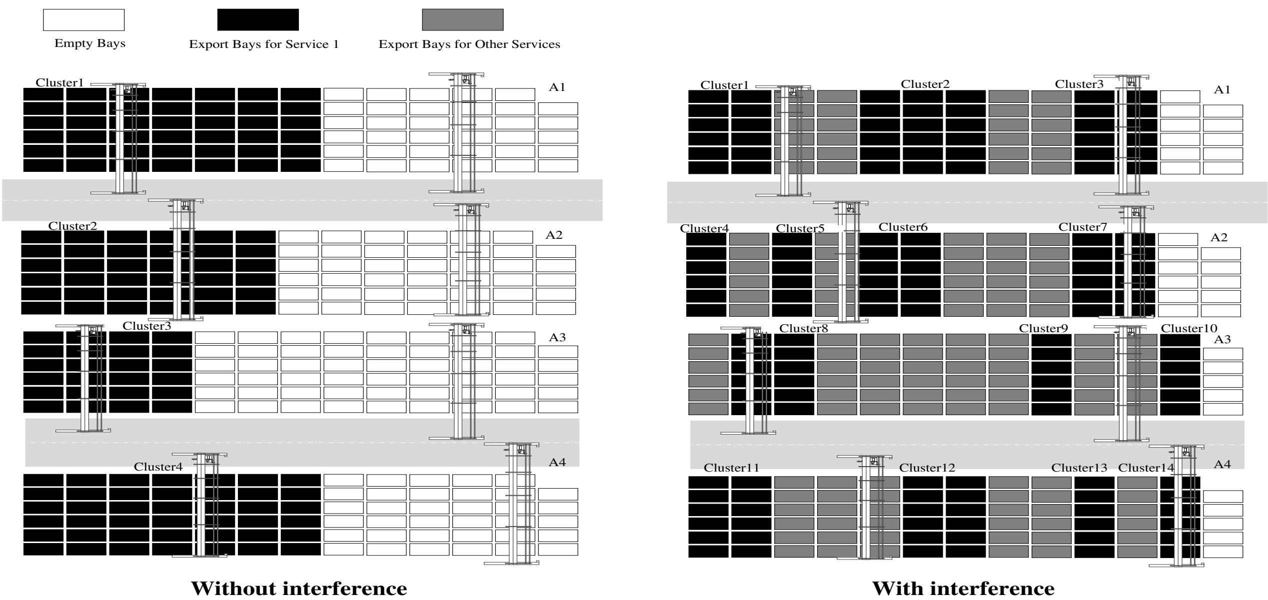

Figure 10: Yard templates schedule with adequate equipment (Area A)

The average GCR performances with scarce equipment deployment are shown as Figure 11. As the equipment decreased and interferences added, the general performance is much worse than before. The GCR is hard to be 25move/h, and just around 20move/h in high workloads with 6 or 8 service lines. An interesting finding is the best GCR often appear in lower location dispersion in this scenario. Except for service with 2 lines getting its best GCR in level 3, all other services get their best GCR in level 2.The reason may be found in Figure 12.

Shown as Figure 12, each block is only served by one QC. For a low workload service with 2 lines, a dispersion level 3 allocations can mitigate the congestion due to the concentrate allocation and restrain the total traveling distance increases. But, with the increasing of service lines, all the blocks are busy with services over their handling capabilities. As a result, the spread allocations often get congestion in other block too and increase the traveling distance at the same time. So, stacking with lower dispersion level always works well, that make service with 4, 6 and 8 lines perform better in dispersion level 2.

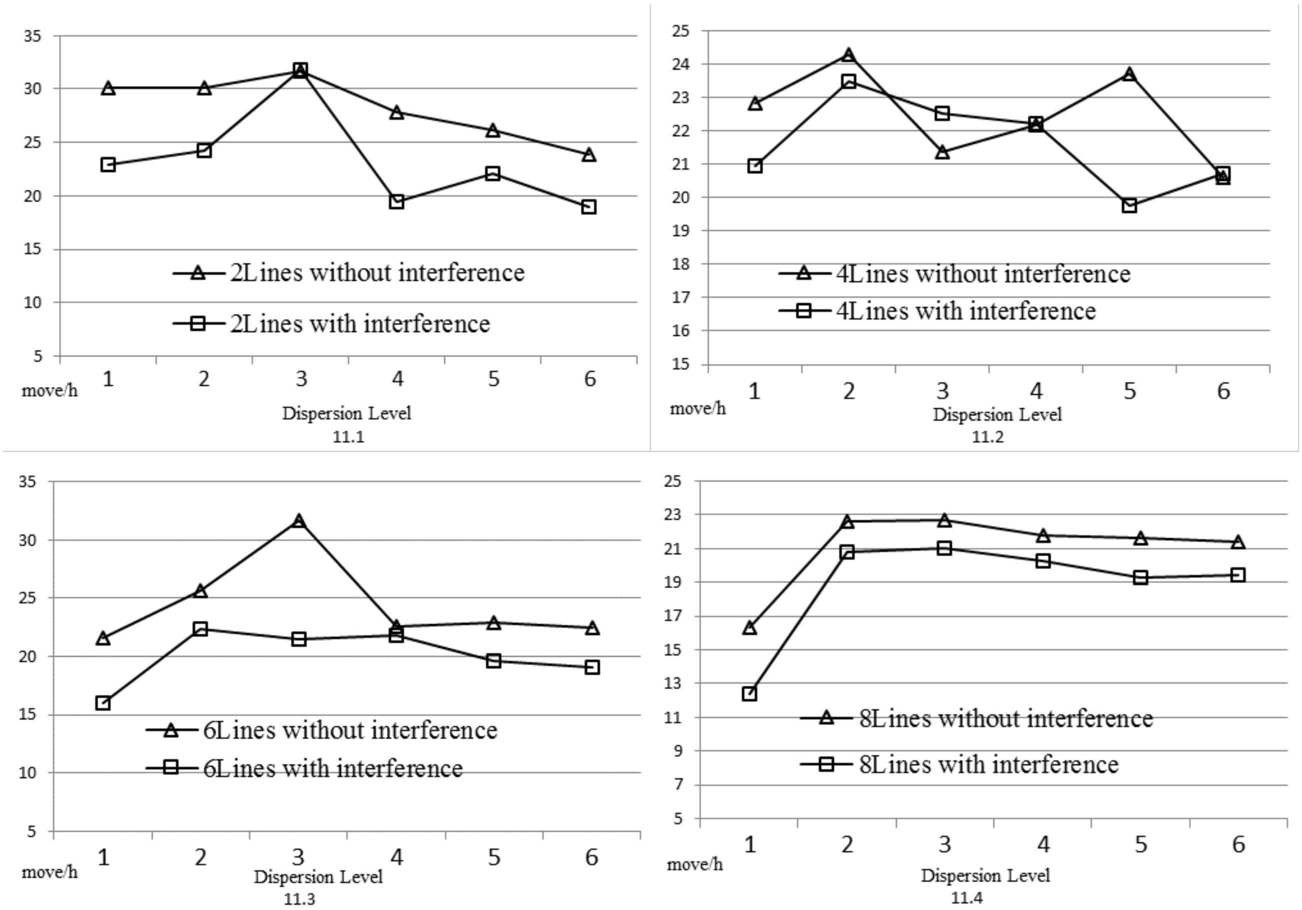

Figure 11: Average GCR with scarce equipment under interference

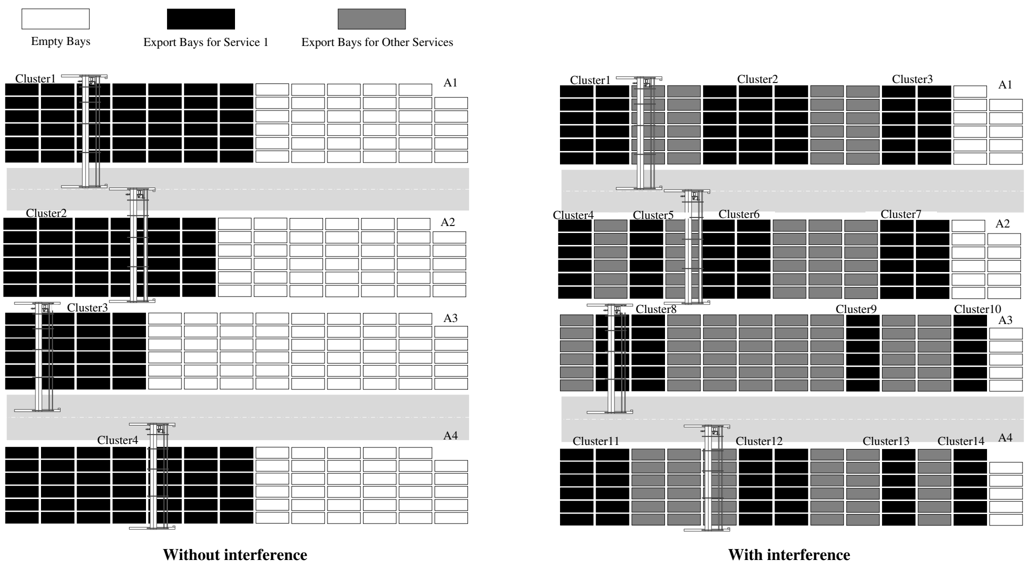

Figure 12: Yard templates schedule with scarce equipment (Area A)

From the above findings in study 2, additional conclusion about GCR and container allocation in real productivity can be drawn as below.

- The GCRs in real productivity are generally worse than the ideal environment as the interference affecting.

- In real productivity, higher dispersion level is preferred in an adequate environment. It's different from the ideal scenario in study 1, which due to the YCs' real capability decreasing with interference works added.

- In real productivity, lower dispersion level often preferred by scarce equipment terminals as the spread locations seldom decrease the congestion but increase the total travel distance.

- The best dispersion levels choices always depend on the workloads, the optimal of loading clusters allocations are changing with different kinds of services.

Another interesting finding is more loading clusters with a concentrate allocated always get better GCR performance in equipment adequate terminals. As the number of loading clusters is not the main concern of this research, we may continue this topic later.

6. Conclusion

We have used a simulation based method to evaluate effects of container location dispersion on the performance of container loading at a terminal. For this purpose, we built an integrated yard operations simulation model by means of FlexTerm to evaluate the GCR resulted from different location dispersion strategies. Some experiments and their major output are presented. The notion of container location dispersion is proven to be important in the further research on yard storage allocation. Some highlights are listed below.

- The location dispersion of loading cluster is closely related to the long-run performance of GCR. It's an important index that terminal should consider during the yard allocation.

- The location dispersion of the loading clusters is highly depending on the number of loading containers. Different workload services prefer different number of loading clusters and various export containers location range.

- The optimization of location dispersion is extremely efficient in improving the handling performance of a busy container terminal with frequently extra handlings during loading.

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Long Memory Analysis of Bulk Freight Rate under Structural Breaks

Si-Yu Dai[1,] Ya-Dong Zeng[1], Fei-Er Chen[1,2], Xin zhang[3], Jihong Chen[3] and Cungen Liu[1,2]*

[1]State Key Laboratory of Ocean Engineering, School of Naval Architecture, Ocean and Civil Engineering, Shanghai Jiao Tong University, Shanghai, China
[2]Collaborative Innovation Center for Advanced Ship and Deep-Sea Exploration, China
[3]College of Transport and Communications, Shanghai Maritime University, Shanghai, China

[*]*Corresponding Author: chenfeier@sjtu.edu.cn*

Abstract

Analysis of freight rate volatility characters under structural breaks is of great importance after year 2008. In this paper, the presence of structural break points in bulk freight rate index time series is investigated by employing the Iterated Cumulative Sum of Squares (ICSS) algorithm. Furthermore, long memory features comparison of different vessel sizes, Supramax, Panamax and Capesize bulk carriers is also accomplished, and emperical results show that dry bulk carriers with smaller ship size are inclined to have stronger long-range correlation. Results of different types of Detrended Fluctuation Analysis (DFA) Method are compared, and influence of seasonality is taken into consideration. For policy makers and investors with different trading horizons, switching point is an important indicator of different long memory characters of freight rate index time series in different time ranges. Hence switching points in DFA results are picked out and conclusions of long memory feature are achieved.

Keywords: Freight rate; Long memory; Structural break; Detrended fluctuation analysis

1. Introduction

Freight rate market is a vital component of shipping industry, of which the distinctive characteristic is dynamic and volatile (Zhang et al., 2014). Freight rate volatility represents the fluctuation or dispersion of the freight rate in shipping market. It has been validated by large amount of researches that freight rate volatility can be rather large, while its fluctuation trend can be estimated according to its time-varying feature (Jing, 2008; Kavussanos, 1996, 2003).

Recent studies suggested that shocks on volatility have long-lasting effects. This phenomenon is known in the empirical finance literature as long-range dependence behavior or long memory behavior (Charfeddine and Ajmi, 2013). When the effects of volatility shocks decay slowly, long memory in volatility would occur. Significance is attached to the long memory feature, mainly for the sake of its accordance with the presence of nonlinear dependence between observations. Although long memory features have been discussed in many fields, including hydrology, Internet traffic, commodity market and energy future market (Barkoulas et al., 1998; Chen et al., 2006; Crato and Ray, 2000; Elder and Jin, 2007; Ohanissian et al., 2008; Panas, 2001; Wang and Wu, 2012), few researches focus on the long memory feature in freight rate market. As claimed by Yalama and Celik (2013), different financial markets and different sampling periods may present different characteristics of long-range correlation. Therefore, the long memory study focused on freight rate market is indispensable. In this paper, the Detrended Fluctuation Analysis (DFA) method is employed to study the long memory feature of freight rate volatility and the robustness of long-memory inference on daily freight rate index prediction. Compared with other methods which can be used in long memory analysis, such as Rescaled Range Method (R/S) and spectrum analysis method employed in the study of Kai et al. (Kai et al., 2008), an indisputable advantage of DFA is that it can detect the long-range correlations embedded in a non-stationary time series, without being influenced by spurious detection of apparent long-range correlations caused by external trends. The impact of seasonality has also been taken into account in the optimization of DFA, since literatures have shown that freight rate market is seasonal (Kavussanos, 2001, 2002).

Additionally, a crucial issue that arises when analyzing the characteristic of long memory is that the existence of structural breaks can have influence on the long memory of freight rate volatility. In spite of the considerable researches that focus on long memory features of volatility, long memory studies on time series with structural breaks are still limited. The Iterated Cumulative Sum of Squares (ICSS) algorithm, which was developed by Inclan and Tiao (1994), is proved to be one of the most popular and useful ways in studying the structural transition points of volatility (Aggarwal et al., 1999; Fernández and Aragó, 2003; Malik, 2003; Malik et al., 2005). Thus, ICSS method is adopted in order to detect structural break points in this paper.

Studies on freight rate volatility as well as the long memory component and structural breaks have been thoroughly established by plentiful empirical studies (Baillie et al., 2007; Elder and Serletis, 2008; Fernandez, 2010; Wang and Wu, 2012). Nevertheless, tests for potential structural breaks and their impacts on the estimated fractional long memory parameter have been conducted in only a few studies (Arouri et al., 2012; Baillie and Morana, 2009; Christensen et al., 2010; Ozdemir et al., 2013). Moreover, DFA-based researches on long memory features in bulk freight market are still inadequate. Therefore, in this paper, we provide DFA results of Baltic Panamax Index (BPI), Baltic Supramax Index (BSI) and Baltic Capesize Index (BCI), which validate the long memory features in bulk freight rate market. The impact of seasonality has also been taken into account in the optimization of DFA.

The paper is further organized as follows: Section 2 applies the DFA and ICSS model to analyze of freight rate volatility; Section 3 describes the data used in the long memory test; Section 4 demonstrates the analysis of long memory and structural break of historical data with DFA and ICSS method respectively; Section 5 summaries and concludes.

2. Methodology

2.1. DFA Model

The Detrended Fluctuation Analysis (DFA) was first proposed by Peng et al. (1995) while examining series of DNA nucleotides. The DFA method has its intrinsic advantage when analyzing the long-range correlation of time series, since it can effectively eliminate the trend component of in the series, as well as detect the long-range correlation of signals superposed with noise and polynomial trend. Due to the validity of DFA in analysis of the long-range power law correlation of non-stationary time series, we employ this method in our long memory test of bulk freight market. Corresponding to the DFA algorithms with $n=1$, $n=2$ and $n=3$, DFA1, DFA2 and DFA 3 are named separately.

2.2. ICSS Model

The Iterative Cumulative Sums of Squares algorithm (ICSS) was first proposed by (Inclan and Tiao, 1994). It owns overwhelming superiority in terms of analysis of structural mutability and detection of structural breaks. This method assumes that the volatility is stationary until an external shock induces a structural change of volatility. After a shock, the volatility becomes stationary again until another structural change occurs. In this paper, this method is employed in order to detect the structural breaks of freight rate index.

3. Data

Bulk cargo shipping market is not only one of the most important markets of shipping, but also a global bellwether, signalling industrial health wherever it trades, for bulks are mainly used to transport steel, pulp, grain, coal, iron ore, ore, bauxite and other daily necessities and industrial raw materials. Therefore, we pay great attention to Baltic Dry Index (BDI). In the analysis, we choose Supramax, Panamax and Capesize to study the fluctuations in freight rate of dry bulk shipping market since there is an obvious trend of large-scale ship in dry bulk market, and these three kinds of bulks can better reflect the volatility. Three types of BDI: Baltic Supramax Index (BSI), Baltic Panamax Index (BPI), and Baltic Capesize Index (BCI), which reflect the cost of hiring a vessel across a range of indicative shipping routes, are utilized in the following study. The sample for BPI, BSI and BCI covers the period from July 1st, 2005 to February 26th, 2015. Figure 1 is the line graph of BSI, BPI and BCI in the sample period. The index curves show sharp fluctuations and the indices underwent intensive changes in the year 2008, when the world financial crisis happened.

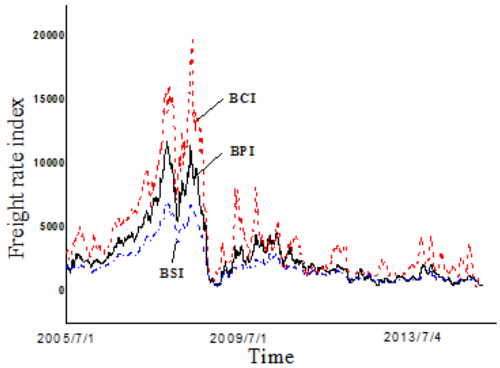

Figure 1: Line graph of Baltic Dry Index (BDI)

4. Results and Discussion

4.1. Results of Structural Breaks Test

The ICSS algorithm is employed in the structural break test of original BCI, BPI and BSI time series, of which the results are displayed in Figure 2-4 respectively. Comparing these three figures, we can conclude that, in each of the three series, numerous structural break points exist, proving that the BCI, BPI and BSI time series are all non-stationary. Thus, long memory test with the help of DFA method is of great significance. It can be further observed that the structural breaks with the most dramatic fluctuation in all the three figures are around the year 2008. This could be a proof of the serious impact on the freight rate market, brought about by the economic crisis. Considering that researches focusing on the severe strike of the economic crisis in 2008 on freight rate market volatility is inadequate, our study takes data after the economic shock into account and accomplishes the long memory analysis of time series which have obvious structural breaks.

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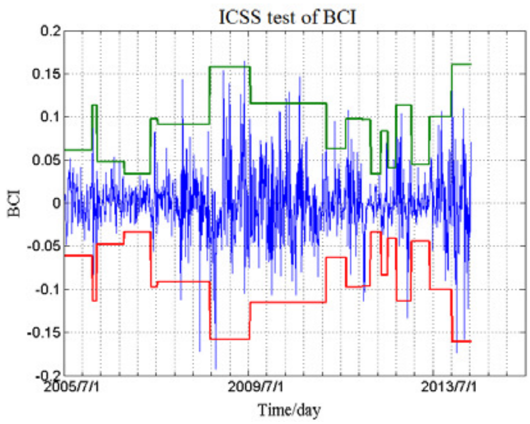

Figure 2: Daily returns dynamics of BCI. Green and red lines are at ±3 standard deviations where structural change points are estimated by the ICSS algorithm

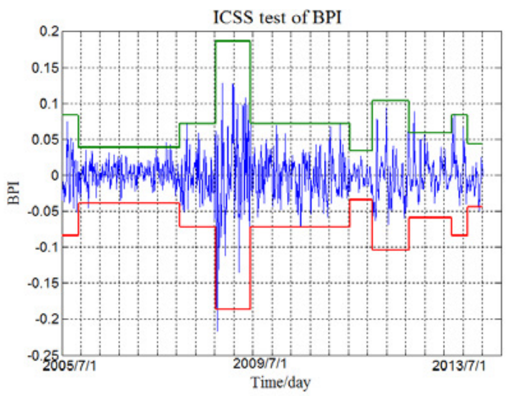

Figure 3: Daily returns dynamics of BPI. Green and red lines are at ±3 standard deviations where structural change points are estimated by the ICSS algorithm.

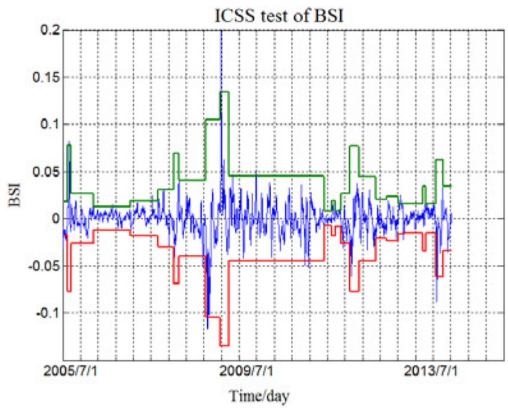

Figure 4: Daily returns dynamics of BSI. Green and red lines are at ±3 standard deviations where structural change points are estimated by the ICSS algorithm

4.2. Results of Long Memory Test

4.2.1. Comparison between Different DFA method

Results of DFA tests with different orders are shown in Figure 5. The slope of each fitting line means the corresponding scaling exponent α. Obviously, fluctuation function $F(s)$ and time step s present strong logarithmic linear correlation in all the three types of DFA. When comparing the three curves of different orders, we can reach the conclusion that a higher order of DFA will contribute to a more precise fitting of local trend, since the value of $F(s)$ tends to ascend as order of DFA n descends. One can further observe that the difference value between $F(s)$ of neighboring-order DFAs is inclined to decrease as s increases.

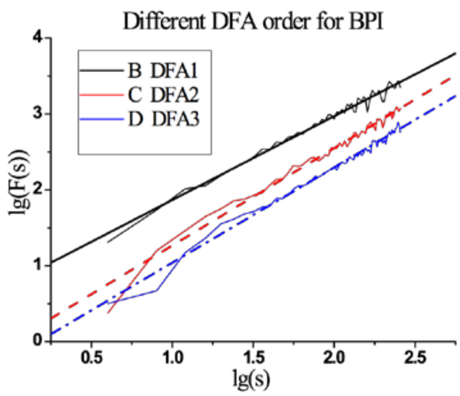

Figure 5: Log-log plot of the fluctuation function with respect to time step ($\lg(F(s))$ vs. $\lg(s)$) in DFA1, DFA2, and DFA3

Table 1: Scaling exponent of different DFA methods

Different DFA methods	Scaling exponent α
DFA1	1.10
DFA2	1.28
DFA3	1.26

4.2.2. Seasonal influence

Since periodicties can have impact on detection of long memory character, X-12-ARIMA method in Eviews is employed so as to investigate the influence of seasonality in BPI time series. The DFA2 results of original and deseasonalized BPI series are displayed in Figure 3. It can be observed that both time series own strong logarithmic linear correlation between and , while the slope of the deseasonalized BPI series (1.3) is larger than that of the original BPI series (1.2), indicating that a stronger long-range correlation can still be revealed after deseasonalization. Nevertheless, the difference between them is small, revealing that the impact of seasonality on BPI series is negligible. What's more, deseasonalization in this method should be based on monthly mean data, which may bring about the reduction of available data. Due to these two reasons, influence of seasonality isn't taken into consideration in the following analysis.

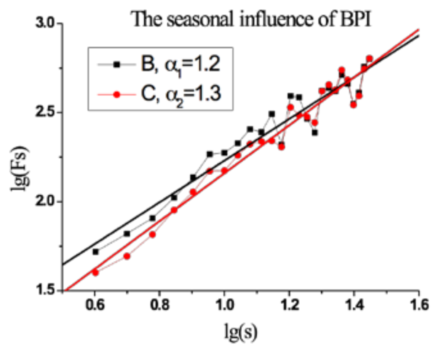

Figure 6: Log-log plot of the fluctuation function with respect to time step ($\lg(F(s))$ vs $\lg(s)$) in DFA2 of original and deseasonalized BPI time. α_1 and α_2 are the slope for fitting lines before and after deseasonalization respectively

4.2.3. BPI Analysis with DFA2

Figure 7 exhibits the result of DFA2 test of BPI time series. The slope of the fitting line means the corresponding scaling exponent α. Obviously, fluctuation function $F(s)$ and time step s present strong logarithmic linear correlation. The scaling exponent α, as defined from the slopes of linear fits to these points, were determined as 1.28, indicating a relatively strong long-range correlation in BPI time series. Since $\alpha > 0.5$, positive long-range correlation can be detected in BPI, which means that persistence exists in volatility of Panamax freight rate market in the range from July 1st, 2005 to February 26th, 2015.

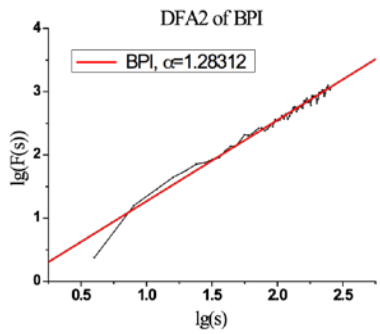

Figure 7: Log-log plot of the fluctuation function with respect to time step ($\lg(F(s))$ vs $\lg(s)$) in DFA2 test of BPI time series. α is the slope of fitting line

4.2.4. Comparison between Supramax, Panamax and Capesize

DFA2 method is also utilized in the analysis of influence of ship size on the long memory character of nonlinear freight rate volatility. In Figure 8, we provide the result of DFA2 test of BSI, BPI and BCI time series. For all the three types of dry bulk carriers, the scaling exponent is between 1 and 1.5, indicating a strong and persistent long-range correlation in each time series. Therefore, we can conclude that freight rate volatility of dry bulk carrier is not a random series with no autocorrelation. Actually, the condition of freight rate market in the current stage can have crucial influence on that of next stage. Consequently, the long memory characteristic has been verified in the freight rate time series of Supramax, Panamax and Capesize.

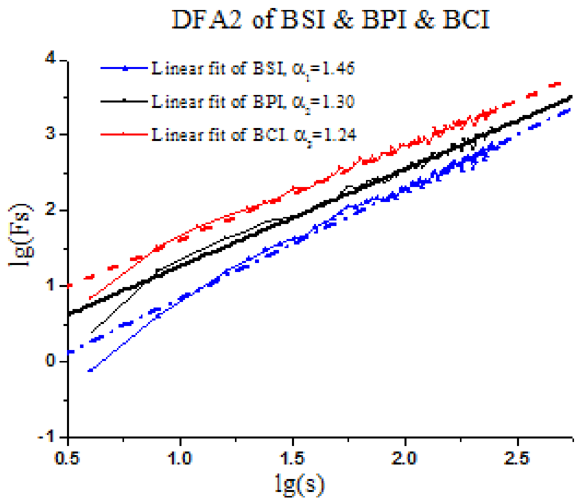

Figure 8: Log-log plot of the fluctuation function with respect to time step ($\lg(F(s))$ vs $\lg(s)$) in DFA2 test of BSI, BPI and BCI time series. α_1, α_2 and α_3 are the slope of fitting lines for BSI, BPI and BCI respectively

Table 2: Scaling exponent of different freight rate indexes

Different indexes	Scaling exponent α
BSI	1.46
BPI	1.30
BCI	1.24

It can be further observed that $\alpha_{BSI} > \alpha_{BPI} > \alpha_{BCI}$, showing that a smaller ship size is correlated with a larger scaling exponent in DFA2 test. This conclusion validates the hypothesis that ship size can have impact on the long memory feature of dry bulk carrier freight rate market. As Capesize is the one with the largest ship size among all the types of dry bulk carriers, its freight rate is more sensitive to external factors than other types. During a booming market, Capesize would precede other vessels in terms of surge in demand, while in depression, it would also be the first to experience severe slump. Consequently, the long-range correlation in BCI time series is the weakest.

4.2.5. Switching Points in DFA2

An in-depth exploration into the results of DFA2 test of BSI, BPI and BCI time series would reveal that better fitting can be realized if we divide the linear fitting into two stages at a certain time step. The new linear fitting result of BPI series is shown in Figure 9, while the coordinate values of switching points in those three time series and the corresponding time steps are listed in Table 3. It can be seen that the slope of two fitting lines differ in each figure, indicating the shift of long memory property. The time step, at which the time series experience a notable shift in terms of scaling exponent, is called switching point (Rivera-Castro et al., 2012).

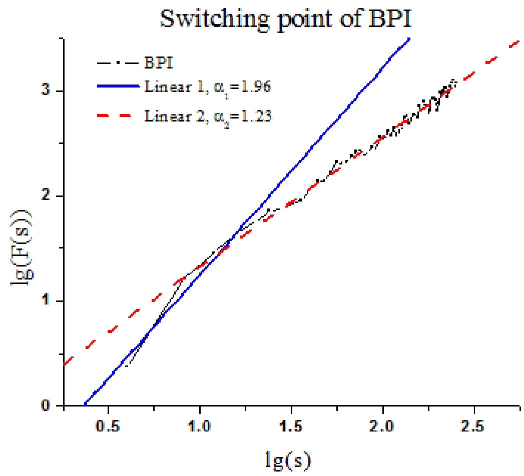

Figure 9: Log-log plot of the fluctuation function with respect to time step ($\lg(F(s))$ vs. $\lg(s)$) of BPI in DFA2 test. α is the slope of fitting line

Table 3: Switching points

Freight rate index	$\lg(s)$ of switching points	Time step s
BPI	1.38	24
BCI	1.51	32
BSI	1.45	28

5. Conclusion

In this paper, we analyze the long memory feature of freight rate index time series under structural breaks. DFA and ICSS model are established and applied in the study of nonstationary BSI, BPI and BCI time series. For the sake of optimization of DFA method, we present the differences of different orders of DFA and conclude that DFA2 is appropriate in this study. Furthermore, although impact of seasonality on freight rate market is analyzed, we don’t take it into account in long-range correlation evaluation since its influence is negligible. Additionally, long memory character and switching points of BSI, BPI and BCI time series are exhibited.

Our empirical results show that, in the time range from July 1st, 2005 to February 26th, 2015 BSI, BPI and BCI time series all have structural breaks, the most notable one of which exists around 2008. Thus, the advantage of DFA method used in our study is considerable, since DFA never calls for stability in time series. Besides, long-range correlation is also validated in BSI, BPI and BCI time series, proving the influence of current freight rate market condition on its next stage. Another finding is that ship size has negative correlation with the long memory character of dry bulk carrier freight rate market. Capesize, as the largest in terms of ship size, has the weakest long-range correlation in freight rate time series. It is also verified that switching points exist in the DFA linear fitting of all the three indexes, at which would experience evident shift. Long-range correlation tends to be stronger with shorter time range, indicating that long memory feature of freight rate market is quite different for short-term and long-term investors. Overall, switching point analysis is of great significance because of the existence of diverse trading horizons. With the help of long memory analysis in this paper, investors and policy makers can make better predictions of volatility behaviors of dry bulk carrier freight rate market, as well as adjust their trading strategies timely. The power of forecasting the freight rate index could be studied in the future work.

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The Effect of Noise Reduction on Long Memory Test of Bulk Freight Rate Index

Si-Yu Dai[1], Ya-Dong Zeng[1], Fei-Er Chen[1,2], Jihong Chen[3], Han Xu[4] and Cungen Liu[1,2]*

[1]State Key Laboratory of Ocean Engineering, School of Naval Architecture, Ocean and Civil Engineering, Shanghai Jiao Tong University, Shanghai, China
[2]Collaborative Innovation Center for Advanced Ship and Deep-Sea Exploration, China
[3]College of Transport and Communications, Shanghai Maritime University, Shanghai, China
[4]School of Mechanical Engineering, Ocean and Civil Engineering, Shanghai Jiao Tong University, China

[*]*Corresponding Author: chenfeier@sjtu.edu.cn*

Abstract

Analysis of nonlinear freight rate volatility characteristics attracts more attention after year 2008. In this paper, we test the long memory feature of bulk freight rate index and discover scaling behavior. The switching points, indicators of scaling behavior, can be eliminated after nonlinear noise reduction technique, thus we conclude that high-frequency noise is the cause of scaling behavior. Additionally, comparison of long memory features between different vessel sizes, Supramax, Panamax and Capesize bulk carriers, is also accomplished both before and after noise reduction. Empirical results show that their differences would disappear after noise reduction, indicating that ship size is one of the short-term external factors which result in high-frequency noises in freight rate index time series.

Keywords: Freight rate; Long memory; Noise reduction; Detrended fluctuation analysis; Vondrák filtering; Nonlinear

1. Introduction

As the freight rate market has gradually transformed into a market where freight rate can be bought and sold for investment purposes like any other financial asset or commodity, more attention has been paid to the dynamics and volatility of freight rate market (Nomikos et al., 2013). Freight rate volatility represents the nonlinear fluctuation or dispersion of the freight rate in shipping market. It has been validated by large amount of researches that freight rate volatility can be rather large, while its fluctuation trend can be estimated according to its time-varying feature (Kavussanos, 1996a, b, 2003; Lu et al., 2008). In this paper, the bulk carrier freight rate index is analyzed, since the bulk carrier market is more competitive and typical, whereas the tanker market and container ship market are considerably influenced by oligopoly.

Recent studies suggested that shocks on volatility have long-lasting effects. This phenomenon is known in the empirical finance literature as long-range dependence behavior or long memory behavior (Charfeddine and Ajmi, 2013). When the effects of volatility shocks decay slowly, long memory in volatility would occur. Significance is attached to the feature of long memory mainly for the sake of its accordance with the presence of nonlinear dependence between observations, which in other words means predictions of future can be realized with the help of researches on long memory. Although long memory features have been discussed in many fields, including hydrology, Internet traffic, commodity market and energy future market (Barkoulas et al., 1998; Chen et al., 2006; Crato and Ray, 2000; Elder and Jin, 2007; Ohanissian et al., 2008; Panas, 2001; Wang and Wu, 2012), few researches focus on the long memory feature in freight rate market. As claimed by Yalama and Celik (2013), despite of the common belief that volatility is characterized by long memory processes, the presence of long memory characteristic depends on volatility measurements. Different financial markets and different sampling periods may present different characteristics of long-range correlation. Therefore, the long memory study of freight rate market is indispensable. In this paper, the nonlinear Detrended Fluctuation Analysis (DFA) method is employed to study the long memory feature of freight rate volatility and the robustness of long-memory inference on daily freight rate index prediction. Compared with other methods which can be used in long memory analysis, such as Rescaled Range Method (R/S) and spectrum analysis method employed in the study of Kai et al.(Kai et al., 2008), an indisputable advantage of DFA is that it can detect the long-range correlations embedded in a fluctuant time series without being influenced by spurious detection of apparent long-range correlations caused by external trends. Additionally, since we have analyzed the influence of seasonality on long-range correlation and concluded that its effect is negligible, deseasonalization is not covered in this paper.

Nevertheless, noise in the time series can influence the accuracy of long memory test (Nagarajan, 2006; Rodriguez et al., 2007; Sun and Sheng, 2011; Valencia et al., 2008), which would further affect the estimation of the freight rate market and bring about risks to the investors (Gosse, 2010; Hassani et al., 2010). Hence, filtering, as a technique for denoising, is worthy of attention when analyzing the long-range correlation of freight rate market. In order to find an apropos filter for noise reduction in this paper, we have compared the denoising effect of Vondrák filter, established by J. Vondrák (1969, 1977) and developed by Ding et al. (2005) and Li et al. (2006; 2008), N-point weighted moving average filter and fast Fourier filter. He et al. found that N-point weighted moving average filter can't eliminate the existence of switching point caused by noise during DFA test, while fast Fourier filter depends greatly on the threshold of filtering period (He et al., 2011). In contrast, the nonlinear Vondrák filter can almost eliminate the switching phenomenon completely without strong dependence on the selection of filtering period threshold, presenting relative superiority in the effectiveness and reliability of noise reduction during the long memory test. Additionally, Vondrák filtering is also able to effectively smooth the data without knowing the change rule and fitting function of the data. High fidelity and elimination of transition phenomenon can be achieved simultaneously in the nonlinear Vondrák filtering process. Results of long memory test before and after Vondrák filtering are contrasted in this paper, which can provide advice on risk management when assessing the long memory feature of freight rate market.

The paper is further organized as follows: Section 2 introduces the DFA model and Vondrák filtering method; Section 3 describes the data used in the long memory test; Section 4 demonstrates the results of long memory test before and after Vondrák filtering; Section 5 summaries and concludes.

2. Methodology

2.1. DFA Model

The Detrended Fluctuation Analysis (DFA) was first proposed by Peng et al. (1995) while examining series of DNA nucleotides. The DFA method has its intrinsic advantage when analyzing the long-range correlation of time series, since it can effectively eliminate the trend component of in the series, as well as detect the long-range correlation of signals superposed with noise and polynomial trend. Due to the validity of DFA in analysis of the long-range power law correlation of non-stationary time series, we employ this method in our long memory test of bulk freight market. Corresponding to the DFA algorithms with $n=1$, $n=2$ and $n=3$, DFA1, DFA2 and DFA 3 are named separately. Basing on the balance between higher accuracy and lower cost of time and energy, we found that the DFA2 model is the most appropriate one. Thus, we choose the DFA2 model to analyze the long-range correlation of the non-stationary freight rate time series in this paper.

2.2. Vondrák Filtering Method

Vondrák filtering is a nonlinear data processing method aiming at balancing the fidelity and smoothness of the original data (Ding, 2005). In the filtering process, requirement of smoothness and fitness should both be satisfied. By employing Vondrák filtering method, higher-frequency signals and low-frequency signals distinguished, and the function of low-pass filter, band-pass filter or high-pass filter can be realized. In this paper, the Vondrák filtering method functions as a low-pass filter.

3. Data

Bulk cargo shipping market is not only one of the most important markets of shipping, but also a global bellwether, signaling industrial health wherever it trades, for bulks are mainly used to transport steel, pulp, grain, coal, iron ore, ore, bauxite and other daily necessities and industrial raw materials. Therefore, we pay great attention to dry bulk index. In the analysis, we choose Supramax, Panamax and Capesize to study the fluctuations in freight rate of dry bulk shipping market since there is an obvious trend of large-scale ship in dry bulk market, and these three kinds of bulks can better reflect the volatility. Baltic Supramax Index (BSI), Baltic Panamax Index (BPI), and Baltic Capesize Index (BCI), which reflect the cost of hiring a vessel across a range of indicative shipping routes, are taken advantage of in the following study.

The sample for BPI, BSI and BCI covers the period from July 1st, 2005 to February 26th, 2015. Figure 1 is the line graph of BSI, BPI and BCI in the sample period. The index curves show sharp fluctuations and the indices underwent intensive changes in the year 2008, when the world financial crisis happened.

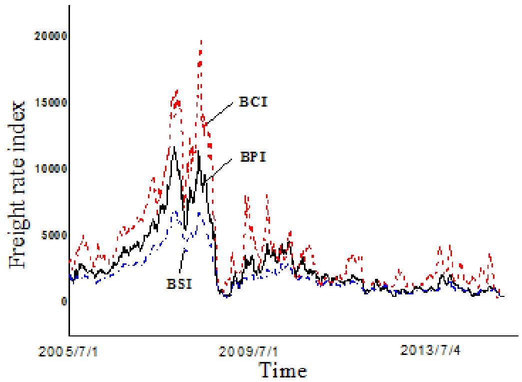

Figure 1: Baltic Dry Bulk Freight rate index

4. Results and Discussion

4.1. Results of Long Memory Test before Vondrák Filtering

4.1.1. Comparison between Supramax, Panamax and Capesize

DFA2 method is utilized in the analysis of influence of ship size on the long memory character of nonlinear freight rate volatility. The scaling exponents of DFA2 test of BSI, BPI and BCI time series are 1.46, 1.30 and 1.24 respectively. For all the three types of dry bulk carriers, the scaling exponent is between 1 and 1.5, indicating a strong and persistent long-range correlation in each time series. Therefore, we can conclude that freight rate volatility of dry bulk carrier is not a random series with no autocorrelation. Actually, the condition of freight rate market in the current stage can have crucial influence on that of next stage. Consequently, the long memory characteristic has been verified in the freight rate time series of Supramax, Panamax and Capesize.

It can be further observed that $\alpha_{BSI} > \alpha_{BPI} > \alpha_{BCI}$, showing that a smaller ship size is correlated with a larger scaling exponent in DFA2 test. This conclusion validates the hypothesis that ship size can have impact on the long memory feature of dry bulk carrier freight rate market. As Capesize is the one with the largest ship size among all the types of dry bulk carriers, its freight rate is more sensitive to external factors than other types. During a booming market, Capesize would precede other vessels in terms of surge in demand, while in depression, it would also be the first to experience severe slump. Consequently, the long-range correlation in BCI time series is the weakest.

4.1.2. Switching Points in DFA2

An in-depth exploration into the results of DFA2 test of BSI, BPI and BCI time series would reveal that better fitting can be realized if we divide the linear fitting into two stages at a certain time step. The time step, at which the time series experience a notable shift in terms of scaling exponent, is called switching point (Rivera-Castro et al., 2012). The coordinate values of switching points in those three time series and the corresponding time steps are listed in Table 2.

Table 1: Switching points

Freight rate index	$\lg(s)$ of switching points	Time step s
BPI	1.38	24
BCI	1.51	32
BSI	1.45	28

The phenomenon that slope of fitting line, i.e. scaling exponent , will experience a considerable shift at a specific scale range in the DFA2 test of freight rate index time series can be named the scaling behavior (Choo et al., 2012; Gulich and Zunino, 2014). This phenomenon can be explained by the existence of high-frequency noises in the time series. The nonlinear fluctuation of freight rate market is susceptible to many external factors such as oil price, political condition, prices of cargos and fleet size. These factors are relatively short-term and can often cause high-frequency fluctuations in the freight rate market, which can be viewed as high-frequency noises in the time series. When the time scale is relatively shorter, the influence of those factors is taken into account, giving rise to stronger high-frequency noises. In contrast, the effect of those factors, under a longer time scale, may last merely within one fragment of the time series, thus the high-frequency noises would be concealed when analyzing the long-range correlation of the whole time series. Consequently, the discrepancy of the influence caused by high-frequency noises can explicate the scaling behavior during the long memory test.

4.2. Results of Long Memory Test after Vondrák Filtering

As stated in the previous subsection, high-frequency noises may influence the long memory test results of bulk freight rate index. To validate this hypothesis, we apply the nonlinear Vondrák filtering technique to the original time series and provide the DFA test result after noise reduction. We have compared the filtering results when the smooth factor ε is set at 10^{-6}, 10^{-7} 10^{-8} 10^{-9} respectively, and concluded that the differences between them are inconsiderable. Since the period threshold of filtering is determined by ε, it is validated that the influence of period threshold merely has limited influence on the filtering effect of Vondrák filter, which has been stated in Section 1 as one of the advantages of Vondrák filter. In this section, the value of smooth factor ε is 10^{-9}.

4.2.1. Separation of the High-frequency Noises

Noise reduction based on Vondrák filtering is conducted to BPI, BCI and BSI time series, and the results of BPI series are presented in Fig.2 for the sake of demonstration. In Fig.2, the black bold solid curve depicts the original time series, while the blue thin solid curve and the red dash curve represent the high frequency component and low frequency component of the original series respectively. Although smoothed to a great extent, the low frequency component can still reflect the trend of the original series, which proves the data fidelity after filtering. We can observe that the length of the time series after filtering is exactly the same as that of the original series, which is one of the advantages of Vondrák filtering. The low frequency component of the original series is used as the new time series after noise reduction in the following DFA test.

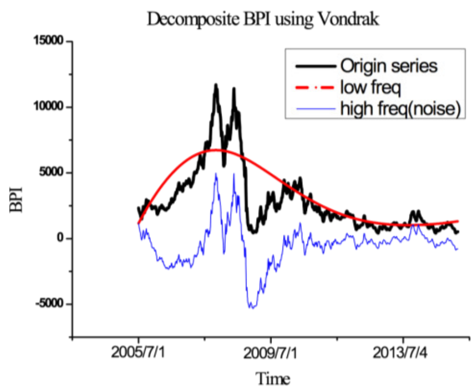

Figure 2: Separation of high-frequency noises for BPI time series

4.2.2. *Effect of Vondrák Filtering on Long Memory Test Results*

The DFA-based long memory test result of BPI is exhibited in Fig. 3. The black solid curve describes the fluctuation of original $\lg(F(s))$, while the blue solid line and the red dash line are two fitting lines before Vondrák filtering, the slope of which are named α_1 and α_2 respectively. The red solid line depicts the trend of $\lg(F(s))$ after Vondrák filtering and the purple dot dash line is its fitting line with the slope α. Comparison of long memory test results before and after Vondrák filtering is also conducted on BCI and BSI time series. The value of α_1, α_2 and α in the long memory test results of BPI, BCI and BSI are exhibited in Table 2.

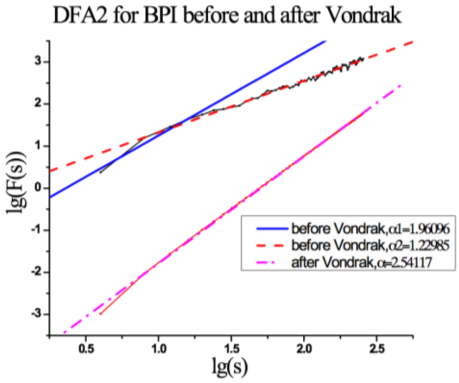

Figure 3: Long memory test result of BPI after Vondrák filtering

Table 2: Comparison of α before and after Vondrák Filtering

Freight rate index	α_1 of original series before switching point	α_2 of original series after switching point	α of denoised series
BPI	1.96096	1.22985	2.54117
BCI	1.52463	1.16590	2.54222
BSI	1.99012	1.30150	2.54096

By analyzing Figure 3 and Table 2, we can reach several conclusions:

(1) The switching point is eliminated after Vondrák filtering, and our hypothesis that the switching point is brought about by the high-frequency noise is validated. Since the high frequency component of the time series has already been separated, the scaling behavior caused by the high-frequency noise is also eliminated. Hence Vondrák filtering can be utilized as an excellent tool to remove the influence of some short-term factors, in order to analyze the intrinsic fluctuant characteristic of freight rate market.

(2) The slope of fitting line for $\lg(F(s))$ - $\lg(s)$ curve after Vondrák filtering, i.e. α, is not between the value of α_1 and α_2; instead, α is much larger than α_1 and α_2. A stronger long memory feature is presented after filtering the high frequency component, noises generated by short-term influence factors. Thus we can believe that these external factors are disturbance in the long memory behavior of freight rate index time series, while the intrinsic dominant factor in freight rate market is strong and steady, leading to relatively robust long-range correlation phenomenon in its fluctuation. This dominant factor is surmised to be the equilibrium power between market supply and demand.

(3) α of all the three types of dry bulk carrier are around 2.54, which means ship size no longer affects the long memory feature of freight rate market after eliminating the high-frequency noises. Compare this conclusion with the considerable discrepancy between different types of bulk carriers before noise reduction, and we can conclude that ship size is also one of the external factors which result in high-

frequency noises. Therefore, we can presume that noise reduction can help achieve a unified law of bulk freight rate fluctuation despite of the variation of ship size. Further researches on other vessel types can be conducted in order to verify this assumption.

5. Conclusion

In this paper, we compare the long memory test results of freight rate index time series before and after noise reduction. Nonlinear DFA model is established and applied in the long memory study of non-stationary BSI, BPI and BCI time series. The scaling behavior shown in the DFA test is analyzed and the switching points of those three freight rate indexes are exhibited. Furthermore, Vondrák filtering is employed as the denoising tool. The influence of high-frequency noises on long memory test results is also analyzed.

Our empirical results show that, in the time range from July 1st, 2005 to February 26th, 2015, BSI, BPI and BCI time series all present long-range correlation, proving the influence of current freight rate market condition on its next stage. Another finding is that ship size has negative correlation with the long memory character of dry bulk carrier freight rate market. Capesize, as the largest in terms of ship size, has the weakest long-range correlation in freight rate time series. Besides, it is also verified that switching points exist in the DFA linear fitting of all the three indexes, at which would experience evident shift. This scaling behavior is presumed to be caused by high-frequency noises, since the influence of short-term external factors on freight rate long memory test can't be avoided when the time step is relatively short. By filtering out the high frequency component in the time series with Vondrák filter, we validate our hypothesis, since there is no switching point in the denoised time series. Through the comparison of the long memory test results before and after Vondrák filtering, we can find that the long memory behavior appears stronger after filtering. Additionally, we also observe that the influence of ship size disappears after the filtering, proving that ship size is also a form of short-term external factors.

With the help of long memory analysis in this paper, advice on risk management when analyzing the long memory of freight rate market can be provided. Simultaneously, investors and policy makers can also make better predictions of nonlinear volatility behaviors of dry bulk carrier freight rate market, as well as adjust their trading strategies timely. However, this study can still be extended in several directions. Researches on other vessel types, such as oil tankers and container vessels, can be conducted to validate whether it is true that different types of ship share one unified long memory law after filtering. The dominant intrinsic influence factor of freight rate market can also be explored.

6. Acknowledgements

The sources of all non-original data/information must be quoted. Articles which have been co-authored by two authors must be fully quoted, while articles which have been co-authored by three or more authors should be quoted as "(first author) et al." For example: According to Bagchi and Virum (1996), alliance would start to flourish within the logistics industry in the 21st century, although Meersman et al. (2005) have warned whether such scenario would take place highly depends on port efficiency, of which such view has been supported by the experience of Indian ports (Dayal, 2006).

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Market Concentration and Dynamics in the Liner Shipping Industry

Shih-Chan Ting[*], *Yi-Ting Hsieh and Shih-Ju Chen*

Department of Transportation Science, National Taiwan Ocean University, Taiwan

Abstract

Container-ship sizes also continue to grow and average sizes of new deliveries and vessel deployment are also continuing to increase, bringing fierce market competition in the liner industry. Larger companies tend to order new-building larger ships and deploy these mega ships to main-lines. As for smaller companies, they rarely deploy large container ships due to having difficulties to fill them and arrange join services through mergers or alliances. Mergers and alliances have been important issues in this industry in recent years. Larger ships and market concentration may have potential benefits and drawbacks to the liner shipping companies. They reduce operating costs and also create more over-capacity and competition as well, these cost savings were passed on to the shippers. This market was tense and freight rates remained volatile, low rates leading low returns to the carriers. However, in the long term aspects, the mega trends toward to larger container ships and mega carriers and alliances will lead to more market concentration which may cause the market stability and less competition. Market concentration is related to industrial concentration, which concerns the distribution of production within an industry and market concentration may be used as a measure of competition. The purpose of this paper is to present and predict the future dynamics of this industry and the Herfindahl Hirschman Index (HHI) is applied to measure of the size of companies in relation to the industry and an indicator of the amount of competition among them. This paper analyzes the dynamics of this industry in several aspects of container ship fleet, individual carrier capacity and alliance capacity and derives HHI of the carriers and alliances to measure the market concentration. The results show that there was a dramatic change in 2014, HHI of liner alliances increase to 1,497 with total market share 75.1% so that the four alliances would result in highly concentrated markets and will be presumed to be likely to enhance market power.

Keywords: Liner shipping, Market Concentration, Alliance, Herfindahl Hirschman Index

1. Introduction

As illustrated in Figure 1, global container transport demand growth has averaged 6.74% per year over the past five years 2010-2014. On the contrary, containership sizes (as shown in Table 1) also continue to grow and average sizes of new deliveries and vessel deployment are also continuing to increase, bringing fierce market competition in the liner industry. Larger companies tend to order new-building larger ships and deploy these mega ships to main-lines. As for smaller companies, they rarely deploy large container ships due to having difficulties to fill them and arrange join services through mergers or alliances.

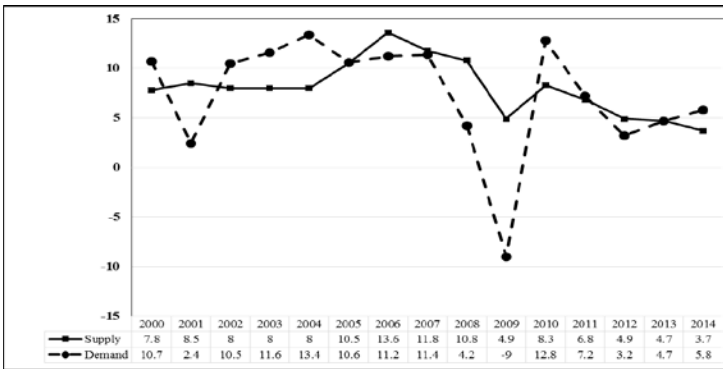

Figure 1: Annual Growth Rates (%) of Container Transport Supply and Demand 2000-2014
Source: United Nations Conference on Trade and Development (UNCTAD) (2014)

Table 1: World container ship fleet - May 2015

TEU Size Range	In Service May 2015		On Order 2015-2017	
	Vessels	TEUs	Vessels	TEUs
0-499	325	85,556	3	570
500-999	705	535,153	7	5,053
1,000-2,999	1,848	3,331,731	149	288,872
3,000-4,999	922	3,810,973	27	101,815
5,000-7,499	628	3,785,690	2	13,400
7,500-9,999	391	3,379,483	76	690,706
10,000-12,999	89	965,046	42	440,320
13,000-15,999	158	2,135,090	50	704,960
16,000+	31	558,854	64	1,224,010
Total	**5,097**	**18,587,576**	**420**	**3,469,706**

Source: Lloyd's List intelligence (2015)

The reorganization of liner alliances from 2000 to 2014 is illustrated as Table 2. Since 2014, liner carriers entered into new era of liner alliances with almost all the big carriers being regrouped with the others in order to increase their market shares and to extend economies of scale, scope and network, through joint agreements such as the integrating of individual service networks, vessel sharing, slot-chartering, joint ownership and/or utilization of equipment and terminals (Ting and Tzeng, 2004). In addition, the strategic alliances provide liner carriers with a better opportunity to slow steam and hence save on bunker costs and to provide better services to customers.

Table 2: Liner shipping alliances from 2000 to 2014

Alliances 2000	Carrier
New World Alliance	APL/NOL, Hyundai
Grand Alliance	NYK, OOCL, Hapag Lloyd, P&O Nedlloyd, MISC
The United Alliance	Hanjin DSR/Senator, Cho Yang, UASC
CKY	COSCO, K Line, Yang Ming

⬇

Alliances 2001-2009	Carrier
The New World Alliance	APL, Hyundai, MOL
Grand Alliance	P&O Nedlloyd, Hapag Lloyd, OOCL, NYK, MISC
CKYH	COSCO, K Line, Yang Ming, Hanjin

⬇

Alliances 2010-2011	Carrier
The New World Alliance	APL, Hyundai, MOL
Grand Alliance	Hapag Lloyd, OOCL, NYK
CKYH	COSCO, K Line, Yang Ming, Hanjin

⬇

Alliances 2012-2014	Carrier
CKYHE	**COSCO, K Line, Yang Ming, Hanjin, Evergreen**
G6	**APL, Hyundai, MOL, Hapag Lloyd, OOCL, NYK**
2M	**Maersk, MSC**
O3	**CMA-CGM, CSCL, UASC**

Remarks: In 2000, OOCL and MISC withdrew from Global Alliance, and then entered into Grand Alliance. After Hyundai entered into Global Alliance, this alliance was renamed as The New World Alliance In 2009, MISC withdrew from Grand Alliance. In 2012, Grand Alliance and The New World Alliance joined together to be the G6 Alliance.

For the time being, there is the CKYHE alliance, formed by COSCO, K Line, Yang Ming, Hanjin Shipping and Evergreen. Meanwhile, American President Lines (APL), Hyundai Merchant Marine, Mitsui OSK Lines (MOL), Hapag Lloyd, Orient Overseas Container Line (OOCL), NYK Line form the G6 alliance. Maersk Line and Mediterranean Shipping Company (MSC) signed vessel-sharing agreements to be the 2M alliance. CMA CGM, China Shipping Container Lines (CSCL), United Arab Shipping Company (UASC) comprised the Ocean Three (O3) alliance. In 2014, with the wave of formation of such alliances, the four major alliances took control of about 75.1% of the global market share (as shown in Table 4).

Mergers and alliances have been important issues in this industry in recent years. Larger ships and market concentration may have potential benefits and drawbacks to the liner shipping companies. The alliance carriers ordered ultra-large container ship (ULCS) so that this industry will remain under pressure. They reduce operating costs and also create much more over-capacity and competition as well, these cost savings were passed on to the shippers. This market was tense and freight rates remained volatile, low rates leading low returns to the carriers. However, in the long term aspects, the mega trends toward to larger container ships and mega carriers and alliances will lead to more market concentration which may cause the market stability and less competition. The purpose of this paper is to present and predict the future dynamics of this industry and the Herfindahl Hirschman Index (HHI) is applied to measure of the size of companies in relation to the industry and an indicator of the amount of competition among them. This paper analyzes the dynamics of this industry in several aspects of container ship fleet, individual carrier capacity and alliance capacity and derives HHI of the carriers and alliances to measure the market concentration.

This paper proceeds as follows. The related study and research methodology, Herfindahl-Hirschman Index (HHI) is described in Section 2. Section 3 analyzes the liner shipping market concentration. Section 4illustrates the market dynamics and some findings are discussed in, followed by concluding remarks.

2. Literature Review and Research Methodology

2.1 Literature Review

Ryoo and Thanopoulou (1999) explore the objectives of liner alliances, which include risk and investment sharing, the reaping of economies of scale, cost control and a capability to increase service frequencies in a dynamic environment of growing containerized trade. Against background of the globalization of world markets and poor profitability and financial performance in the 1990s, these objectives have prompted the formation of strategic alliances. Midoro and Pitto (2000) suggest that alliance stability and efficiency may be achieved by focusing on one or more of the following three measures: reduction in the number of partners, differentiation in their roles and contributions, and co-ordination of sales and marketing activities. Song and Panayides (2002) present analysis of strategic alliance in liner shipping by applying cooperation game theory to conduct multi-attribute based analysis in terms of alliance stability. Slack et al. (2002) examine the formation of alliances in container shipping focus on renovation of services, the evolution of fleet, changes made to the ports of call. They emphasize that correct partner selection process would make the alliance successful such as trustful and honest relationships, common strategic goals, and resource sharing. Firms seeking long-term alliances selected partners with substantial capital and financial stability to survive a market's downturn, as well as the resources required for expansion during a recession. Fussillo (2006) analyze the impact of US OSRA and EU regulation in the liner shipping market and summarize that the demotion of the conference system primarily through the US OSRA (1998) and the abolition of the exemption form anti-trust rules by the EU (2008) have led companies to seek other forms of collaboration in the effort to gain advantages.

Kim et al. (2006) study a relationship between alliance success factors and performances of strategic alliances in liner shipping. This study found that mutual complementarity and information sharing mostly affects alliance's success and performance. Lam et al. (2007) find that concentration process in liner shipping industry does not necessarily lead to improved financial performance. Sjostrom (2010) describe the structure and conduct of strategic alliances in container liner shipping and present the service characteristics of the top 20 container carriers. Panayides and Wiedmer (2011) illustrate the dynamics in the container shipping market. Liner services are classified by geographic coverage and vessel deployment. In addition, this paper provides a better understanding of the collaboration among service providers. Huang and Yoshida (2013) investigate the key service quality requirements improved through alliances by using quality function deployment and also analyze empirical investigation and top management's perspective on current market situation and some meaningful managerial suggestions.

Most of the previous study focuses on the formation, key successful factors, operational performance, partner selection of liner alliances, but little attention is paid to the market concentration caused by liner alliances. The market concentration would affect the market dynamics and competition. We try to use the Herfindahl Hirschman Index (HHI) to measure of the size of companies in relation to the industry and an indicator of the amount of competition among them.

2.2 *Research Methodology*

Market shares may be based on dollar sales, units sold, capacity, or other measures that reflect the competitive impact of each firm in the market. In this paper, we use the TEU capacity of liner carriers to calculate the market shares. The overall level of concentration in a market is measured by the Herfindahl-Hirschman Index (HHI), which is the sum of the squares of the market shares of all liner carriers, as the Equation (1).

$$\text{HHI} = \sum_{i=1}^{n} (X_i / X)^2 = \sum_{i=1}^{n} S_i^2, \qquad (1)$$

X : The total TEU capacity of all liner carriers,

X_i : The TEU capacity of each liner carrier *i*,

S_i : The market share of each liner carrier *i*,

n: The number of all liner carriers.

Generally, HHI value is bounded between 0 and 1 but it is usually multiplied by 10,000. The U.S. Department of Justice and the Federal Trade Commission use HHI to evaluate the degree of concentration in the market and to classify market structure into four classifications as the following Table 3:

Table 3: Market structure classified by HHI

HHI (0-10000)	HHI < 100	100 < HHI < 1500	1500 < HHI < 2500	2500 < HHI
Market Structure	Highly competitive Market	Unconcentrated Market	Moderately Concentrated Market	Highly Concentrated Market

Source: U.S. Federal Trade Commission (2015)

For evaluating the overall market concentration by considering the market share of the alliances, we derive HHIA as the Equation (2), which is the sum of the squares of the market shares of all alliances and other liner carriers.

$$\text{HHIA} = \sum_{i=1}^{m} (A_i / X)^2 + \sum_{j=1}^{n} (X_j / X)^2, \qquad (2)$$

X : The total TEU capacity of all liner carriers,

A_i : The total TEU capacity of each alliance *i*,

m: The number of alliances,

X_j : The TEU capacity of each other carrier *j* outside of alliances,

n : The number of other carriers outside of alliances.

We calculate HHI of all liner carriers and HHIA of alliances respectively to compare the change of market concentration. The following general standards are employed for the relevant markets (U.S. Department of Justice and the Federal Trade Commission, 2010):

(1) Small change in concentration: alliances involving an increase in the HHI of less than 100 points are unlikely to have adverse competitive effects.

(2) Unconcentrated markets: alliances resulting in unconcentrated markets are unlikely to have adverse competitive effects.

(3) Moderately concentrated markets: alliances resulting in moderately concentrated markets that involve an increase in the HHI of more than 100 points potentially raise significant competitive concerns and often warrant scrutiny.

(4) Highly concentrated markets: alliances resulting in highly concentrated markets that involve an increase in the HHI of between 100 points and 200 points potentially raise significant competitive concerns and often warrant scrutiny. Alliances resulting in highly concentrated markets that involve an increase in the HHI of more than 200 points will be presumed to be likely to enhance market power.

3. Market Concentration in the Liner Shipping Industry

We compile the data of liner carriers' capacity from the Review of Maritime Transport (UNCTAD, 2000-2014) to calculate HHI of all liner companies and HHIA of liner alliances by years, illustrated as Figure 2.According to HHI of all liner companies, the annul HHI shows that the liner shipping market is unconcentrated (100 < HHI < 1500), closer to highly competitive market. Even though the top 20 carriers had market share 80.8% in 2013 and 82.8% in 2014, the HHI 543 (2013) and 550 (2014) are still located in unconcentrated market with high competition. There was a dramatic change in 2014, HHIA of liner alliances increase to 1,497 being close to the boundary of the moderately concentrated market.

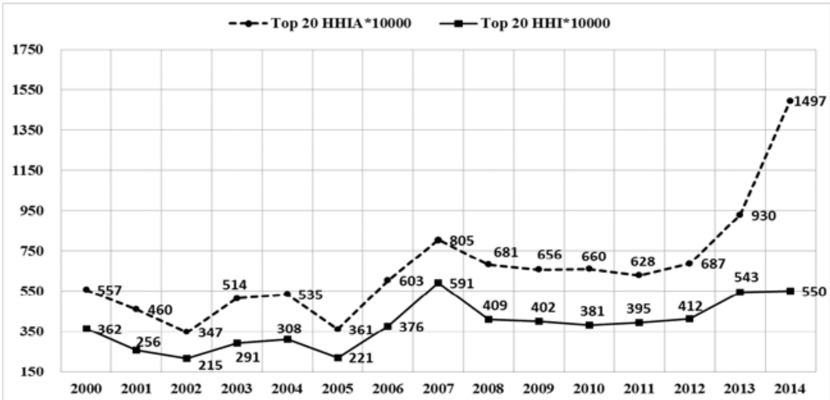

Figure 2: HHI of All Liner Companies and HHIA of Liner Alliances, 2000-2014

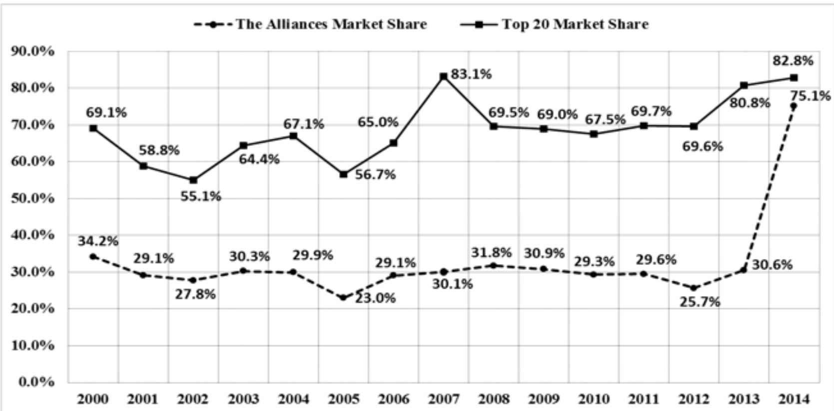

Figure 3: Market Share of the Top 20 Liner Companies and Liner Alliances, 2000-2014

As shown in Table 4, in 2014, liner carriers restructured into four major strategic alliances: CKYHE, G6, 2M and O3. Before then, CKYH, G6 were the world's major liner Alliances but Evergreen entered into the CKYH together as CKYHE; Maersk and MSC, the first and second biggest liner shipping companies in the world, developed partnership into the alliance 2M. In September 2014, CMA-CGM, CSCL and UASC signed joint service agreements to be the O3 Alliance.so this market was reorganized into big four alliances with market share 75.1% in which CKYHE (18.0%), G6 (17.0%), 2M (25.7%) and O3 (14.4%). The top 20 carriers had total market share 82.8%.

Through Equation (1) and Equation (2), the HHI is 550 and HHIA is 1,497increasing by 947 points of which CKYHE contributes 251 points to 947 points and G6, 240 points; 2M, 330 points; O3, 127 points respectively. The dramatic difference shows that the four alliances would result in highly concentrated markets so that the alliances will be presumed to be likely to enhance market power. The four alliances keep on expanding their capacity and all major carriers in the east-west trade routes are in one of four alliances, therefore liner alliances are becoming increasingly powerful and they may secure competitive rates.

Table 4: Capacity and market shares of the alliances in 2014

Alliance	Carrier	Rank	Vessels	Capacity TEUs	Market share
CKYHE	COSCO	5	163	879,696	4.4%
	KLine	17	72	368,746	1.9%
	YangMing	12	107	561,172	2.8%
	Hanjin	8	115	671,210	3.4%
	Evergreen	4	229	1,102,245	5.5%
	Sub-total CKYHE		**686**	**3,583,069**	**18.0%**
G6	APL	9	121	629,479	3.2%
	MOL	11	119	607,562	3.1%
	NYK	15	104	488,848	2.5%
	OOCL	14	98	510,115	2.6%
	Hyundai	16	64	392,874	2.0%
	Hapag-Lloyd	6	159	762,613	3.8%
	Sub-total G6		**665**	**3,391,491**	**17.0%**
2M	MSC	1	461	2,609,181	13.1%
	Maersk	2	456	2,505,935	12.6%
	Sub-total 2M		**917**	**5,115,116**	**25.7%**
O3	CMA-CGM	3	348	1,508,007	7.6%
	CSCL	7	134	750,644	3.8%
	UASC	10	73	610,292	3.1%
	Sub-total O3		**555**	**2,868,943**	**14.4%**
Other top 20 carriers	Hamburg Süd	13	112	539,793	2.7%
	PIL	18	137	365,693	1.8%
	CSAV	19	58	320,273	1.6%
	ZIM	20	71	305,192	1.5%
HHI = 550	**Sub-totaltop20carriers**		**3,201**	**16,489,570**	**82.8%**
HHIA = 1,497	All others		2,974	3,424,804	17.2%
	Total		6,175	19,914,374	100.0%

Source: Compiled by this research using Review of Maritime Transport (UNCTAD, 2014)

Remarks: CSAV (Sud Americana de Vapores)

4. Market Dynamics

According to the above market concentration analysis, after 2014 the four alliances may have more power to stabilize the freight rates. In spite of the market advantages of carriers, the liner shipping market was tense throughout 2014 and 2015, with freight rates remaining volatile and struggling to rise. IHS Maritime 360 (2015) data show that deliveries for 2015 are expected to total 250 ships of 1,860,583 TEUs in which there are 69 ULCSs. This compares with the delivery of 206 ships of 1,519,343 TEUs in 2014, including 60 ULCSs. The total fleet growth increase by over 22%, however, container transport demand growth still keep at single digits. The unabated trend of these giant vessels (ULCS) orders means the liner shipping industry will remain under pressure. Overall overcapacity and surging empty container repositioning costs lead to low freight rates and low returns with which carriers had to struggle from their deficits. Moreover, savings on bunker prices and lower operating costs are not helping the carriers, either, as savings have been passed on to shippers as carriers compete on rates for increasing space utilization and market share. We illustrate this crucial cycle as the following Figure 4 which may depict “A toxic mixture of overcapacity, weak demand and aggressive commercial pricing is threatening liner shipping industry profitability for the rest of 2015," Drewry Shipping Consultants Ltd. (2015) said.

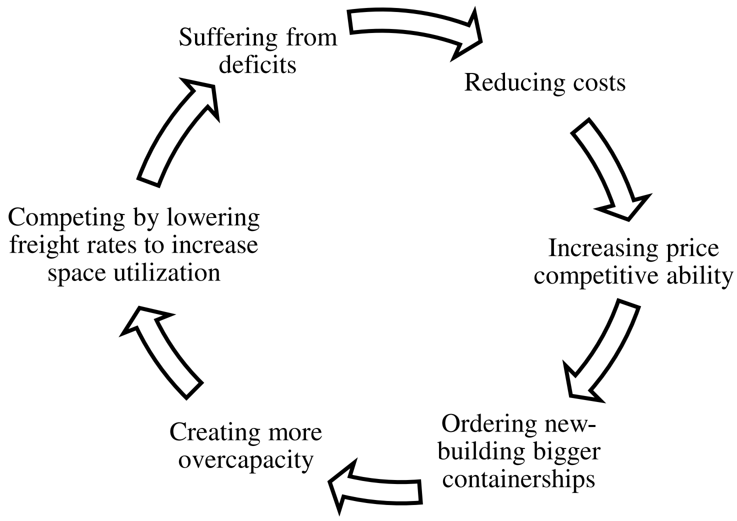

Figure 4: The Crucial Cycle of Liner Shipping Market, 2000-2015

The four alliances have bigger ship fever, focusing on greater concentration of enlarging load capacity by ordering bigger-ship building contracts one after another and newly built ships certainly have better fuel efficiency plus more unit cost reduction. However, these so-called post-Panamax ships, very large container ships (VLCS) and ultra-large container ships (ULCS) have been deployed to east-west main trade routes, and many of similar type ships are under ordering, construction and to be delivered in a couple of years. Despite the increase in container traffic due to the global economic recovery, these new-building ships bring more competition to this so freight rates are expected to have limited raise in spite of the four alliances' more market concentration and total shares. Obviously, overcapacity will be increasing seriously so that the market will be fiercely competitive with freight rates fluctuating wildly in the recent years. A pessimistic concept in explaining the dynamics of the liner shipping market is that of destructive competition. This crucial cycle, whereby competition will eventually lead to the destruction of weak liner shipping players themselves, also provides the inspiration of some new concepts and strategies for the carriers and alliances.

5. Conclusions and Recommendations

In the long term aspects, the mega trends toward to larger container ships and mega carriers and alliances will lead to more market concentration which may cause the market stability and less competition. This paper presents the market dynamics of this industry and the Herfindahl Hirschman Index (HHI) is applied to measure of the size of companies in relation to the industry. We conclude several remarks as follows:

(1) According to HHI of all liner companies, the annul HHI shows that the liner shipping market is unconcentrated (100 < HHI < 1500), closer to highly competitive market. Even though the top 20 carriers had market share 80.8% in 2013 and 82.8% in 2014, the HHI 543 (2013) and 550 (2014) are still located in unconcentrated market with high competition.

(2) In 2014, the HHI is 550 and HHIA is 1,497 increasing by 947 points of which CKYHE contributes 251 points to 947 points and G6, 240 points; 2M, 330 points; O3, 127 points respectively. The dramatic difference shows that the four alliances would result in highly concentrated markets so that the alliances will be presumed to be likely to enhance market power. The four alliances keep on expanding their capacity and all major carriers in the east-west trade routes are in one of four alliances, therefore liner alliances are becoming increasingly powerful and they may secure competitive rates.

(3) The four alliances have bigger ship fever. The unabated trend of these giant vessels (ULCS) orders means the liner shipping industry will remain under pressure. Overall overcapacity and surging empty container

repositioning costs lead to low freight rates and low returns with which carriers had to struggle from their deficits. Moreover, savings on bunker prices and lower operating costs are not helping the carriers, either, as savings have been passed on to shippers as carriers compete on rates for increasing space utilization and market share.

(4) Obviously, overcapacity will be increasing seriously so that the market will be fiercely competitive with freight rates fluctuating wildly in the recent years. We propose pessimistic concept, destructive competition to explain the dynamics of the liner shipping market. This crucial cycle, whereby competition will eventually lead to the destruction of weak liner shipping players themselves, also provides the inspiration of some new concepts and strategies for the carriers and alliances.

(5) The alliances and other liner carriers should take the advantages of market concentration to stabilize freight rates and to change their marketing and pricing strategies while facing unabated overcapacity. They have to alter out of their current marketing strategies which focus on space utilization and market share. As everyone knows well, low prices could seduce more sales and then it is easy to achieve their high space utilization goal. However, they enhance load factors on each ship, but they could not have profits. We suggest that carriers should focus both on marginal freight contribution and customer relationship management, and also consider the impact on repositioning costs due to trade imbalances.

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Ship Registration Mechanism with Second Ship Registers Using Aggregate Data

Lixian Fan[1], Xingyuan Wang[1], Jingbo Yin[2] and Kevin X. Li[3]*

[1]School of Management, Shanghai University, 599 Shangda Rd., Shanghai 200444, China
[2] State Key Laboratory of Ocean Engineering, School of Naval Architecture, Ocean and Civil Engineering, Shanghai Jiao Tong University, 800 Dongchuan RD., Shanghai 200240, China
[3]Shipping & Logistics Research Centre, Department of International Logistics, College of Business & Economics, Chung-Ang University, Korea

Abstract

In the highly competitive shipping industry, flagging out has become one of the most important operation strategies for shipowners. In order to attract the vessels back to their national country flags, the traditional maritime countries have adopted various marine policies. Among them, establishment of second ship registers is considered as one of the most effective way in attracting vessels back since the success of the Norwegian International Ship Register and the Danish International Ship Register. In order to understand the influence of the second ship register upon the vessel registration and the mechanism of flag choice decisions, this study transforms the binary and nested logit models with individual-level data to aggregate-level models. The empirical estimate suggests that the policy of establishing second ship registers have a significant effect for attracting vessels registered back to their national countries and this effect will be different for different countries. The results of the nested logit model in analyzing the flag choice mechanism suggest that the second ship register is clustered to the nest of foreign ship registers. This indicates that the second register is more similar to open ship registers in function than their national ones and the key consideration in establishing second registers is the policy adopted which should follow the practice of open registers in order to compete with them. The results also suggest that the economics of national countries and the quality of flags have significant effects on the choice behavior as well.

Keywords: Ship register, Open ship registration, Second ship register, International ship register, offshore ship register, Nested logit model

1. Introduction

According to the regulation of international maritime law, any nation can decide on what kind of vessels should be granted the right of flagging its flag for identifying the vessels' identity. Consequently, a vessel can be registered under its own nationality and that is called closed registration; it can also be registered under foreign countries, such as Panama or Liberia etc. and this is called open registration (Li & Wonham, 1999). Open registration can not only reduce the operational cost of running a vessel, it also enjoys the relaxed requirement on vessel quality because the open registration countries usually do not intervene the operations and have no specific requirements on vessel conditions regarding vessel inspection, maintenance, and nationality of sailors. As a result, the percentage of foreign registration (in dwt) has been growing from 41.5% in 1989 to 73% in 2014 (UNCTAD, 1997-2014).

Because of its relaxed legislations on ship registration, open registers almost have no control on the registered vessels. Not surprisingly, this trend of flagging out has huge impact on both the traditional maritime countries (TMCs) and international environment. This is also the reason for the implement of the SOLAS 74/78/88 (International Convention for the Safety of Life at Sea), MARPOL 73/78 (Marine Pollution), STCW 78 (Standards of Training, Certification and Watchkeeping for Seafarers), COLREG 72 (International Regulations for Preventing Collisions at Sea), and ILO 147 (International Labour Organization) conventions. From the perspective of the TMCs, in order to attract the vessels back to their national country flags, they have adopted various marine policies. Among them, establishment of second ship registers is considered as the most effective way in attracting vessels back since the success of the Norwegian International Ship

Register (NIS) and the Danish International Ship Register (DIS). Since then, UK, Germany, France, Brazil, and Italy gradually established their own offshore or international ship registers. The main purpose of these second registers is to maintain the merchant fleet under national flag for control and at the same time level the operation cost of vessels (Sornn-Friese & Iversen, 2014).

However, is this establishment of second register effective in restricting the flagging out trend? Are there any underlying mechanisms in decision making when there are multiple options? Importantly, what are the factors influencing the decision makers' choices? These are relevant for the TMCs and international institutions in the shipping industry since the flag choice could determine the operation of a vessel and many countries are considering of establishing their own second registers to compete with open registers in attracting vessels registration, such as China and Korea.

Searching from the literature, although some researchers have discussed the practice and reasons for flagging out (Li & Wonham, 1999; Hoffmann et al., 2005; Luo et al., 2013), there is a lack of systematic and quantified analysis of the role or practice of establishing second registers. In order to understand the influence of the second ship register upon vessel registration and the mechanism of flag choice decisions with second ship register, this study reviews the development of second registers, especially the NIS, DIS, and the UK's second registers. It then investigates the role of second registers in ship registration using binary logit model and the decision mechanism in choosing specific vessel flags using nested logit model. Traditionally, logit models are estimated using individual choice data. In this study, the individual-level logit models are mathematically transformed to aggregate-level models. Using the data extracted from the UNCTAD's (United Nations Conference on Trade and Development) annual report, the estimated results suggest that the policy of establishing a second ship register have a significant effect for attracting vessels registered back to their national countries and this effect will be different for different countries. It also finds that the second ship register is clustered to the nest of foreign ship registers. This indicates that the second register is more similar to open registers in function and the key factor in attracting national vessels is the policy adopted in the second register, which should follow the practice in open registers, such as the relaxed requirement on company equity and sailor nationality.

The remainder of this paper is structured as follows. Section 2 provides an overview on the development of second ship registers. Section 3 reviews the related studies on ship registration. Second 4 presents the data source and methodology used in this paper. Second 5 reports the empirical results and discussion. Second 6 concludes the paper.

2. Development of Second Ship Registers

The flag choice is important for the operation of a ship in the global competitive shipping market because open registration can help operators to avoid strict regulations, increase competitive advantages, escape national taxation or hide identities (Metaxas, 1981; Thuong, 1987; Bergantino & Marlow, 1998), so a lot of vessels have been registered to open registration countries, such as Panama and Liberia. As a result, the proportion of open registered vessels has been growing from 1989 as suggested in Figure 1 (UNCTAD, 1997-2014). This fast expanding of open registered fleets has been noticed by the TMCs because it limits the growth of the domestic fleets and causes the decrease of the national income and the rise in unemployment rates. Most importantly, the high occurrence of marine accident involving environmental disasters has alarmed the public and the authorities. As a result, the TMCs implement various measures to retain the national fleet, such as financial subsidies, tax exemption, cabotage reservation, and establishing of second registers. Among them, establishment of second ship registers is considered as the most effective way in attracting vessels back since the success of the Norwegian International Ship Register (NIS) and the Danish International Ship Register (DIS). Humphrey (see Sletmo and Holste (1993)) defined second registers as the grey area between traditional registers in which there are genuine links, and open registers without genuine links. He also defined the offshore or dependency registers where ships registered in territories and international registers and genuine link exists between ship and registry of state.

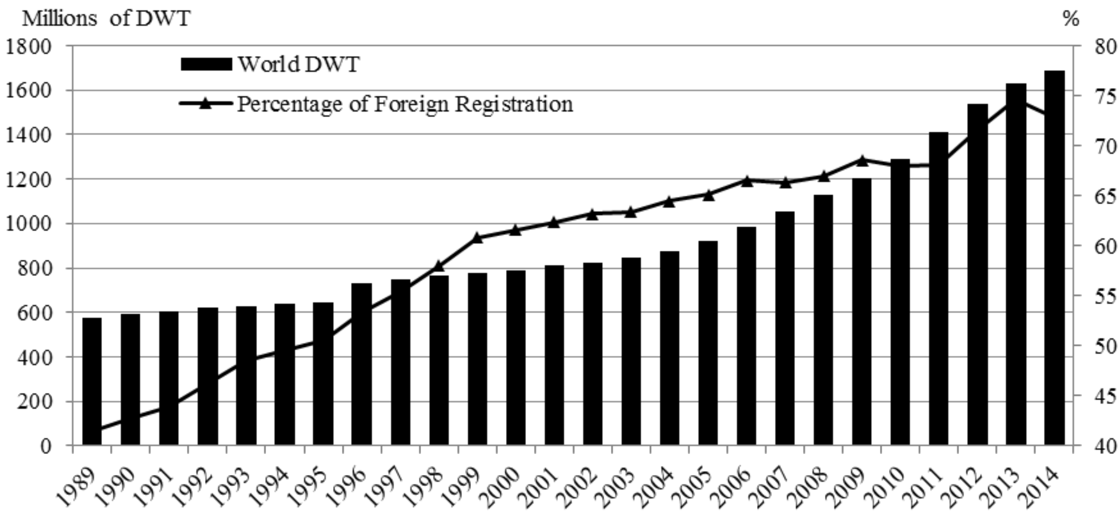

Figure 1: Development of world fleet and percentage of foreign flag registration.
Source: UNCTAD's annual Review of Maritime Transport from 1997-2014, and Clarkson PLC (2015)

Actually, the official appearance of the second ship register can be traced back to 1980s when the TMCs experiencing a noticeable merchant fleet decline. In 1984 the UK officially established its offshore register at Isle of Man, which marked the emergence of second registers maintained by the TMCs aiming at fleet retaining. Afterwards, France, Norway, and Denmark etc. gradually established their offshore or international registers. Table 1 summarizes the countries with second ship registers (including offshore, international, or special registers) and their fleet in 2014. The data suggests that the percentage of foreign registration is lower than the average world level of 73% for most of the TMCs which indicates they have obtained more national registration by contrast.

Table 1: The share of foreign registration (as of 1 Jan 2014) and development of second ship registers

Country or Territory of Ownership	Owned Fleet (DWT)	Foreign Registered Share[a]	Second Ship Register	Year of Establishment	Requirement of Registration
Germany	125626708	86.23%	German International Register of Shipping (IRS)	1989	German-owned ships only
Norway	43099867	63.41%	Norwegian International Ship Register (NIS)	1987	Foreign-owned ships but managed in Norway, Norwegian master
Denmark	39991334	66.33%	Danish International Ship Register (DIS)	1988	Substantial Danish interest
Italy	24988732	27.51%	Italian International Ship Register (IIS)	1998	Six EU officers including master and chief engineer
Turkey	23480628	63.57%	Turkish International Ship Register (TISR)	1999	No requirements
Russian Federation	20368207	73.44%	Russian International Ship Register (RISR)	2006	No requirements
United Kingdom	18429755	88.96%	Isle of Man Ship Registry	1984	No requirements
			Cayman Island Shipping Registry (CISR)	1991	
			Gibraltar Ship Registry (GSR)	1997	
			Bermuda's Register of Shipping	1974	
Brazil	13761528	83.43%	Brazilian Special Register (REB)	1998	No information
Netherlands	11701244	58.11%	Netherlands Antilles Ship Register	N/A	No information

France	11170913	69.29%	The Kerguelen Ship Register (TAAF)	1987	French-owned ships, four French officers, 25% French crew
			French International Ship Register (FIS)	2005	
Average	**33261892**	**68.03%**			

Note: [a] it does not include the vessels registered under their second register

Source: UNCTAD's annual Review of Maritime Transport (2014), Goulielmos (1998), Li and Wonham (1999), Roberts et al. (2012) and Sornn-Friese and Iversen (2014)

Compared with open registers, the TMCs usually have relatively higher requirements on ownership, management and manning of the registered ship. Table 2 illustrates the detailed conditions for ship registration of some TMCs and open registers. These differences in registration conditions not only influence the operational cost of a ship, it also impact the maintenance cost of quality maintaining to deal with the regular inspection from flag countries. Although the underlying factors of competitiveness in shipping are much complex (Thanopoulou, 1998), manning cost is regarded as the main problem because it is the only cost that differs under different flags. It is estimated that the manning cost of ships under open flags is approximately 50% lower than those registered in Denmark (Sornn-Friese & Iversen, 2014). This difference in marine legislations suggests one of the important reasons of choosing open flags.

Table 2: Registration requirements of some TMCs and open registers

Flag	Register Type	Equity (%)	National Managers (Director, Chair of board)	National Office (Location)	National Crew
Bahamas	Open Registers	0	0	0	0
Bermuda		0	0	Representative	Master
Cyprus		0	0	0	15% crew
Liberia		0	0	0	0
Malta		0	0	A place of business	0
Marshall Islands		0	0	0	0
Panama		0	0	0	10% crew
Brazil	Closed Registers	60%	Managers are native-born nationals	Implied	Master and 2/3 crew
China		50%+	Chairman or general manager	Principal business place	100%
Denmark		0	2/3 of board to be resident	Implied	Master
France		0	Majority of board	Administrative office	95%
Germany		Handled on a discretionary basis			
Italy		0	Majority of board and managers	Local representative	100%
Netherlands		67	45% directors residents	Actual managing ship	Master
Norway		60%	Majority of board, chair domiciled nationals	Head office and board	Master and 67% crew
Russia		100%	Implied	Implied	100%
United Kingdom		0%	0	Principal business place	Master
United States		50%+	Majority of board	Principal business place	Officers and 75% crew

Sources: compiled from Li and Wonham (1999) and Hill Dickinson LLP (2008)

By establishing second registers, the TMCs can lower down the requirements of national ship registration (see the last column of Table 1). Ships registered under second registers can enjoy the flexible polices just as those in open registers, at the same time they can also retain the benefit provided by their national countries, such as subsidies from government and cabotage reservation etc. (Li & Wonham, 1999).

3. Literature Review

Because of its significant impact on operation cost reduction, open registry has been studied by numerous studies. The reasons of foreign registration in the early time are mostly focused on policy consideration, such as seeking protection and avoiding hostile trade partners. Currently, the motivations for foreign registration may include: regulations avoiding, competitive advantages, taxation escaping and identities hiding (Metaxas, 1981; Thuong, 1987; Bergantino & Marlow, 1998). Goulielmos (1998) and Knudsen (1997) both suggested that taxation from shipping should not be the objective of a nation. Taxation on vessels usually reduces competitiveness of the shipowners. Besides taxation, the national registers usually require the shipowners' vessels be built or repaired at their national shipyards which are huge costs. In contrast, the open register not only enjoys the relaxed regulation, it also allows shipowners to employ non-national crew members with lower wages. Chung and Hwang (2007) analyzed that foreign registry enables shipowners to avoid government regulations and supervisions or to be released from constraints of certain markets.

From the perspective of micro company level, Bergantino and Marlow (1998) assessed the factors influencing the choice of flag in the UK shipping industry, and they found the primary reason for flagging out is the crew cost, and followed by availability of skilled labour, degree of government control, and other fiscal reasons. Veenstra and Bergantino (2000) also mentioned that the savings in operating costs are an important factor driving shipowners to flag out. Alderton and Winchester (2002) analyzed that the earlier examples of flagging out are usually for political or military reasons, while the recent examples are much more on economic grounds such as making savings in operational costs. They also pointed out that the important one among all components of operating costs is crew costs. Chung and Hwang (2007) investigated that the most important objective factors for shipowners to flag out in Taiwan bulk shipping industry is 'reducing operational cost', following are 'improving operational conditions' and 'complying with government policy'. Hoffmann et al. (2005) analyzed the factors determine the choices of flag. They found that the probability for a vessel to flag out is determined by various factors such as vessel age, size and carrying capacity; country of build; characteristics of the country where the operator is domiciled; vessel type; and its classification society. Their results also confirmed that the operators from developed countries are more likely to choose a foreign flag than those from developing countries. Based on the above studies, Luo et al. (2013) analyzed the flag selection behavior using binary and nested logit models. They found that in addition to ship and company characteristics, Port State Control (PSC), Flag State Control (FSC) and flag quality have significant impact on flag preferences.

With the emergence of offshore and international ship registers, the second register has also got the attention from researchers. Sletmo and Holste (1993) discussed the development of foreign registration of the OECD countries and the reasons of flagging out. They concluded that the introduction of second registries would not change significantly the shipping participation of the OECD countries, and the case of Norway is unique and cannot be copied. The key elements for the development is creating shipping milieu. Later, Li and Wonham (1999) described the definition of second register and the conditions for registration. They also made a detailed comparison among national, second, and open registrations. Roberts et al. (2012) compared the shipping casualties and crew fatalities among UK shipping, UK second registers and other open registers and identified the factors affect foundering and crew fatalities. More recently, Sornn-Friese and Iversen (2014) discussed the development of second ship registers and their connections to the maritime cluster. They summarized the establishment of second registers of the TMCs and investigated the reasons and procedures of the establishing of DIS and its relation to the broader maritime policy. These studies provided a detailed analysis on the current situation and reasons of establishing second registers for the TMCs. However, the actual role and effect of second registers are missing in the literature. More importantly, this study tries to investigate the underlying mechanism in choosing flags among national, second and foreign registers which is also ignored by previous studies.

Although the above studies have made substantial contribution in discussing the reasons for vessel flagging out and the practice of second register establishment, there is a lack of systematic and quantified analysis of the role or effect of establishing second registers. Additionally, from the perspective of methodology used in previous studies, AHP and Data Envelopment Analysis (DEA) (Chung et al., 2007), Fuzzy (Haralambides & Yang, 2003), binary logit (Bergantino & Marlow, 1998; Hoffmann et al., 2005; Fan et al., 2014), and nested logit (Luo et al., 2013) models are mostly adopted since they usually use individual-level data by investigation or actual ship registration data set. In practice, aggregate state by state level data are more common and objective, such as the state by state registration data reported by many international agencies or institutions. So, in order to understand the influence of the second ship register upon vessel registration and the mechanism of flag choice decisions with second ship registers, this study mathematically transforms the binary and nested logit models fit for individual-level dada to aggregated state by state level data. The empirical estimates of these models identify the reasons for vessels choosing foreign flags and disclose the decision mechanism in ship registration.

4. Model

This section begins with the conventional individual-level disaggregate binary and nested logit models. The mathematical transformation demonstrates how it can be adapted to accommodate aggregate-level data.

Based on the frame work of Luo et al. (2013), the decision procedure of flag choice can be illustrated as in Figure 3. In this study, two scenarios simulating the choice mechanism are proposed. In scenario 1, the second ship register is classified to the national flag nest, while in scenario 2, it is classified to the foreign flag nest. Since the aim is to analyze the role of the second register in attracting national fleet registration and the decision mechanism in flag choice behavior, this study firstly employs the binary logit model to investigate the flagging out decision using aggregated data. Then, the nested logit model is adapted to analyze the decision mechanism when there are second registers in the options.

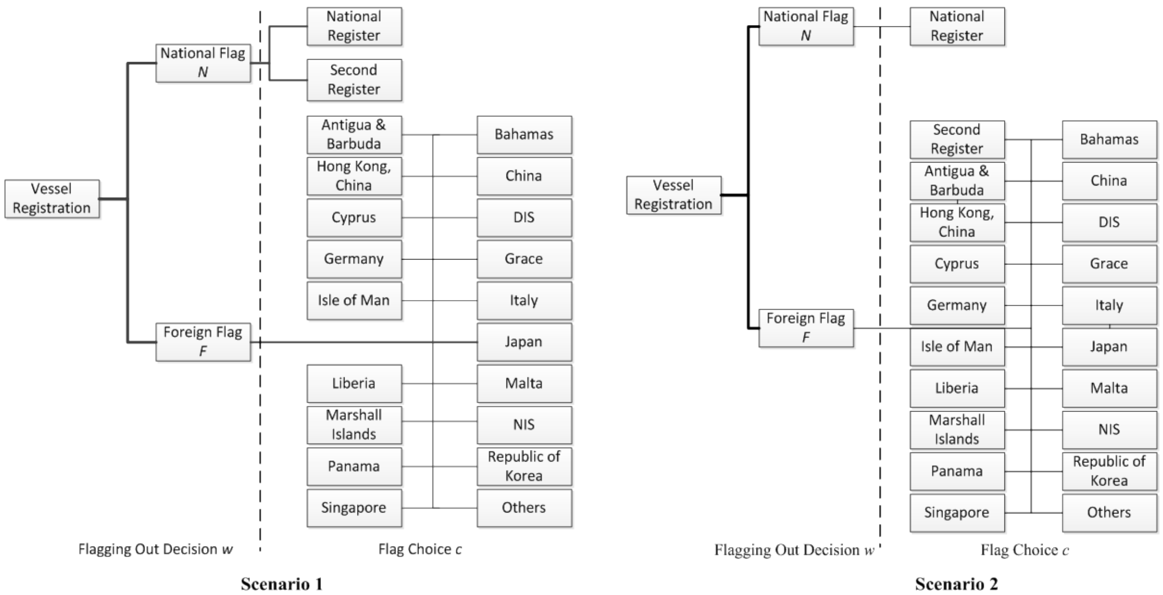

Figure 3: Two scenarios on flag choice mechanism in ship registration

4.1. *Binary Logit model for the role of second register*

Let Y denote the discrete choice of flagging out or not and P(Y=1) is the probability of flagging out to foreign flags or its second registers. According to the definition of individual-level binary decision, this can be expressed as (Greene, 2003):

$$P(Y=1) = \frac{e^{X'\beta}}{1+e^{X'\beta}} = \Lambda\left(e^{X'\beta}\right) \quad (1)$$

Where $\Lambda(.)$ denotes the logistic cumulative distribution function. X is the vector of independent variables influencing flagging out decisions and β is the estimated coefficient. Following the transformation developed by Dubin et al. (1992), the log-odds of flagging out and national flag is:

$$\ln\left(\frac{P(Y=1)}{1-P(Y=1)}\right) = \ln\left(\frac{share\ of\ foreign\ flag}{\text{share of national flag}+share\ of\ second\ register}\right) = X'\beta \quad (2)$$

4.2. *Nested logit model for decision mechanism*

According to Figure 3, there are 2 alternatives–national or foreign flag (denote w=N, F), for the first level flagging out decision. After deciding on flagging out or not, there are multiple alternatives for each. Denote $P_{c|w}$ as the conditional probability of choosing flag c by the vessel that decides on national or foreign flag nest. Using these notation, under the usual disaggregate nested logit model, the choice of flag c conditional on flagging out or not decisions is:

$$P_{c|w} = \frac{X'_{c|w}\beta}{\sum_{c=1}^{c_w} X'_{c|w}\beta} \tag{3}$$

Where cN=2 and cF=19 for scenario 1, for scenario 2 cN=1 and cF=20. Then the probability in the first level can be expressed as:

$$P_w = \frac{e^{Z'_w\gamma+\tau_w I_w}}{\sum_{w=N,F} e^{Z'_w\gamma+\tau_w I_w}} \tag{4}$$

Where parameters Iw is the inclusive value for the wth nest as $I_w=\ln\sum_{c_w} e^{X'_{c|w}\beta}$ and τw is the estimated coefficient which should between 0 and 1 for nested logit models (Mcfadden, 1978). Using the concept of log-odds, Equation (3) can be transformed corresponding to different nest selected. The national flag nest of scenario 1 is:

$$\ln\left(\frac{P_{1|National\ nest}}{P_{2|National\ nest}}\right) = \left(X'_{1|National\ nest} - X'_{2|National\ nest}\right)\beta = X'_{1|National\ nest}\beta,\ 1 = National\ register\ and\ 2 = Second\ \ register \tag{5}$$

As the foreign flag nest includes all the alternatives except national and second registers for a certain country, the independent variables in X2 may be regarded as a general level or a constant, so it is eliminated from the equation. It is worth to note that in scenario 2, there is only one alternative, it is no need to transform.
Similarly, for the choices in the foreign flag nest, the conditional probability of choosing one flag is:

$$\ln\left(\frac{P_{c|Foreign\ nest}}{P_{\text{other}|Foreign\ nest}}\right) = \left(X'_{c|Foreign\ nest} - X'_{\text{other}|\ Foreign\ nest}\right)\beta = X'_{c|Foreign\ nest}\beta,\ c = 1 \ldots 19 \text{ in scenario 1 and 20 for scenario 2} \tag{6}$$

Finally, Equation (4) can be transformed by calculating the odds ratio between national nest and foreign nest just like in Equation 2.

$$\ln\left(\frac{P_{w=F}}{P_{w=N}}\right) = \ln\left(\frac{share\ of\ foreign\ flag}{share\ of\ natioanl\ flag}\right) = -Z'_N\gamma - \tau_N I_N + \tau_F I_F \tag{7}$$

The dependent variables of log-odds in Equation (2) and (7) are similar. Actually they are the same for scenario 1. For scenario 2, the log-odds is (share of foreign flag + share of second register)/(share of national flag). Additionally, Equation (2) is used to analyze the effects of independent variables, especially establishing second registers, on the flagging out decisions; while, Equation (7) is used to investigate the flag choice mechanism.

5. Data and Variables Description

Data used in this study mainly comes from UNCTAD's annual report of Review of maritime transport from 1997 to 2014 (UNCTAD, 1997-2014). It reports the top 35 countries with the largest owned tonnage each year, and importantly it also lists the top 20 registered flags for each country. In 2013, the top 35 largest countries controlled about 99.7% of the world total tonnage, so it can represent the common situation of the ship registration. Table 3 calculates the average total tonnage owned by each country and their share of foreign registration from 1997 to 2013. It is worth to note that since the list of the top 35 countries are different each year, so there are total 46 countries included in this study and we finally get 594 observations with a panel data.

Another important data source is the World Bank. According to the related studies on ship registration, the following variables are extracted: FFSHARE is the percentage of foreign registered vessels in tonnage for each country in each year. GDPPER represents the GDP per capita. PARTIRATIO is the labor force participation rate. It is the percentage of labor force of the total population aged above 15. TAX measures the amount of taxes and mandatory contributions payable by businesses after accounting for allowable deductions and exemptions as a share of commercial profits. The World Bank also provides the share of exports (imports) of goods and services to GDP, which is the value of all goods and other market services provided to (received from) the rest of the world. As these two variables are highly correlated, the average of exports and imports shares is calculated as IMEXSHARE.

Table 3: Mean of the variables for the top 35 countries with the largest owned tonnage from 1997- 2013

Country	Total DWT	FFSHARE	GDPPER	PARTIRATIO	TAX	COMPANY[a]	IMEXSHARE
Greece	164782.20	68.56	20601.96	52.92	46.56	4.00	26.44
Japan	137335.62	87.21	36923.26	60.97	51.09	1.00	13.13
China	71962.82	51.57	2632.06	73.88	71.23	4.00	26.50
Germany	67072.86	79.85	35054.54	58.74	47.22	5.00	34.74
Norway	50175.78	59.59	65339.02	65.79	40.83	4.00	35.75
US	46240.99	69.14	42915.25	64.88	45.98	4.00	12.96
HK (China)	36022.89	58.75	28999.62	60.49	23.44	3.00	177.13
Republic of Korea	35171.91	63.41	17360.20	61.06	31.90	4.00	39.92
Singapore	26124.98	40.89	33998.44	65.71	22.47	3.00	187.12
Taiwan Province of China	25232.24	74.67	.	.	.	.	.
UK	23895.62	62.01	35515.25	61.94	34.97	1.00	27.95
Denmark	22873.91	55.12	47010.09	65.30	29.11	1.00	44.37
Bermuda	19513.19	97.36	88144.06	.	.	1.00	.
Russian Federation	17277.16	55.21	6689.16	61.49	50.58	5.00	27.86
Italy	16341.37	32.61	30195.55	48.44	70.74	1.00	25.11
India	14659.90	14.62	865.89	58.21	66.86	4.00	19.33
Turkey	12994.34	32.61	6965.95	48.39	44.46	.	24.77
Saudi Arabia	11551.68	90.24	14511.84	50.48	14.50	3.00	38.39
Canada	9943.41	72.95	37663.66	66.40	33.97	.	34.54
Iran	9472.45	32.80	3407.89	44.88	44.16	3.00	22.87
Sweden	9346.48	80.63	42923.53	63.24	53.12	4.00	41.39
Malaysia	9251.52	24.94	6301.67	60.74	35.31	4.00	94.94
Belgium	9228.17	72.38	35944.10	52.42	57.17	4.00	71.63
Netherlands	8143.47	47.67	40357.02	64.02	40.94	4.00	64.40
Brazil	8071.14	46.18	6511.18	69.16	67.90	4.00	12.07
Switzerland	7497.00	86.71	56309.24	67.73	28.46	4.00	51.62
UAE	7299.47	90.18	38780.71	77.47	14.40	.	69.28
France	6901.89	53.81	33829.63	55.69	66.19	1.00	26.69
Indonesia	6690.47	27.57	1738.89	67.35	30.48	.	29.61
Cyprus	6668.84	65.91	25001.48	63.64	21.70	1.00	48.23
Oman	6139.13	99.91	21929.01	65.10	23.00	.	.
Viet Nam	5946.08	27.98	1408.36	76.89	38.24	.	77.18
Isle of Man	5545.89	98.78	.	.	.	1.00	.
Philippines	4788.10	14.32	1144.07	65.94	47.97	4.00	49.63
Kuwait	4651.51	20.94	33136.40	67.78	11.08	.	45.70
Qatar	4410.79	80.00	90831.02	86.65	11.30	3.00	48.73
Spain	4216.93	84.23	23877.96	55.49	55.43	.	27.31
Monaco	3943.64	100.00	97239.34	.	.	.	.

Thailand	3716.61	20.88	3538.85	73.04	36.32	4.00	66.69
Romania	3709.95	33.51	1670.44	65.50	.	.	31.32
Finland	3333.23	66.09	25614.90	60.53	.	4.00	33.59
Ukraine	3322.79	49.43	1010.68	58.33	57.30	.	51.32
Australia	3012.43	40.01	26509.00	63.80	51.10	1.00	20.05
Croatia	2881.77	50.20	9444.48	53.20	21.40	.	39.54
Israel	2697.00	67.78	21581.76	55.70	38.20	.	40.99
Chile	2227.25	61.29	4866.33	54.10	.	.	32.56

Notes: [a] Compiled from Li and Wonham (1999) and Hill Dickinson LLP (2008). The value for company is calculated from requirements for company equity: 1 for no requirement, 5 for the strictest requirement.

Since one of the aims of this study is to investigate the flag choice mechanism based on the proposed scenarios in section 3, the detailed data on registered flags for the vessels controlled by Norway, Denmark and UK are collected from 2011 to 2013. The most selected 19 registers are illustrated in Figure 3 (UNCTAD, 2011-2013). Then a dataset for flag choice with 180 observations is obtained. The dependent variable is the registered tonnage share to each flag. Similar to the variables in the binary choice model, the independent variables of GDP per capita and the labor force participation rate for the flag countries are included with an F suffix.

Finally, to investigate the impact of the flag quality on the choice decision, the inspection and detention of vessels from Tokyo (Tokyo MoU, 2011-2013), Paris (Paris MoU, 2011-2013), India (Indian MoU, 2011-2013), and US MoU (Memorandum of Understanding) (United States Coast Guard, 2011-2013) are also included. According to the most selected flags in Figure 3, the number of inspections, percentage of deficiencies and detentions by the 4 MoUs from 2011 to 2013 are reported in Table 4.

Table 4: Average inspections, deficiencies, and detentions from 4 MoUs for each flag, 2011-2013

Flags	Number of Inspections	% of Inspections with Deficiencies	% of Inspections with Detentions	% Detention
Antigua and Barbuda	2269	48.44	41.76	10.68
Bahamas	2361	36.72	35.25	4.40
China	1165	36.91	29.12	2.62
Cyprus	1530	42.48	38.36	6.49
Denmark	622	34.67	30.16	4.26
Germany	688	40.41	32.26	5.67
Greece	1076	34.56	28.06	5.27
Hong Kong (China)	4357	37.39	32.28	3.22
Isle of Man	584	33.00	26.20	2.99
Italy	763	38.97	36.56	4.46
Japan	302	33.33	25.33	3.02
Liberia	5182	39.99	35.23	5.72
Malta	2871	42.53	37.54	6.03
Marshall Islands	3419	37.05	31.21	4.81
Norway	1063	35.20	35.18	3.34
Panama	14508	43.49	39.55	6.90
Republic of Korea	1524	50.50	44.90	4.46
Singapore	3258	35.29	30.43	3.78
United Kingdom	976	36.38	31.99	3.71

Note: the NIS and DIS are not classified to FOCs (Flag of Convenience) by the 4 MoUs, so they are regarded as their national flag of Norway and Denmark.

Combining the flag choice data with this flag quality of inspections, the descriptive statistics for the variables in the flag choice mechanism model are illustrated in Table 5. INSDEFRATE_F is the percentage of inspections with deficiencies from the 4 MoUs for certain flags in each year. INSDETRATE_F is the percentage of inspections with detentions and DETENTIONRATE_F is the detention rate of the inspections.

Table 5: Descriptive statistics for the flag choice mechanism model

Variables	N	Mean	Std. Dev.	Minimum	Maximum
SHARE	180	5.00	8.49	0.00	39.87
GDPPER	180	66903.38	24555.02	40972.03	100818.50
PARTIRATIO	180	63.52	1.39	61.90	65.50
IMEXSHARE	180	38.82	8.71	30.78	51.42
TAX	180	34.17	5.85	26.30	40.70
COMPANY	180	2.00	1.42	1.00	4.00
GDPPER_F	171	32084.36	25242.83	376.93	100818.50
INSDEFRATE_F	180	39.22	8.45	27.92	62.92
INSDETRATE_F	180	34.23	23.60	0.00	76.92
DETENRATE_F	180	5.19	2.87	0.00	13.69

Note: In the following regression models, the *GDPPER* is transformed by logarithm with a prefix of *L*.

VARIABLES	(1) *LSHAREODD*	(2) *LSHAREODD*	(3) *LSHAREODD*	(4) *LSHAREODD*
LM test for random effects	335.55	318.37	334.94	331.94
DEVELOPED		5.440***		6.672***
		(1.569)		(1.650)
LGDPPER	0.467***	0.659***	0.325***	0.555***
	(0.083)	(0.105)	(0.094)	(0.111)
DEVELOPED_LGDPPER		-0.524***		-0.647***
		(0.157)		(0.164)
PARTIRATIO	-0.043**	-0.034*	-0.065***	-0.049**
	(0.020)	(0.019)	(0.022)	(0.021)
IMEXSHARE	-0.016***	-0.015***	-0.016***	-0.015***
	(0.003)	(0.003)	(0.003)	(0.003)
COMPANY	0.241	0.269*	0.225	0.271
	(0.158)	(0.151)	(0.187)	(0.176)
TAX	-0.022**	-0.017*	-0.022*	-0.016
	(0.010)	(0.010)	(0.011)	(0.011)
ISR[1]	0.290	0.233	-9.851***	-10.438***
	(0.198)	(0.194)	(3.152)	(3.024)
ISR_LGDPPER			0.496***	0.645***
			(0.170)	(0.170)
ISR_PARTIRATIO			0.091***	0.075**
			(0.035)	(0.033)
Constant	-0.732	-3.567**	1.894	-1.725
	(1.675)	(1.779)	(1.946)	(2.017)
LR Chi2	73.13	84.93	83.82	99.90
Prob(F/Chi-test)	0.00	0.00	0.00	0.00

6. Literature Review

6.1. Results for Role of Second Ship Registers

As explained in Equation (2), the binary logit model for individual-level data can be transformed to log-odds for aggregate-level data. The dependent variable is changed to the log-odds between foreign and national tonnage share, LSHAREODD. Since the data set is a panel data from 1997 to 2013 for each country (not balanced), the Breusch and Pagan Lagrange multiplier test is conducted for testing heterogeneity among different countries. Under the null hypothesis of equal variance across countries, the LM is distributed as Chi-squared with degree of freedom of 1 (Greene, 2003). The estimated values of LM test in Table 6 suggest that the pooled regression models without discriminating for countries are inappropriate for these data. The results of the test are to reject the null hypothesis in favor of the random effects model.

Table 6: Estimate result of random effect model for role of second register

VARIABLES	(1) *LSHAREODD*	(2) *LSHAREODD*	(3) *LSHAREODD*	(4) *LSHAREODD*
LM test for random effects	335.55	318.37	334.94	331.94
DEVELOPED		5.440***		6.672***
		(1.569)		(1.650)
LGDPPER	0.467***	0.659***	0.325***	0.555***
	(0.083)	(0.105)	(0.094)	(0.111)
DEVELOPED_LGDPPER		-0.524***		-0.647***
		(0.157)		(0.164)
PARTIRATIO	-0.043**	-0.034*	-0.065***	-0.049**
	(0.020)	(0.019)	(0.022)	(0.021)
IMEXSHARE	-0.016***	-0.015***	-0.016***	-0.015***
	(0.003)	(0.003)	(0.003)	(0.003)
COMPANY	0.241	0.269*	0.225	0.271
	(0.158)	(0.151)	(0.187)	(0.176)
TAX	-0.022**	-0.017*	-0.022*	-0.016
	(0.010)	(0.010)	(0.011)	(0.011)
ISR[1]	0.290	0.233	-9.851***	-10.438***
	(0.198)	(0.194)	(3.152)	(3.024)
ISR_LGDPPER			0.496***	0.645***
			(0.170)	(0.170)
ISR_PARTIRATIO			0.091***	0.075**
			(0.035)	(0.033)
Constant	-0.732	-3.567**	1.894	-1.725
	(1.675)	(1.779)	(1.946)	(2.017)
LR Chi2	73.13	84.93	83.82	99.90
Prob(F/Chi-test)	0.00	0.00	0.00	0.00

Note: (1.) *ISR* is a dummy variable with the value 1 representing the owner country has second registers in a certain year, (2.) Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1 and (3.) Correlations between variables are low except that between *DEVELOPED* and *LGDPPER* (0.78). So the variable *DEVELOPED* is not included in model (1) and (3) in order to uncover the potential estimated bias caused by multicollinearity. Comparisons of model (1) and (2), and model (3) and (4) suggest the unbiasedness of the estimates.

The estimated results are similar to the findings of previous studies (Bergantino & Marlow, 1998; Luo et al., 2013). First, developed countries are more likely to flag out their vessels. Second, the higher the national income level, the higher the likelihood of flagging out since high GDP per capita indicates high operation cost for hiring national sailors. Third, the interception between DEVELOPED and GDP per capita suggests the different impacts of income level on the flagging out decision. For the vessels from developing countries, the income level has a bigger impact on the choice of a foreign flag. Fourth, countries with a higher level of labor force participation rate have a lower tendency of flagging out, because it is easier for them to find qualified crews for the vessels. Fifth, countries with larger export/import requirements are less likely to flag out their vessel since most countries have cabotage reservation for national fleets (Li & Wonham, 1999). Sixth, the wake negative significant for the coefficient of tax ratio suggests the less likely of flagging out for countries with a higher tax ratio. This result seems conflict with the practical belief. However, this may to some extend manifest the fact that those countries with a high level of income tax, such as Brazil (FFSHARE=82 and TAX=69 in 2013) and Germen (FFSHARE=87, TAX=49 in 2013), have a higher share of foreign registration. Seventh, the coefficients for ISR are not significant in model (1) and (2), but they are significant in model (3) and (4). This suggests the moderation effects of LGDPPER and PARTIRATIO on second registers. Obviously, establishing second registers has a significant effect in preventing the flagging out tendency, and this effect is moderated by countries' income level and labor supply. This means that the countries with second registers cannot totally offset the negative effects of income level and labor supply on flagging out.

6.2. *Results for Ship Registration Mechanism*

To analyze the ship registration mechanism, Equation (5) and (6) are estimated for scenario 1 for the national and foreign nest separately and Equation (6) is estimated for scenario 2 as there is only one alternative in national nest. Detailed results are shown in Table 7. The results suggest that Equation (5) is not significant for scenario 1 with lower P values for the F test, while, Equation (6) for scenario 1 and 2 are significant with significant F test vales. In addition, these results also show that the GDP per capita is not significant in choosing a flag, while the labor force participation rate has a significant positive impact for choosing a certain flag. Another important factor in flag choice is the detention rate by the MoUs, because these will directly impact their possibility of inspection by the MoUs in the future.

Table 7: Estimated results of Equation (5) and (6) for scenario 1 and 2

	Equation (5) for Scenario 1		Equation (6) for Scenario 1		Equation (6) for Scenario 2	
Variable	Estimate	P Value	Estimate	P Value	Estimate	P Value
Intercept	7.32	0.94	-4.79	0.15	-5.74	0.09
LGDPPER_F	-0.99	0.94	-0.13	0.40	-0.03	0.83
PARTIRATIO_F	**0.62**	**0.87**	**0.07**	**0.02**	**0.08**	**0.01**
INSDEFRATE_F	-0.68	0.18	0.01	0.73	0.00	0.97
INSDETRATE_F	-0.23	0.21	0.01	0.58	0.00	0.76
DETENRATE_F	**0.48**	**0.37**	**-0.19**	**0.06**	**-0.18**	**0.08**
R-Square	0.20		0.09		0.09	
F test	0.46		**2.49**		**2.69**	
P Value	0.80		0.03		0.02	

After the above analysis, Equation (7) for scenario 1 and 2 are estimated separately and the results are reported in Table 8 and 9. UNCTAD only reports the detailed registration data for the top 20 flag registers as shown in Figure 3, in which only NIS, DIS and Isle of Man are included as second registers. So, in this flag mechanism analysis, only the flag choice behavior for the owner countries of Norway, Denmark and UK are analyzed. According to Equation (7) for scenario 1, a positive τF and a negative τN are expected. Results in Table 8 suggest that the nest structure in scenario 1 is rejected by the data as the sign for τF is mismatch.

Table 8: Estimated results of Equation (7) for scenario 1

Variable	DF	Estimate	Error	t Value	P Value
Intercept	1	44.01	7.71	5.71	<.0001
LGDPPER	1	-3.23	0.69	-4.67	<.0001
PARTIRATIO	1	-0.15	0.02	-6.80	<.0001
IMEXSHARE	1	0.05	0.01	6.26	<.0001
COMPANY	1	1.12	0.24	4.71	<.0001
TAX	1	-0.05	0.03	-1.82	0.07
$\boldsymbol{\tau_N}$	**1**	**-0.05**	**0.02**	**-3.17**	**0.00**
$\boldsymbol{\tau_F}$	**1**	**-0.34**	**0.10**	**-3.31**	**0.00**
R-Square		0.45			
F test		19.32			
P Value		<.0001			

Scenario 2 is supported by this study as suggested in Table 9. The estimated results are different with those obtained in Table 6 since the dependent variables of the log-odds are different (see section 4.2 for Equation (2) and (7)) and the analysis objects are different now. For these three countries of Norway, Denmark and UK that has established second registers, the higher the GDP per capita, the less likely of flagging out. The high level of labor force participation and import/export activities may increase the likelihood of foreign registration. Similarly, the strict requirement on company equity and taxation rate my drive vessels flagging out.

The most important coefficient is the τF, which is between 0 and 1, and positively significant. This suggests that the second ship register is clustered to the foreign flag nest as illustrated in scenario 2. It indicates that second registers are more similar to open ship registers in function than their national registers and establishing second ship registers do have a significant effect in attracting vessels back. The key point is the policy adopted in the second registers (as illustrated in section 2), which should follow the practice of the open registers in order to compete with them, such as the relaxed requirement on company equity and sailor nationality and exemption of taxes etc.

Table 9: Estimated results of Equation (7) for scenario 2

Variable	DF	Estimate	Error	t Value	P Value
Intercept	1	89.22	10.49	8.50	<.0001
LGDPPER	1	-12.00	0.95	-12.59	<.0001
PARTIRATIO	1	0.25	0.04	6.79	<.0001
IMEXSHARE	1	0.52	0.01	44.80	<.0001
COMPANY	1	2.95	0.33	8.89	<.0001
TAX	1	0.16	0.04	4.03	<.0001
τ_F	**1**	**0.12**	**0.05**	**2.46**	**0.02**
Adj R-Square		0.99			
F test		3626.70			
P Value		<.0001			

7. Conclusion

In the highly competitive shipping industry, flagging out has become one of the most important strategies for shipowners to reduce operation cost or obtain flexibility in operating the vessel. To deal with this increasing flagging out trend, the TMCs have employed various measures, among which establishing second registers is regarded as an effective way since the success of NIS and DIS.

In order to understand the influence of the second ship register upon the vessel registration and the mechanism of flag choice decisions with second ship register, this study transforms the Binary logit and Nested logit models with individual-level data to aggregate-level state by state data. The estimated result suggests that the policy of establishing a second ship register has a significant effect for attracting vessels registered back to their national countries and this effect will be different for different countries. The estimation for the choice mechanism suggests that the second ship register is clustered to the nest of foreign ship registers. This indicates the key consideration in establishing second registers is the marine polices adopted in the regime which should follow the practice in those open registers in order to compete with them. The result also suggests that the economics of national countries and the quality of flags have significant effects on the choice behavior as well.

This paper contributes in three ways: first, it is the first attempt to analyze the role of second ship registers in ship registration regime. This bridges a gap in the relevant literature. Second, it is difficult to obtain the detailed registration data for each vessel in the world, but it is easy to get the tonnage registered in each flag for each owner country, i.e. the state by state aggregate registry data. So in this study, the binary and nested logit models for disaggregated data are transformed to models for aggregated data. This could provide some illumination for the empirical studies suffering from obtaining disaggregated data. Third, this study proposes two scenarios for ship registration and the empirical data confirms that the second register is classified as a foreign register in function since the establishment of it is to compete with open registers. The TMCs should consider the policies adopted in the open registers and other second registers in order to attract vessels using national flags.

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Modeling Sustainable Ship Reconstruction in a Supply Chain with Competing Shipyards

Gang Xie[1], *Wuyi Yue*[2] *and Shouyang Wang*[1]

[1]Academy of Mathematics and Systems Science, Chinese Academy of Sciences, Beijing 100190, China
[2]Department of Intelligence and Informatics, Konan University 8-9-1 Okamoto, Kobe 658-8501, Japan

Abstract

In this study, mathematical models are developed to assess the sustainability in a ship reconstruction supply chain with competing shipyards. Members' decisions are investigated by examining three different cases of supply chain strategies: two non-coordinated shipyards, one coordinated shipyard and one non-coordinated shipyard, and two coordinated shipyards. In addition, experimental analysis is implemented to illustrate the related issues. Finally, conclusions are drawn and managerial insights are indicated for the improvement of sustainability in the ship reconstruction industry.

Keywords: Ship reconstruction, Sustainability, Supply chain management, Price competition

1. Introduction

Shipping is one of the most environmentally friendly transport modes in terms of both energy efficiency and pollution prevention. There are usual six types of ships such as bulk carrier, general cargo, container, refrigerator and passenger (Hiremath, et al., 2015). Nowadays, increasing numbers of shipping firms are adopting green shipping practices that emphasize environmental management throughout their operations. To balance productivity with the environment, the design of shipping activities in compliance with energy efficiency and resource saving is an important part of greening efforts by many shipping firms (Lai et al., 2013). However, due to the scale of operation and number of ships active around the world, shipping still produces prodigious quantities of carbon emissions (Yang et al. 2013).

The term "sustainability" has been interpreted in a variety of ways, ranging from an inter-generational philosophical position to a multi-dimensional term for business management. Early sustainability initiatives tended to focus on environmental issues but, as time goes on, they are increasingly adopting a triple bottom line (i.e., environment, economic, and social) approach to sustainability (Ahi and Searcy, 2013). In accordance with the three "pillars" of sustainability interrelationship model between society, environment and economic development (Elkington, 1994), in this study we refer to sustainability as the integration of energy efficiency (environment), consumer surplus (society) and organizational profits (economy). In practice, the impact of organizations on the society, environment and economy should not be studied from an isolated perspective, but rather by explicitly recognizing the upstream and downstream organizations in a supply chain (Ciliberti et al., 2008). Sustainable supply chain management is thus receiving increased prominence and greater scrutiny (Xie et al., 2012; Xie et al., 2015). However, researchers have not addressed how to model sustainable ship reconstruction from a supply chain perspective yet.

Many firms have searched for mechanisms that integrate environmental supply chain practices and performance objectives (Caprace and Rigo, 2012; Lee, 2013). Savaskan and Van Wassenhove (2006) focused on the interaction between a manufacturer's reverse channel choice to collect postconsumer goods and the strategic product pricing decisions in the forward channel when retailing is competitive. The investigation suggested that the buy-back payments transferred to the retailers for postconsumer goods provide a wholesale pricing flexibility that can be used to price discriminate between retailers of different profitability. In the case of maritime transport, energy efficiency is generally determined by their marine main engines. In a ship reconstruction supply chain, the upstream manufacturers provide spare parts for marine main engines to shipyards for ship reconstruction. Considering previous research work and the problem we investigate, we have selected energy efficiency, price, consumer surplus and profits as performance measures in this study.

In the ship reconstruction market, high competition is a normal state (Audia and Greve, 2006; Celik et al., 2009). In a supply chain, the competition between members often reduces their profits. In particular, when competition intensity increases to the extent where there is no profit for the competing members, they have to withdraw from the market segment (Xie, 2015). From the perspective of a decentralized supply chain, cooperation between members may allow more effective methods to realize Pareto improvement for the supply chain performance and make progress in achieving more sustainable practices (van Hoof and Thiell, 2014). The situation motivates us to investigate how to improve sustainability through coordination of a ship reconstruction supply chain between competing shipyards.

In this study, the decisions in a ship reconstruction supply chain with competing shipyards are examined in three cases of supply chain strategies: two non-coordinated shipyards, one coordinated and one non-coordinated shipyards, and two coordinated shipyards. Moreover, a numerical example is used to illustrate some related issues and some observations are made. Finally, conclusions are drawn and some topics for future work are suggested.

2. Description of the Problem

In a ship reconstruction supply chain, the upstream manufacturer provides spare parts (e.g. lubricators) of marine main engines to shipyards for ship reconstruction. The shipyards set a price for ship reconstruction service, where the energy efficiency of reconstructed marine main engines is determined by the spare parts. The consumers are shipping companies, where most of their ships do not meet the criteria for carbon emissions and energy efficiency of maritime transport formulated by the International Maritime Organization (IMO). The following notations are used in the model:

s Supply chain strategy (combination) between the manufacturer and the shipyard(s) (s =*NN*, *CN*, *CC*);
NN The manufacturer is non-coordinated with the two competing shipyards;
CN The manufacturer is coordinated with one shipyard but non-coordinated with the other shipyard;
CC The manufacturer is coordinated with the two shipyards;
x^s Energy efficiency of spare parts provided by the manufacturer within s;
p_i^s Price per unit of ship reconstruction service provided by the i th shipyard (i, j =1, 2, $i \neq j$);
w_i Wholesale price per unit of spare parts to the manufacturer (i, j =1, 2, $i \neq j$);
v_M Variable production cost per unit of spare parts to the manufacturer;
v_S Variable cost per unit of ship reconstruction service to the shipyards;
ε Energy efficiency related variable cost of spare parts to the manufacturer;
c Fixed cost related to the energy efficiency of spare parts provided by the manufacturer;
k_i Share of the intrinsic demand potential of ship reconstruction for the i th shipyard;
α Demand sensitivity of ship reconstruction to the energy efficiency of spare parts;
β Demand sensitivity of ship reconstruction to the price of service;
γ Competition intensity denoting the competitive effects of price for the shipyard pair (i, j).

In this study, x^s, p_i^s and p_j^s are decision variables and other variables are exogenous variables, which are known to both the manufacturer and the shipyards in the supply chain.

Assumption 1. $p_i > w_i + v_S$ and $w_i > v_M + \varepsilon x^s$. The inequalities ensure that each player in the supply chain makes a positive profit.

Assumption 2. In the ship reconstruction market, the demand for ship reconstruction is determined by the energy efficiency of the spare parts provided by the manufacturer and the price set by the shipyard(s).

Assumption 3. The energy efficiency of spare parts can be recognized by the shipyards and ship companies. This assumption is also reasonable because the shipyards can determine the energy efficiency of the spare parts by testing.

The demand function for the ship reconstruction service provided by the i th shipyard is shown as follows:

$$D_i^s = k_i a + \alpha x^s - \beta p_i^s + \gamma(p_j^s - p_i^s) \tag{1}$$

where $k_i + k_j = 1$, i, j =1, 2, $i \neq j$. Here, $k_i a$ is the intrinsic demand potential for the i th shipyard. The demand function D_i^s implies three key empirical regularities: (i) D_i^s has a positive correlation with energy efficiency x^s of the spare parts provided by the manufacturer; (ii) D_i^s has a positive correlation with the preponderance of p_j^s over p_i^s, i.e. $p_j^s - p_i^s$; and (iii) if both shipyards enhance the price of their service by one unit, then demand for ship reconstruction service of both should decrease.

In the ship reconstruction supply chain between competing shipyards, the cost is expressed as

$$\begin{aligned} C^s = {} & (v_S + v_M + \varepsilon x^s)[k_i a + \alpha x^s - \beta p_i^s + \gamma(p_j^s - p_i^s)] \\ & + (v_S + v_M + \varepsilon x^s)[k_j a + \alpha x^s - \beta p_j^s + \gamma(p_i^s - p_j^s)] + f + c(x^s)^2 . \end{aligned} \tag{2}$$

Here, f is a fixed cost not related to the energy efficiency x^s, $c(x^s)^2$ is a fixed cost respectively related to x^s, and $(v_S + v_M + \varepsilon x^s)[k_i a + \alpha x^s - \beta p_i^s + \gamma(p_j^s - p_i^s)]$ and $(v_S + v_M + \varepsilon x^s)[k_j a + \alpha x^s - \beta p_j^s + \gamma(p_i^s - p_j^s)]$ are variable costs. Therefore, C^s is increasing and convex in x^s.

For simplicity of analysis, we consider the case where the energy efficiency of reconstructed ships is determined by the spare parts provided by the manufacturer for the marine main engines of the ships. In the following section, the energy efficiency of spare parts and the price of the ship reconstruction service are investigated in a supply chain with two competing shipyards.

3. Decisions in A Supply Chain with Competing Shipyards

In three cases of supply chain strategies, i.e. two non-coordinated shipyards, one coordinated shipyard, and one non-coordinated shipyard, and two coordinated shipyards, the decisions on the energy efficiency of spare parts and the price of the ship reconstruction service are derived, respectively.

3.1. Two Non-coordinated Shipyards

In a supply chain with two non-coordinated shipyards (s =*NN*), the decision processes of the players can be described in the following sequential steps:

(i) The manufacturer invests in the energy efficiency of spare parts for marine main engines;
(ii) The two shipyards observe the energy efficiency of the spare parts, then they set prices for the ship reconstruction service and place orders with the manufacturer;
(iii) Demand is realized based on the energy efficiency of the spare parts and prices set by the two shipyards.

The profit $\Pi_M^{NN}(x)$ of the manufacturer is:

$$\Pi_M^{NN}(x) = (w_i - v_M - \varepsilon x^{NN})[k_i a + \alpha x^{NN} - \beta p_i^{NN} + \gamma(p_j^{NN} - p_i^{NN})] +$$
$$(w_j - v_M - \varepsilon x^{NN})[k_j a + \alpha x^{NN} - \beta p_j^{NN} + \gamma(p_i^{NN} - p_j^{NN})] - f - c(x^{NN})^2 . \quad (3)$$

Also, the profit $\Pi_{S_i}^{NN}(x)$ of the i th shipyard is

$$\Pi_{S_i}^{NN}(x) = (p_i^{NN} - w_i - v_S)[k_i a + \alpha x^{NN} - \beta p_i^{NN} + \gamma(p_j^{NN} - p_i^{NN})] . \quad (4)$$

Proposition 1 and **Corollary 2** then summarize our findings on the energy efficiency of spare parts and the price of ship construction service when s =*NN* as follows:

Proposition 1. *When there are two non-coordinated shipyards, the equilibrium solutions* x^{NN*}, p_i^{NN*} *and* p_j^{NN*} *and for ship construction service are*:

$$x^{NN*} = \frac{\varepsilon\beta[a + (\beta+\gamma)(w_i + w_j + 2v_S)] - (2\beta+\gamma)[\varepsilon a - \alpha(w_i + w_j - 2v_M)]}{2[(2\varepsilon\alpha + c)(2\beta+\gamma) - \alpha\varepsilon\beta]} , \quad (5)$$

$$p_i^{NN*} = \frac{\alpha x^{NN*}}{(2\beta+\gamma)} + \frac{k_i a + (\beta+\gamma)(w_i + v_S)}{(2\beta+3\gamma)} + \frac{\gamma[a + (\beta+\gamma)(w_i + w_j + 2v_S)]}{(2\beta+3\gamma)(2\beta+\gamma)} , \quad (6)$$

and

$$p_j^{NN*} = \frac{\alpha x^{NN*}}{(2\beta+\gamma)} + \frac{k_j a + (\beta+\gamma)(w_j + v_S)}{(2\beta+3\gamma)} + \frac{\gamma[a + (\beta+\gamma)(w_j + w_i + 2v_S)]}{(2\beta+3\gamma)(2\beta+\gamma)} . \quad (7)$$

Proof: See the Appendix.

Corollary 2. *In the case of* s *=NN, the energy efficiency of the spare parts provided by the manufacturer increases in* w_i *(* i *,* j *=1,2,* $i \neq j$ *) but decreases in* a *and fixed cost* c *related to the energy efficiency of the spare parts; while the price of service set by the* i *th shipyard increases in* a *and its share* k_i *of the instinct demand potential.*

Proof: See the Appendix.

From **Proposition 1** and **Corollary 2**, managerial insights are indicated whereby in the case of two non-coordinated shipyards, improvement in the energy efficiency of the spare parts provided by the manufacturer can be realized by enhancing the wholesale price to the manufacturer and lowering the fixed cost c related to the energy efficiency of the spare parts.

In the following section, we introduce the case that the manufacturer is coordinated with one shipyard but not coordinated with the other shipyard, and then the equilibrium solutions are derived.

3.2. One Coordinated and One Non-coordinated Shipyards

When one shipyard is coordinated with the manufacturer but the other is non-coordinated (s = *CN*), decision sequences of the two shipyards are described as follows:

(i) The two shipyards observe the energy efficiency of spare parts and each other's price for ship reconstruction services;

(ii) The i th shipyard makes an agreement with the manufacturer on coordination to maximize their profits, while the j th shipyard remains non-coordinated with the manufacturer;

(iii) Demand for ship reconstruction is realized based on the energy efficiency of spare parts provided by the manufacturer and the price set by the two shipyards.

When coordination is realized between the manufacturer and the i th shipyard, the profit $\Pi_{M+S_i}^{CN}(x)$ of the manufacturer and the i th shipyard is

$$\Pi_{M+S_i}^{CN}(x) = (p_i^{CN} - v_M - v_S - \varepsilon x^{CN})[k_i a + \alpha x^{CN} - \beta p_i^{CN} + \gamma(p_j^{CN} - p_i^{CN})] - f - c(x^{CN})^2$$
$$+ (w_j - v_M - \varepsilon x^{CN})[k_j a + \alpha x^{CN} - \beta p_j^{CN} + \gamma(p_i^{CN} - p_j^{CN})]. \quad (8)$$

Profit $\Pi_{S_j}^{CN}(x)$ of the j th shipyard is

$$\Pi_{S_j}^{CN}(x) = (p_j^{CN} - w_j - v_S)[k_j a + \alpha x^{CN} - \beta p_j^{CN} + \gamma(p_i^{CN} - p_j^{CN})] \quad (9)$$

Then **Theorem 3** is derived as follows:

Theorem 3. *In a ship reconstruction supply chain with one coordinated and one non-coordinated shipyard, only when* $A < 2\sqrt{(2\alpha\varepsilon + c)(\beta + \gamma)}$, *there are unique optimal solutions for the energy efficiency of spare parts and the prices of ship reconstruction service.*
Proof: See the Appendix.

Let $B = \varepsilon a + \alpha(2v_M + v_S - w_j)$, $T_i = k_i a + \beta(v_M + v_S) + \gamma(w_j + v_S)$ and $T_j = k_j a + (\beta + \gamma)(w_j + v_S)$.

Proposition 4 then summarize our findings on the energy efficiency of spare parts and the prices of the ship construction service when $s = CN$.

Proposition 4. *When one shipyard is coordinated with the manufacturer but the other is non-coordinated, equilibrium solutions* x^{CN*}, p_i^{CN*} *and* p_j^{CN*} *are as follows:*

$$x^{CN*} = \frac{[2\varepsilon\beta(\beta+\gamma) + \gamma A][2(\beta+\gamma)B - \varepsilon\beta T_j] - (\gamma B + \varepsilon\beta T_i)[2(\beta+\gamma)A + \varepsilon\beta\gamma]}{[2(\beta+\gamma)A + \varepsilon\beta\gamma][\varepsilon\beta A + 2\gamma(2\alpha\varepsilon + c)] - [2\varepsilon\beta(\beta+\gamma) + \gamma A][4(\beta+\gamma)(2\alpha\varepsilon + c) - \varepsilon\beta\alpha]}, \quad (10)$$

$$p_i^{CN*} = \frac{[\varepsilon\beta A + 2\gamma(2\alpha\varepsilon + c)]x^{CN*} + \gamma B + \varepsilon\beta T_i}{[2\varepsilon\beta(\beta+\gamma) + \gamma A]}, \quad (11)$$

and

$$p_j^{CN*} = \frac{2(\beta+\gamma)p_i^{CN*} - Ax^{CN*} - T_i}{\gamma}. \quad (12)$$

Proof. See the Appendix.

3.3. Two Coordinated Shipyards

When the two shipyards are coordinated with the manufacturer (s = *CC*), their decision sequences can be described as follows:
(i) The two shipyards observe each other's prices for ship construction services;
(ii) Both shipyards make an agreement with the manufacturer on coordination to maximize their profits;
(iii) Demand is realized based on the energy efficiency of spare parts and the prices of ship construction services.

When coordination is realized between the each shipyard and the manufacturer, the profit $\Pi_{SC}^{CC}(x)$ of the whole supply chain is

$$\begin{aligned}\Pi_{SC}^{CC}(x) = {} & (p_i^{CC} - v_M - v_S - \varepsilon x^{CC})[k_i a + \alpha x^{CC} - \beta p_i^{CC} + \gamma(p_j^{CC} - p_i^{CC})] - f - c[(x^{CC})^2 - (x^{NN*})^2] \\ & + (p_j^{CC} - v_M - v_S - \varepsilon x^{CC})[k_j a + \alpha x^{CC} - \beta p_j^{CC} + \gamma(p_i^{CC} - p_j^{CC})] \qquad (13)\end{aligned}$$

Then **Theorem 5** is derived as follows:

Theorem 5. *In a ship reconstruction supply chain with two coordinated shipyards, only when* $A < \sqrt{2\beta(2\varepsilon\alpha + c)}$, *there are unique optimal solutions for the energy efficiency of spare parts and the prices of ship reconstruction services.*

Proof: See the Appendix.

Proposition 6 and **Corollary 7** then summarize our findings on the energy efficiency of spare parts and the prices of ship construction services when $s = CC$.

Proposition 6. *When both of shipyards are coordinated with the manufacturer, equilibrium solutions* x^{CC*}, p_i^{CC*} *and* p_j^{CC*} *for the energy efficiency of spare parts and the prices of ship construction services are*

$$x^{CC*} = \frac{(\alpha - \varepsilon\beta)a + 2\beta(\alpha + \varepsilon\beta - 2)(v_M + v_S)}{4\beta(2\alpha\varepsilon + c) - 2A^2}, \qquad (14)$$

$$p_i^{CC*} = \frac{(4\gamma + \beta A)(v_M + v_S) + (2\varepsilon\gamma + Ak_i)a + [4\gamma(2\alpha\varepsilon + c) + A^2]x^{CC*}}{2A(\beta + 2\gamma)}, \qquad (15)$$

and

$$p_j^{CC*} = \frac{(4\gamma + \beta A)(v_M + v_S) + (2\varepsilon\gamma + Ak_j)a + [4\gamma(2\alpha\varepsilon + c) + A^2]x^{CC*}}{2A(\beta + 2\gamma)} \qquad (16)$$

Proof. See the Appendix.

Corollary 7. *In case where two shipyards are coordinated with the manufacturer, the price of the ship reconstruction service set by the* i *th shipyard increases in its share* k_i *of instinct demand potential.*
Proof. Straightforward and, therefore, omitted.

Here, economy of scale (small VS large scale shipbuilding) usually affects cost variables, i.e. large scale shipbuilding leads to relative low value of v_S, v_M and f in this model. Just like the proof of **Corollary 2 & 7** in the Appendix, we can easily derive that price decreases in cost v_S and v_M.

4. A Numerical Example

In this section, using a numerical example of a ship reconstruction supply chain with competing shipyards, we further analyze some related issues. Here, competition intensity is variable, and other parameters are fixed. Let =800, =0.45, =60, = =10, =30, =1, =2, =1, =100, =200 and [10, 100]. The unit of is a 10% improvement in energy efficiency compared with a benchmark of ship fuel consumption. In the following subsections, we discuss the impact of competition intensity on the energy efficiency of spare parts, profits and consumer surplus as follows:

4.1. *Energy Efficiency*

Within different supply chain strategies, the impact of competition intensity γ on the equilibrium energy efficiency x^{s*} is shown in Figure 1, where curves NN, CN and CC indicate x^{NN*}, x^{CN*} and x^{CC*}, respectively. From Figure 1, we can observe that there are $x^{CC*} > x^{NN*} > x^{CN*}$ ($10 \le \gamma \le 100$). In particular, decreases in competition intensity, which implies that the higher competition intensity of price leads to lower energy efficiency in the case of $s = NN$.

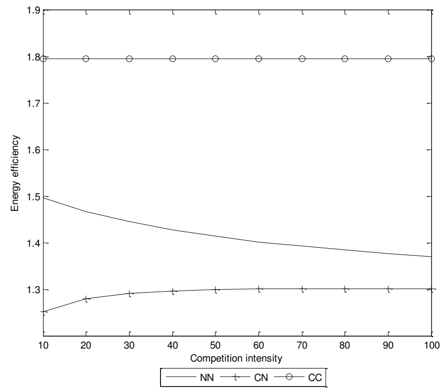

Figure 1: Energy efficiency as a function of competition intensity

4.2. *Profits*

Then, industry profits are compared in different supply chain strategies. The impact of competition intensity on the industry profits is shown in Figure 2, where curves NN, CN and CC indicate $\Pi_{SC}^{NN*}(x) = \Pi_{S_i}^{NN*}(x) + \Pi_{S_j}^{NN*}(x) + \Pi_{M}^{NN*}(x)$, $\Pi_{SC}^{CN*}(x) = \Pi_{M+S_i}^{CN*}(x) + \Pi_{S_j}^{CN*}(x)$ and $\Pi_{SC}^{CC*}(x)$, respectively.

From Figure 2, we can observe that there are $\begin{cases} \Pi_{SC}^{CC*}(x) > \Pi_{SC}^{CN*}(x) > \Pi_{SC}^{NN*}(x), 100 \le \gamma \le 900 \\ \Pi_{SC}^{CN*}(x) > \Pi_{SC}^{CC*}(x) > \Pi_{SC}^{NN*}(x),\ \ \gamma = 1000 \end{cases}$.

The observations suggest that coordination results in an increase in industry profits.

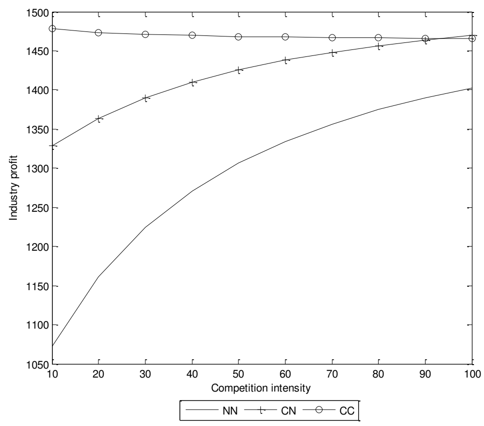

Figure 2: Industry profits as a function of competition intensity

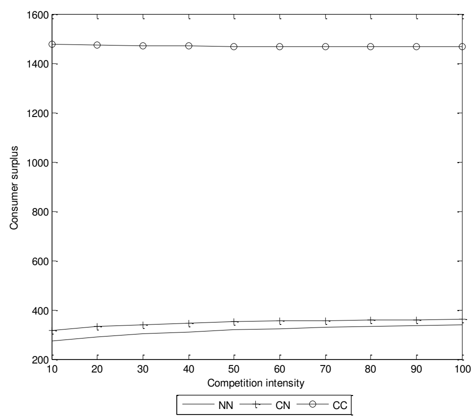

Figure 3: Consumer surplus as a function of competition intensity

4.3. Consumer Surplus

Along with the profits of organizations (economy) and energy efficiency (environment), we investigate another "pillar" of sustainability, i.e. consumer surplus (society). Here, $CS^{s*}(x) = (D_i^{s*} + D_j^{s*})x^{s*}$. The impact of competition intensity γ on the equilibrium consumer surplus $CS^{s*}(x)$ is shown in **Figure 3**, where curves NN, CN and CC indicate CS^{NN*}, CS^{CN*} and CS^{CC*}, respectively. From **Figure 3**, we can observe that there are $CS^{CC*} > CS^{CN*} > CS^{NN*}$, which indicates that *CC* is the best supply chain strategy combination for the society.

5. Conclusion

In this study, from the standpoint of three aspects of sustainability, i.e. environment (energy efficiency), society (consumer surplus) and economy (industry profit), we investigate the impacts of coordination and price competition on sustainability in the ship reconstruction industry. Our research suggests that both supply chain strategy and competition intensity have significant impacts on supply chain performance, including energy efficiency, industry profits and consumer surplus. In terms of the industry profit, the best supply chain strategy is CC except that the competition intensity is extreme high. For energy efficiency and consumer surplus, the supply chain strategy CC is the best. Therefore, coordination is advocated for the members to achieve higher supply chain performance.

One of the limitations of our paper is that this study focuses on the case of two competing shipyards. In fact, there are usually more than two shipyards. In such cases, new models can be developed to analyze managerial decision-making for sustainable ship reconstruction. Moreover, the results of our experimental analysis are decided by parameters, which change over time. As a consequence, the results of our experimental analysis may be inapplicable when the parameters change. This study may be a subject of future research. In future work, the topics expected to be worthy of further study include sustainable ship reconstruction in a supply chain with competing manufacturers, risk management in a ship reconstruction supply chain, the regulation of a sustainable supply chain with uncertain demand and risk management in competing supply chains.

6. Acknowledgements

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Appendices

Proof of Proposition 1

From Eq. (3) and Eq. (4), we obtain first-order partial derivatives of $\Pi_M^{NN}(x)$ and $\Pi_{S_i}^{NN}(x)$ with respect to x^{NN} and p_i^{NN} as follows:

$$\partial\Pi_M^{NN}(x)\big/\partial x^{NN} = -\varepsilon[k_i a + \alpha x^{NN} - \beta p_i^{NN} + \gamma(p_j^{NN} - p_i^{NN})] + \alpha(w_i - v_M - \varepsilon x^{NN})$$
$$-\varepsilon[k_j a + \alpha x^{NN} - \beta p_j^{NN} + \gamma(p_i^{NN} - p_j^{NN})] + \alpha(w_j - v_M - \varepsilon x^{NN}) - 2cx^{NN},$$
$$\partial\Pi_{S_i}^{NN}(x)\big/\partial p_i^{NN} = [k_i a + \alpha x^{NN} - \beta p_i^{NN} + \gamma(p_j^{NN} - p_i^{NN})] - (\beta+\gamma)(p_i^{NN} - w_i - v_S),$$

Letting $\partial\Pi_M^{NN}(x)\big/\partial x^{NN}$ =0, $\partial\Pi_{S_i}^{NN}(x)\big/\partial p_i^{NN}$ =0 and $\partial\Pi_{S_j}^{NN}(x)\big/\partial p_j^{NN}$ =0, the following equations apply:

$$\begin{cases} -2(2\varepsilon\alpha + c)x^{NN} + \varepsilon\beta(p_i^{NN} + p_j^{NN}) - \varepsilon a + \alpha(w_i + w_j - 2v_M) = 0 \\ \alpha x^{NN} - 2(\beta+\gamma)p_i^{NN} + \gamma p_j^{NN} + k_i a + (\beta+\gamma)(w_i + v_S) = 0 \\ \alpha x^{NN} - 2(\beta+\gamma)p_j^{NN} + \gamma p_i^{NN} + k_j a + (\beta+\gamma)(w_j + v_S) = 0 \end{cases}.$$

Then, we can derive equilibrium solutions x^{NN*}, p_i^{NN*} and p_j^{NN*} for energy efficiency and prices of ship construction as follows:

$$x^{NN*} = \frac{\varepsilon\beta[a + (\beta+\gamma)(w_i + w_j + 2v_S)] - (2\beta+\gamma)[\varepsilon a - \alpha(w_i + w_j - 2v_M)]}{2[(2\varepsilon\alpha + c)(2\beta+\gamma) - \alpha\varepsilon\beta]},$$

$$p_i^{NN*} = \frac{\alpha x^{NN*}}{(2\beta+\gamma)} + \frac{k_i a + (\beta+\gamma)(w_i + v_S)}{(2\beta+3\gamma)} + \frac{\gamma[a + (\beta+\gamma)(w_i + w_j + 2v_S)]}{(2\beta+3\gamma)(2\beta+\gamma)},$$

and

$$p_j^{NN*} = \frac{\alpha x^{NN*}}{(2\beta+\gamma)} + \frac{k_j a + (\beta+\gamma)(w_j + v_S)}{(2\beta+3\gamma)} + \frac{\gamma[a + (\beta+\gamma)(w_j + w_i + 2v_S)]}{(2\beta+3\gamma)(2\beta+\gamma)}.$$

Proof of Corollary 2

From Eq. (5), we obtain first-order partial derivatives of x^{NN*} with respect to a, w_i and c as follows:

$$\partial x^{NN*}\big/\partial a = \frac{-\varepsilon(\beta+\gamma)}{2[(2\varepsilon\alpha + c)(2\beta+\gamma) - \alpha\varepsilon\beta]} < 0,$$

$$\partial x^{NN*}\big/\partial w_i = \frac{\varepsilon\beta(\beta+\gamma) + \alpha(2\beta+\gamma)}{2[(2\varepsilon\alpha + c)(2\beta+\gamma) - \alpha\varepsilon\beta]} > 0,$$

$$\partial x^{NN*}\big/\partial c = -\frac{\varepsilon\beta[a + (\beta+\gamma)(w_i + w_j + 2v_S)] - (2\beta+\gamma)[\varepsilon a - \alpha(w_i + w_j - 2v_M)]}{4(2\beta+\gamma)[(2\varepsilon\alpha + c)(2\beta+\gamma) - \alpha\varepsilon\beta]} < 0.$$

Therefore, in the case of s =*NN*, the energy efficiency x^{NN*} of the spare parts provided by the manufacturer increases in w_i (i, j =*1,2*, $i \neq j$) but decreases in a and fixed cost c related to the energy efficiency of the spare parts;

Also, from Eq. (6), we obtain first-order partial derivatives of p_i^{NN*} with respect to a and k_i as follows:

$$\partial p_i^{NN*} \big/ \partial a = \frac{k_i}{(2\beta+3\gamma)} + \frac{\gamma}{(2\beta+3\gamma)(2\beta+\gamma)} > 0 ,$$

$$\partial p_i^{NN*} \big/ \partial k_i = \frac{a}{(2\beta+3\gamma)} > 0 .$$

Therefore, in the case of s =*NN*, the price of service set by the i th shipyard increases in a and its share k_i of the instinct demand potential.

Proof of Theorem 3

From Eq. (8), we obtain first-order partial derivatives of $\Pi_{M+S_i}^{CN}(x)$ with respect to x^{CN} and p_i^{CN} as follows:

$$\partial \Pi_{M+S_i}^{CN}(x) \big/ \partial x^{CN} = -2(2\alpha\varepsilon + c)x^{CN} + (\alpha + \varepsilon\beta)p_i^{CN} + \varepsilon\beta p_j^{CN} - \varepsilon a - \alpha(2v_M + v_S - w_j) ,$$

$$\partial \Pi_{M+S_i}^{CN}(x) \big/ \partial p_i^{CN} = (\alpha + \varepsilon\beta)x^{CN} - 2(\beta+\gamma)p_i^{CN} + \gamma p_j^{CN} + k_i a + \beta(v_M + v_S) + \gamma(w_j + v_S) .$$

Moreover, $A = \alpha + \varepsilon\beta$, and there are

$$\partial^2 \Pi_{M+S_i}^{CN}(x) / \partial (x^{CN})^2 = -2(2\alpha\varepsilon + c) ,$$

$$\partial^2 \Pi_{M+S_i}^{CN}(x) / \partial (p_i^{CN})^2 = -2(\beta+\gamma) ,$$

$$\partial^2 \Pi_{M+S_i}^{CN}(x) / \partial x^{CN} \partial p_i^{CN} = A ,$$

$$\partial^2 \Pi_{M+S_i}^{CN}(x) / \partial p_i^{CN} \partial x^{CN} = A .$$

Hessian matrix H_{CN} of $\Pi_{M+S_i}^{CN}(x)$ is $H_{CN} = \begin{pmatrix} -2(2\alpha\varepsilon + c), & A \\ A, & -2(\beta+\gamma) \end{pmatrix}$. To be certain that $\Pi_{M+S_i}^{CN}(x)$ is maximal in (x^{CN*} , p_i^{CN*}), Hessian matrix H_{CC} should be negative definite. That is, only when $4(2\alpha\varepsilon + c)(\beta+\gamma) - A^2 > 0$, i.e. $A < 2\sqrt{(2\alpha\varepsilon + c)(\beta+\gamma)}$, there are unique optimal solutions for energy efficiency and prices of service.

Proof of Proposition 4

From Eq. (9), we obtain first-order partial derivatives of $\Pi_{S_j}^{CN}(x)$ with respect to p_j^{CN} as follows:

$$\partial \Pi_{S_j}^{CN}(x) \big/ \partial p_j^{CN} = \alpha x^{CN} + \gamma p_i^{CN} - 2(\beta+\gamma)p_j^{CN} + k_j a + (\beta+\gamma)(w_j + v_S) .$$

Let $\partial \Pi_{M+S_i}^{CN}(x) \big/ \partial x^{CN} = 0$, $\partial \Pi_{M+S_i}^{CN}(x) \big/ \partial p_i^{CN} = 0$ and $\partial \Pi_{S_j}^{CN}(x) \big/ \partial p_j^{CN} = 0$.

Then, the following equations apply:

$$\begin{cases} -2(2\alpha\varepsilon + c)x^{CN} + (\alpha + \varepsilon\beta)p_i^{CN} + \varepsilon\beta p_j^{CN} = \varepsilon a + \alpha(2v_M + v_S - w_j) \\ -(\alpha + \varepsilon\beta)x^{CN} + 2(\beta+\gamma)p_i^{CN} - \gamma p_j^{CN} = k_i a + \beta(v_M + v_S) + \gamma(w_j + v_S) \\ -\alpha x^{CN} - \gamma p_i^{CN} + 2(\beta+\gamma)p_j^{CN} = k_j a + (\beta+\gamma)(w_j + v_S) \end{cases} .$$

Let $A = \alpha + \varepsilon\beta$, $B = \varepsilon a + \alpha(2v_M + v_S - w_j)$, $T_i = k_i a + \beta(v_M + v_S) + \gamma(w_j + v_S)$ and $T_j = k_j a + (\beta+\gamma)(w_j + v_S)$. The equations are as follows:

$$\begin{cases} -2(2\alpha\varepsilon + c)x^{CN} + Ap_i^{CN} + \varepsilon\beta p_j^{CN} = B \\ -Ax^{CN} + 2(\beta+\gamma)p_i^{CN} - \gamma p_j^{CN} = T_i \\ -\alpha x^{CN} - \gamma p_i^{CN} + 2(\beta+\gamma)p_j^{CN} = T_j \end{cases}.$$

Then, equilibrium solutions x^{CN*}, p_i^{CN*} and p_j^{CN*} for energy efficiency and prices of ship construction are derived as follows:

$$x^{CN*} = \frac{[2\varepsilon\beta(\beta+\gamma)+\gamma A][2(\beta+\gamma)B - \varepsilon\beta T_j] - (\gamma B + \varepsilon\beta T_i)[2(\beta+\gamma)A + \varepsilon\beta\gamma]}{[2(\beta+\gamma)A + \varepsilon\beta\gamma][\varepsilon\beta A + 2\gamma(2\alpha\varepsilon + c)] - [2\varepsilon\beta(\beta+\gamma)+\gamma A][4(\beta+\gamma)(2\alpha\varepsilon + c) - \varepsilon\beta\alpha]},$$

$$p_i^{CN*} = \frac{[\varepsilon\beta A + 2\gamma(2\alpha\varepsilon + c)]x^{CN*} + \gamma B + \varepsilon\beta T_i}{[2\varepsilon\beta(\beta+\gamma)+\gamma A]},$$

and

$$p_j^{CN*} = \frac{2(\beta+\gamma)p_i^{CN*} - Ax^{CN*} - T_i}{\gamma}.$$

Proof of Theorem 5

From Eq. (13), we obtain first-order partial derivatives of $\Pi_{SC}^{CC}(x)$ with respect to x^{CC}, p_i^{CC} and p_j^{CC} as follows:

$$\partial\Pi_{SC}^{CC}(x)/\partial x^{CC} = -2(2\alpha\varepsilon + c)x^{CC} + (\alpha+\beta\varepsilon)p_i^{CC} + (\alpha+\beta\varepsilon)p_j^{CC} - \varepsilon a - 2(v_M + v_S),$$
$$\partial\Pi_{SC}^{CC}(x)/\partial p_i^{CC} = (\alpha+\varepsilon\beta)x^{CC} - 2(\beta+\gamma)p_i^{CC} + 2\gamma p_j^{CC} + k_i a + \beta(v_M + v_S),$$
$$\partial\Pi_{SC}^{CC}(x)/\partial p_j^{CC} = (\alpha+\varepsilon\beta)x^{CC} + 2\gamma p_i^{CC} - 2(\beta+\gamma)p_j^{CC} + k_j a + \beta(v_M + v_S),$$

Moreover, $A = \alpha + \varepsilon\beta$, and there are

$$\partial^2\Pi_{SC}^{CC}(x)/\partial(x^{CC})^2 = -2(2\alpha\varepsilon + c),$$
$$\partial^2\Pi_{SC}^{CC}(x)/\partial(x^{CC})\partial(p_i^{CC}) = A,$$
$$\partial^2\Pi_{SC}^{CC}(x)/\partial(x^{CC})\partial(p_j^{CC}) = A,$$
$$\partial^2\Pi_{SC}^{CC}(x)/\partial(p_i^{CC})\partial(x^{CC}) = A,$$
$$\partial^2\Pi_{SC}^{CC}(x)/\partial(p_i^{CC})^2 = -2(\beta+\gamma),$$
$$\partial^2\Pi_{SC}^{CC}(x)/\partial(p_i^{CC})\partial(p_j^{CC}) = 2\gamma,$$
$$\partial^2\Pi_{SC}^{CC}(x)/\partial(p_j^{CC})\partial(x^{CC}) = A,$$
$$\partial^2\Pi_{SC}^{CC}(x)/\partial(p_j^{CC})\partial(p_i^{CC}) = 2\gamma,$$
$$\partial^2\Pi_{SC}^{CC}(x)/\partial(p_j^{CC})^2 = -2(\beta+\gamma).$$

The Hessian matrix H_{CC} of $\Pi_{SC}^{CC}(x)$ is $H_{CC} = \begin{pmatrix} -2(2\varepsilon\alpha + c) & A & A \\ A & -2(\beta+\gamma) & 2\gamma \\ A & 2\gamma & -2(\beta+\gamma) \end{pmatrix}$. To be certain that $\Pi_{SC}^{CC}(x)$ is maximal in (x^{CC*}, p_i^{CC*}, p_j^{CC*}), the Hessian matrix H_{CC} should be negative definite, and there should be $-2(2\varepsilon\alpha + c)[4(\beta+\gamma)^2 - 4\gamma^2]$ + $A[2\gamma A + 2A(\beta+\gamma)]$ + $A[2\gamma A + 2A(\beta+\gamma)]$ <0, i.e. $A^2 < 2\beta(2\varepsilon\alpha + c)$. Therefore, only when $A < \sqrt{2\beta(2\varepsilon\alpha + c)}$, there are unique optimal solutions and closed-form expression for energy efficiency and price of service.

Proof of Proposition 6

Letting $\partial\Pi_{SC}^{CC}(x)\big/\partial x^{CC}=0$, $\partial\Pi_{SC}^{CC}(x)\big/\partial p_i^{CC}=0$ and $\partial\Pi_{SC}^{CC}(x)\big/\partial p_j^{CC}=0$, the following equations apply:

$$\begin{cases}-2(2\alpha\varepsilon+c)x^{CC}+Ap_i^{CC}+Ap_j^{CC}=\varepsilon a+2(v_M+v_S)\\ -Ax^{CC}+2(\beta+\gamma)p_i^{CC}-2\gamma p_j^{CC}=k_i a+\beta(v_M+v_S)\\ -Ax^{CC}-2\gamma p_i^{CC}+2(\beta+\gamma)p_j^{CC}=k_j a+\beta(v_M+v_S)\end{cases}.$$

Then, equilibrium solutions x^{CC*}, p_i^{CC*} and p_j^{CC*} for energy efficiency and prices of ship construction are derived as follows:

$$x^{CC*}=\frac{(\alpha-\varepsilon\beta)a+2\beta(\alpha+\varepsilon\beta-2)(v_M+v_S)}{4\beta(2\alpha\varepsilon+c)-2A^2},$$

$$p_i^{CC*}=\frac{(4\gamma+\beta A)(v_M+v_S)+(2\varepsilon\gamma+Ak_i)a+[4\gamma(2\alpha\varepsilon+c)+A^2]x^{CC*}}{2A(\beta+2\gamma)},$$

and

$$p_j^{CC*}=\frac{(4\gamma+\beta A)(v_M+v_S)+(2\varepsilon\gamma+Ak_j)a+[4\gamma(2\alpha\varepsilon+c)+A^2]x^{CC*}}{2A(\beta+2\gamma)}.$$

Proof of Corollary 7

From Eq. (15), we obtain first-order partial derivatives of p_i^{CC*} with respect to k_i as follows:

$$\partial p_i^{CC*}\big/\partial k_i=\frac{aA}{2A(\beta+2\gamma)}>0.$$

Therefore, in the case of s =*CC*, the price of service set by the i th shipyard increases in its share k_i of the instinct demand potential.

Endless Growth in Container Ship Sizes to be Stopped?

Ulrich Malchow

Centre of Maritime Studies, Bremen University of Applied Sciences, Bremen, Germany

Abstract

The increase of containership sizes driven by the need to create greater economies of scale seems to be an endless process. Vessels of more than 21,000 TEU are presently on order. However, the further effects of lower slot costs lessen as ships get larger. Hence a further increase in ship sizes would not significantly reduce transport costs anymore and therefore hardly induce any additional containerised cargo. In contrast the necessary efforts to prepare the ports for ships of ever-increasing size are growing over proportionally with every additional metre of draught and/or beam.

The objective of the paper is to question whether all size-related costs for infrastructure and suprastructure measured at both ends, which are necessary to accommodate mega vessels would still leave an overall positive balance. Costs of fairway deepening and widening and other infrastructure measures are put into relation to the actual savings per slot out of the economies-of-scale effect provided by operating ever bigger vessels.

It is shown that an ongoing increase of containership sizes, e.g. in the Europe-Far East trade, does not bring any further benefit, neither for the ports and their terminals nor even for the lines itself! It is an amazing mechanism that all stakeholders act rationally but the overall effect for all of them (including the public) has turned into negative.

The results may pave the way for a closer cooperation among ports, e.g. within the Hamburg – Le Havre range. Ports and terminals may see the opportunity to escape the spiral of ongoing efforts for deepening und widening the fairways and installing ever bigger gantry cranes by agreeing on a joint policy with regard to maximum ship size.

Keywords: economies of scale, mega ships, ultra large container ships, slot costs

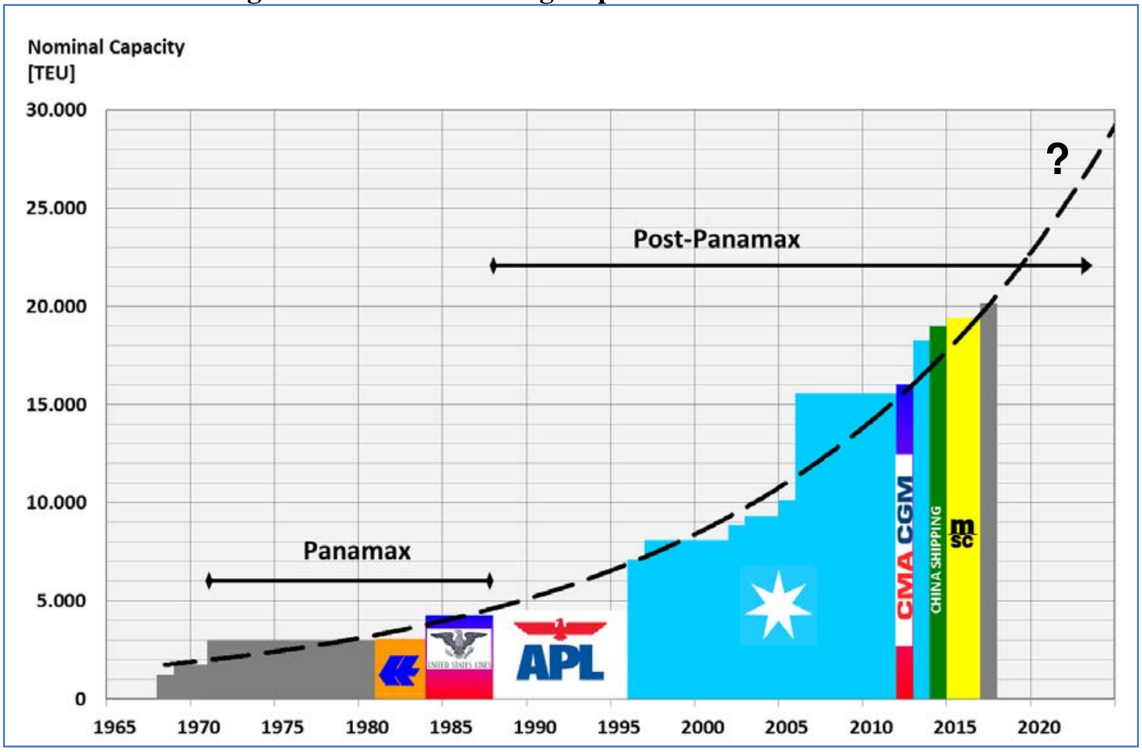
1. Introduction

The stunning growth of container ship sizes which is shown in Figure 1 is only powered by the Economies of Scale (EoS) effect. However it can be questioned whether a positive effect still remains at present mega ship sizes and even if this was the case such small effect would be outweighed by costly operational impacts for the lines out of the huge ship sizes.

From Figure 1 it can also be derived that since the 2nd half of the 1990s industry leader Maersk has led and fuelled the ship size development which other carriers apparently felt forced to follow. With the only two exemption of the jumbo vessels of later bankrupt USL for its RTW service in the late 1980s and the first Post-Panamax vessels of APL for trading across the Pacific in the early 1990s all record breaking box ships have been introduced in the Europe-Far East trade for the last 40 years.

If the future development still followed the exponential regression curve which describes the growth until now very well we would see the first 23,000 TEU vessel around the year 2020 and 30,000 TEU vessels could be expected from 2025 onwards. As this size would correspond with approx. 20 m draught it should be the ultimate limit for the time being due to the depth of the Malacca Strait.

Figure 1: Record breaking ship sizes and their initiators



While it was believed that Maersk's Triple-E-Class ships of 18,270 TEU would mark a record of some validity, other carriers have come up with orders for new record-breaking vessels. Consequently the question is evident how far we are actually following the path up to 30,000 TEU. It is the tanker sector which could act as a case to prove that size limits in shipping do exist and have been already experienced. Decades ago in tanker shipping a limit was reached at around 500,000 dwt, with only two vessels of that size built. The present maximum tanker sizes are much smaller.

2. Effect of Economies of Scale

When making use out of the EoS effect container lines are aiming for a reduction of three major specific cost types:

- Investment per TEU
- Fuel costs per TEU
- Operating costs per TEU (mostly crewing costs)

2.1. Investment per TEU

Shipbuilding can be considered as floating steelworks. To exclude the influence of market price, market power, negotiating skills, exchange rates etc. on the size related investment the pure number of processed tons of steel would be a good indicator for the investment efforts (especially with bigger ships whose investment is not so much determined by engineering and outfitting). As the pure steel weights remain mostly a secret of the shipyards and design offices the light displacement shall be used as a meaningful indicator (according to Archimedes the light displacement equals to the total light ship weight). Beside the steel weight it also comprises the significant weight of the propulsion plant which in all cases is powered by 2-stroke-slow-speed-engines with a consistent power/weight ratio within the relevant power range. That is why the sum of both weights is qualified with sufficient accuracy to be used as an indicator to describe the investment efforts for the entire vessel.

Figure 2

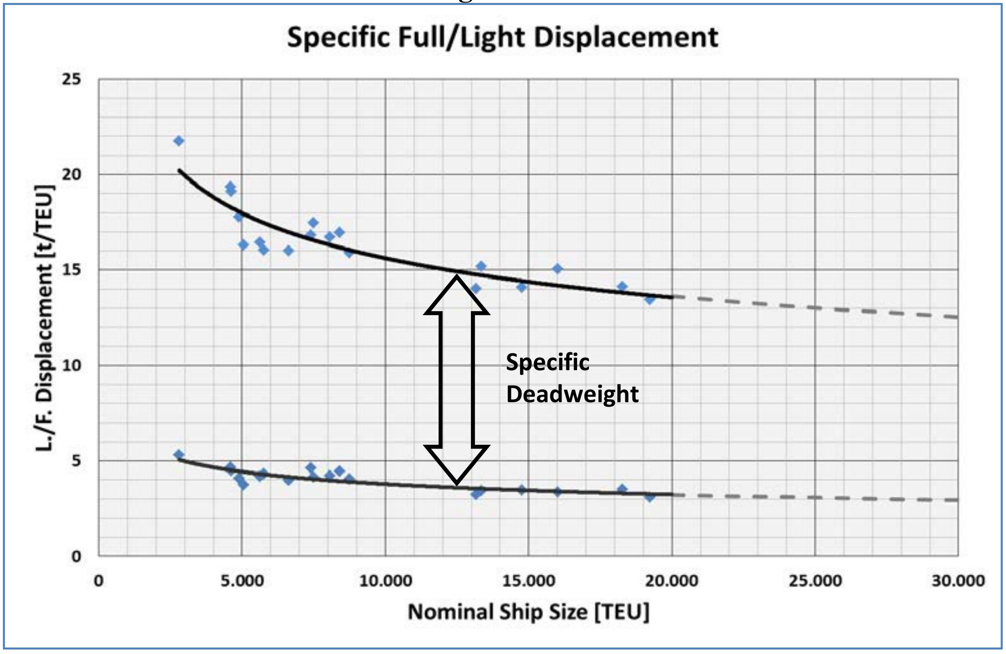


Figure 2 shows the specific light and full displacement per TEU of a number of recent newbuildings from 3,000 to 20,000 TEU and the extrapolation of their regression lines up to 30,000 TEU. It is quite obvious that the specific investment effort is getting less with increasing ship size but the curves are of asymptotic shape, i.e. they are getting flatter with increasing ship size. E.g. from 4,000 TEU to 8,000 TEU the specific investment per TEU is reduced by 15%. However the same step from 14,000 TEU to 18,000 TEU results only in 5% reduction. Interestingly the specific full displacement which comprises also the specific deadweight is deminishing at a higher rate, i.e. also the specific deadweight per TEU is getting less the bigger the ships are. Hence, each additional TEU provided by increased ship size does not only lose more and more of its cost advantage but is also getting less valuable in terms of utilisable deadweight.

2.2. Fuel costs per TEU

Fuel costs are directly proportional to fuel consumption which in turn is directly proportional to the propulsion power. At any given constant speed the specific propulsion power per TEU is decreasing with the ship size according to the famous Admirality formula used by naval architects. Due to its physical background the related curve is also of asymptotic nature as per Figure 3 (without scale, i.e. valid for any given speed).

2.3. Crewing costs per TEU

The biggest costs item within operating expenses are crewing costs. As they are in principle independent from ship size the specific costs per TEU are getting less with increasing ship sizes. The resulting curve for a fixed crewing bill per vessel is of asymptotic shape as well as per Figure 4.

2.4. Summary on slot costs

The curves of all decisive effort parameters per TEU (light displacement, propulsion power, crewing costs) are of asymptotic shape. Hence in principle the impact of the EoS effect is getting weaker the bigger the ships become. At present mega ship sizes the effect of any further potential increase was only marginal.

Nevertheless Maersk is stating that the slot costs of the "Triple-E-Class" (18,270 TEU) are 500 USD less compared to vessels of 14,000 TEU (presumably referring to its own "E-Class"). By comparing both ship generations (Table 1) a tremendous reduction of 40% in specific power demand per TEU (which is proportional to bunker consumption) is indeed obvious.

Figure 3

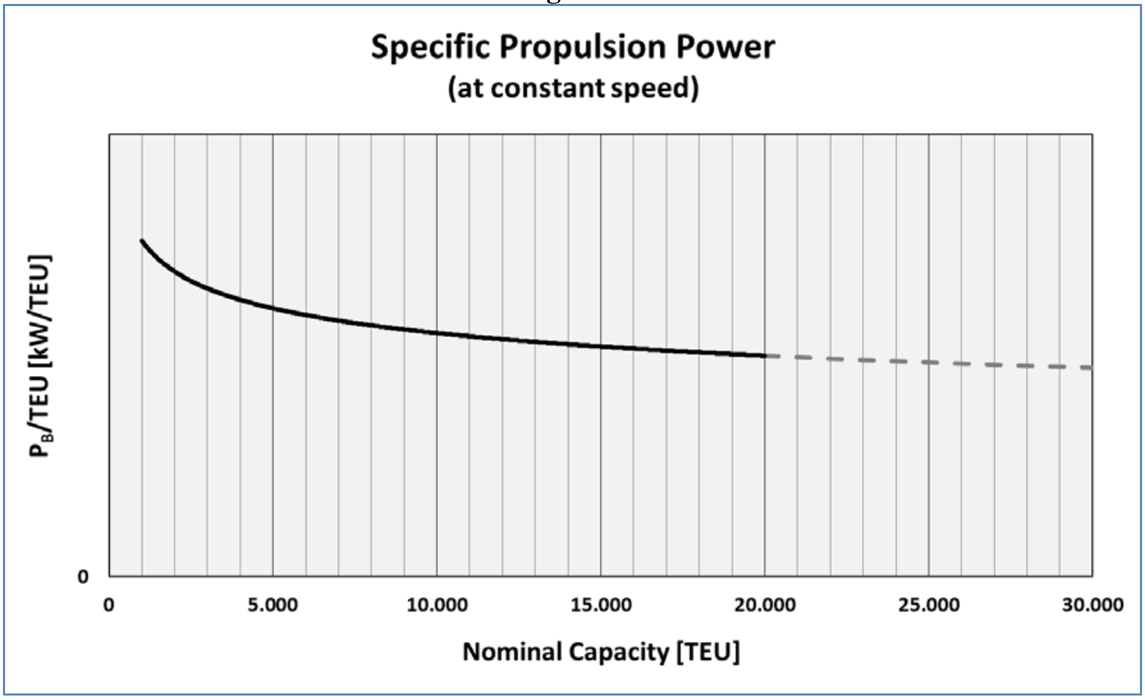
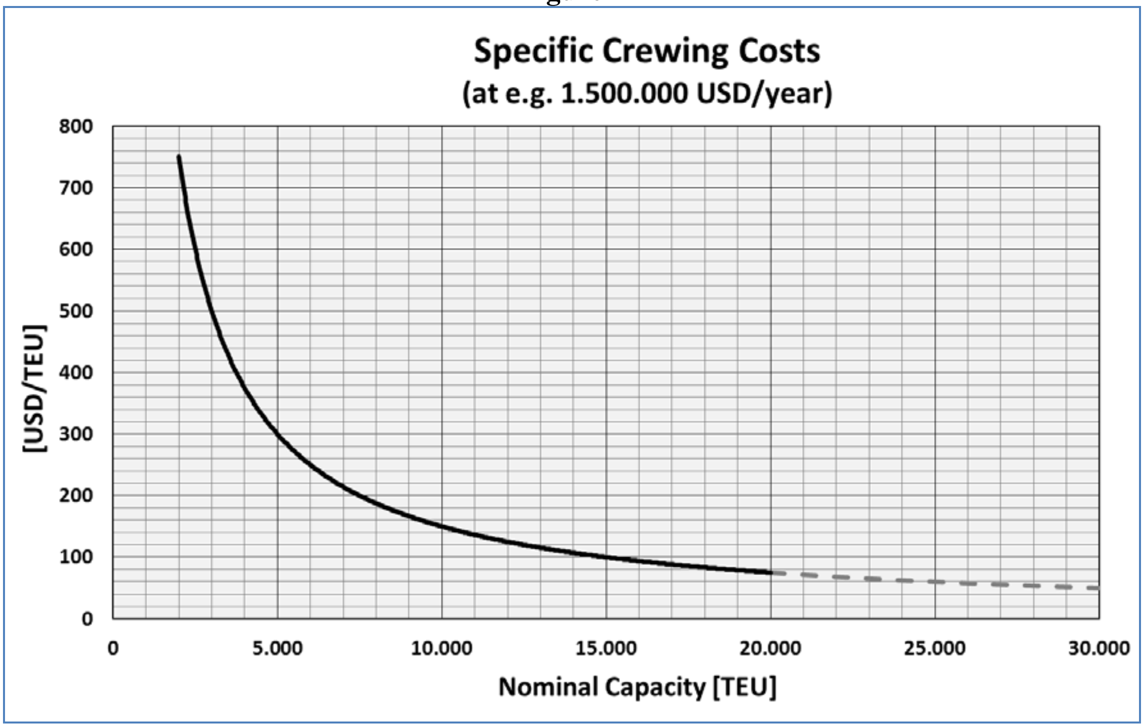


Figure 4



However a calculation based on the Admirality Formula (Eq. 1) has revealed that only 7% out of these savings in specific propulsion power per full displacement [kW/t] are a result of the EoS effect (Eq. 2)! The remaining is simply a consequence of the reduced speed (and increased engine efficiency). As with these ships the TEU capacity has increased at the same rate as the full displacement the assertion is also valid for the specific propulsion power per TEU [kW/TEU] (Eq. 3).

Table 1: Comparison of containership generations

	E-Class	Triple-E-Class		
Year built	2006	2013		
Capacity	14,770 TEU	18,270 TEU	+24 %	
Full displacement	208,000 t	258,000 t	+24 %	
Deadweight	156,907 t	194,000 t	+24 %	
Propulsion power	80,080 kW	59,360 kW	-26 %	
Top speed	26 knots	23 knots	-12 %	
Specific propulsion power	**5.42 kW/TEU**	**3.25 kW/TEU**	**-40 %**	-7 % by size -33 % by speed

Source: Pilot cards of both types of vessel

$$P = \frac{\Delta^{\frac{2}{3}} v^3}{C} \tag{1}$$

$$\frac{\frac{P_{EEE}}{\Delta_{EEE}}}{\frac{P_E}{\Delta_E}} = \left(\frac{\Delta_{EEE}}{\Delta_E}\right)^{-\frac{1}{3}} = 0{,}93 \tag{2}$$

$$\frac{\frac{P_{EEE}}{TEU_{EEE}}}{\frac{P_E}{TEU_E}} = \left(\frac{TEU_{EEE}}{TEU_E}\right)^{-\frac{1}{3}} = 0{,}93 \tag{3}$$

One precondition of making use of the EoS is that ship utilisation does not drop. Otherwise the EoS effect turns even into its opposite and slot costs are getting higher with bigger vessels. DNV-GL has made some evident calculations taking a 14,000 TEU vessel as a base case (Table 2).

Table 2: Impact of size and utilisation on slot costs

		Vessel Size			
		14,000 TEU	**16,000 TEU**	**18,000 TEU**	**21,000 TEU**
Utilisation	100 %	100 %	97 %	91 %	89 %
	95 %	105 %	101 %	96 %	94 %
	90 %	110 %	106 %	101 %	98 %
	85 %	117 %	112 %	106 %	103 %
	80 %	123 %	119 %	112 %	109 %
	75 %	131 %	126 %	119 %	116 %

Source: DNV-GL (2014)

Meanwhile reality has shown that utilisation could not be kept at required high levels. As the massive ordering of mega vessels has heavily contributed to overcapacity the general fleet utilisation has necessarily fallen, i.e. most presumably there is not any cost advantage left at all!

Overcapacity in any price driven market, where the cost leader is generally ahead of the competition, such as liner shipping, results immediately in a price slump. In today's cutthroat competition the necessarily high ship utilisation has to be paid for in terms of freight rebates. Hence it cannot get worse: The imaginary initial but actually not existing cost advantage of the latest newbuildings is completely eaten up by lowered freight rates - an inevitable consequence of the oversupply provided by such vessels. The cost advantage is just handed over to the line's customers, who appreciate such effects without being really dependent on such windfall rebates.

Such rebates however do not present a significant reduction of freight costs as the pure pier-to-pier costs of containers accounts only for 20-30% of the costs of the entire door-to-door transport chain. The impact on the retail price would be, if any, only a few cents. Hence a further increase in ship sizes does not stimulate additional shipments as it was the case e.g. at the beginning of containerisation when reduction in freight costs (compared to break bulk shipments) actually generated additional demand for shipments. Hence oversupply remains and ever lower freight rates do naturally not improve the profitability of the lines.

At the same time, a lot of still-young vessels of 8,000 to 10,000 TEU size are replaced by bigger vessels and have massively lost value as they are simply too fast and too small for today's east-west trunk routes. Consequently they are shifted into trades where they can supersede smaller vessels. This cascading continues into other trades.

In addition as loading/discharging rates do not keep pace with ship size development the mega ships stay more time in port, i.e. forcing the lines to increase the speed during the sea voyage in order to avoid an increased duration of each round voyage, i.e. contrary to the idea of the EoS increased ship size generally contributes also to higher fuel consumption. That is why the lines are pressing the terminals to implement the latest technology to speed up the ship-to-shore container handling.

Table 3: Effect of increasing ship size on port productivity

Ship size [TEU]	Containers exchanged per port call	Number of gantry cranes deployed	Crane moves per hour	Berth moves per hour	Berth moves per day	Total cargo handling time [days]	Ship size increase	Port productivity increase
7,000	2,800	3	25	75	1,650	1.7		
13,000	5,250	5	25	125	2,750	1.9	86 %	67 %
19,000	7,700	6	25	150	3,300	2.3	171 %	100 %
19,000	*7,700*	*6*	***20***	*120*	*2,640*	*2.9*	*171 %*	*60 %*

Source: Drewry Maritime Research (2014), own calculation

Even with assuming the same crane handling rate (independently of ship size) Drewry has shown that port productivity in terms of berth moves per day can not keep pace with the increase of ship size as per Table 3. However calculations have shown that the average load cycle time of a 19,000 TEU vessel is approx. 40% higher compared to a 5,000 TEU vessel just due to the longer distances each container has to travel (assuming the same crane). Hence the handling rate of cranes can not be taken as constant but have to be reduced for bigger ships. Assuming that the rate is only reduced by 20% to 20 moves/hr the 19,000 TEU vessel which has 171% more capacity stays actually 71% more time in port compared with a 7,000 TEU vessel (last line of Table 3). All measures taken in the past to increase the handling rates with bigger ships do certainly apply also for smaller ships.

3. Impact on Ports

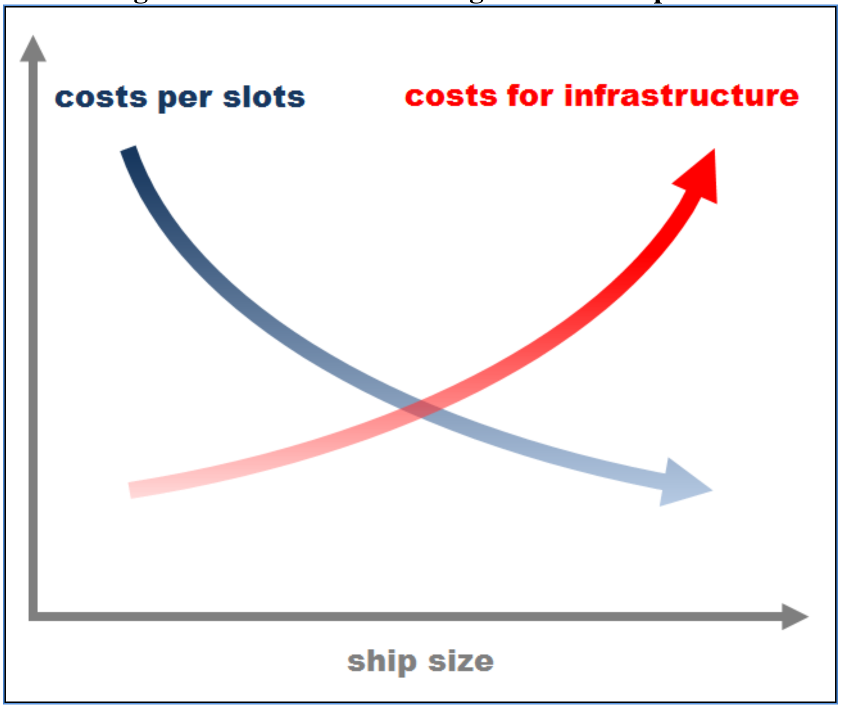
Indeed, in response to the larger vessels, ports are making continuous efforts to prepare for the latest generation of ships. This is a change compared to the times of break bulk liners of the past that were designed to meet the specific needs of their trading area, i.e. mainly to the restrictions of the ports to be called at. As containerisation has made ports more exchangeable, today it only takes the announcement of a new generation of ship to cause ports to make immediate investments to meet the needs of these larger ships.

The ports are continuously adapting their facilities in pre-emptive obedience due to fierce competition within the sector. From the individual port's view, this procedure was justified in the past. Since the start of containerisation the growth in ship sizes has reduced costs per slot, leaving space for continuous downward freight adjustments. The ports have heavily benefited from the resulting cargo boom. Also, from the global economic perspective, all investments in ports to accommodate ever bigger vessels have made sense as this has fostered the worldwide division of labour and therefore contributed to the increase of worldwide wealth - not only in the developed world. While in the future worldwide container traffic will continue to grow it will not be induced by reduced slot costs any more but just by global economic parameters.

In the meantime it has been already widely addressed that increasing ship sizes introduced by the lines to get their benefit out of the EoS effect do provide a lot of costly challenges to port authorities and terminal operators. The necessary efforts to prepare the ports for ships of ever-increasing size are growing with every additional meter of draught and/or beam not only in initial dredging but also in keeping such depth. Ports have to adjust fairways, harbour basins and quay walls to allow the installation of ever larger and faster gantry cranes at cost which are increasing more than proportional with the ship size while the actual cost advantage for the lines out of the increased sizes tends to be negligible (Figure 5) – if not turns into negative. This has made the relationship between mostly publicly financed efforts to develop port infrastructure and the overall economic returns increasingly unfavourable.

Public resources are being spent just to allow those container lines that can afford to invest in such megaships to have a theoretical cost advantage over their competitors. Therefore it is the public sector that bears a major portion of the costs of such competition. Could it be even called a distortion of competition in favour of the very big lines that is sponsored by the public?

Figure 5: Effects of increasing container ship sizes



The situation for the ports gets even worse as the liner shipping industry tends to consolidate through takeovers, mergers and alliances. All 4 major alliances which are handling 95% of the entire east west container trade as per Table 4 have gained approval from the relevant anti-trust authorities with respect to their customers. However ports and their terminals are very much dependent on joint decisions taken by the alliances with regard to ports of call, actual berth/terminal, vessel size and frequency of calls. This kind of market power towards the ports and terminals has presumably not been considered.

Table 4: Market shares of leadung container line alliances

Alliance	East-West	Europe-Far East	Transpacific	Transatlantic
2 M	27 %	34 %	15 %	40 %
O 3	15 %	20 %	13 %	6 %
CKYHE	25 %	23 %	32 %	4 %
G 6	28 %	20 %	33 %	38 %
All	**95 %**	**97 %**	**93 %**	**88 %**

Source: Financial Times (2014)

Those behind this process, which does not bring any sustainable advantage to any of the involved parties, are the big container lines. The ports act as facilitators to the cutthroat competition among the lines by providing the preconditions for increasing sizes. Ports that do not adapt their facilities to the needs of the big vessels will lose mainline business, which will be followed by missing feeder volumes. Understandably, ports are eager to avoid getting involved in such a downward spiral.

While the additional costs of adapting the suprastructure and infrastructure are burdened by terminal operators and port authorities (i.e. mostly by the public) no additional revenue out of the big vessels is gained as the total number of shipped containers is not influenced by the size of the carrying vessels (any more). Sometimes it is even just the opposite: Some port authorities grant rebates in harbour dues for mega vessels just to keep them calling or to possibly compensate any "inconvenience" in the course of the nautical approach.

Hence nobody is actually benefiting (except three Korean shipyards, upcoming Chines ones, four Belgian and Dutch dredging companies and one dominating Chinese gantry crane manufacturer). It is a tragic mechanism which has turned into a global 'lose-lose-lose-situation' for ports, terminals and the lines itself. Even the shippers being not really dependent on the lowest possible freight rates of today are heavily suffering from the operational shortcomings in terms of delays caused by extreme peak loads at the terminals which have never been experienced before.

Although the development has been initiated by the lines it is unlikely that they are able to stop it by themselves. The supposed cost cutting potential by the specious EoS effect and the fear of supposed cost advantages of the competitors is apparently too tempting to be ignored and calculations which integrate all impacts of ship size development to all stakeholders are too complicated. No single line has the standing to withstand the temptation. Even Evergreen being a long standing but lonely believer in smaller vessels, has recently drastically changed its policy by ordering mega vessels in the course of joining the CKYHE alliance. The industry, even in todays consolidated condition, cannot escape by its own initiative from this vicious circle but obviously needs some help from outside.

4. Limiting Options

Assuming that there are no technical limits ship sizes will most probably grow to 30,000 TEU unless measures are taken from outside to escape the useless spiral. Possibly even the lines would feel relieved, as they would be freed from the compulsion to invest in ever-bigger vessels in ever shorter intervals.

4.1. Insurers

Insurers are increasingly concerned about the huge cluster risks connected with the operation of mega container ships. The total loss of one of such vessel and its cargo could easily cause a damage of 1 to 2 Bill. USD (incl. salvage). In their own interest a size limit could be set, i.e. denying insurance cover for such big cluster risks, or the premium for mega ships could be drastically raised to destroy any theoretical cost advantage out of their operation.

4.2. Suez Canal

As all mega ships are at first introduced in the Europe–Far East trade the passage of the Suez Canal has to be considered. With present nautical restrictions the canal allows for vessels of approx. 24,000 TEU size. However the canal has just been upgraded: Transit time has been shortened from 18 to 11 hours and capacity has been increased to 97 transits up from the current 47 ships per day. In the course of the extension also the depth has been increased. Once the depth is adapted over the full length of the canal (in both directions) the present draught limitations could be adapted accordingly – paving the way for vessels of more than 24,000 TEU. Hence the Suez Canal Authority could play a key role with regard to the limitation of ship sizes!

4.3. Ports

Ports which for the time being are all fighting (and suffering) on their own and consider draught as one of their decisive criteria in competition could take the chance by stepping into more cooperation by setting a joint size limit. As there is much overlapping in their hinterland and their number is relatively small the ports of the Hamburg-Le Havre range are strategically most suited to set such limit at least on the European side, which would be sufficient. These few ports (except Rotterdam for obvious reasons) could play a strategic role in finally limiting container ship sizes on a global scale – not only to their own benefit!

5. Conclusion

The development of container ship sizes has reached a level that does not bring any benefit to the container lines any more whereas other stakeholders are suffering from the consequences in terms of additional investment (ports, terminals) or operational shortcomings (shippers). The container shipping industry is not able to escape from the useless spiral of growth by its own. With the current draught and beam limits for the Suez Canal approx. 24,000 TEU is the present limit, which will be most probably reached very soon. However the recent expansion of the Suez Canal would allow to increase its beam and draught limitations (to 20 m). Hence ship sizes would most probably grow up to 30,000 TEU (Malaccamax) unless limiting measures are taken from outside.

Beside the Suez Canal Authority only a joint action of some strategic ports could stop the ever increasing ship sizes. Such measure should be supported by insurers asking for unattractive premiums to cover the huge cluster risks related to ships bigger than 24,000 TEU.

In view of the enormous private and public funds that become necessary to accommodate the ever-bigger vessels without any sustainable benefit for none of the parties involved, it is worth considering the meaningfulness of such limiting measures and its practical and political feasibility.

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Strategic Analysis of Taiwan Liner Shipping Companies by Using the Sustainable Growth Model

Yu-Chun Chang, Shih-Chan Ting[*], Hui-Kee Woon, Ching-Wen Chiu and Siang-Ting Hong

Department of Transportation Science, National Taiwan Ocean University, Taiwan

Abstract

A successful company must have a comprehensive financial and investment plan, and the growth rate is important information to formulate its future development strategies. Although rapid growth may gain more market share, on the other hand, rapid growth may exhaust most of a company's resources, which will probably result in financial distress or bankruptcy. With slow growth, a company may not fully utilize its resources and it will also miss the opportunity to enlarge its scale and benefits. In view of sustainable growth, both excessive growth and slow growth will not lead to a company continuing future development. A company has to balance its strategic plan between rapid and slow growth rates, whereas, the optimal solution is to derive its suitable growth rate to make decisions for future investment and capital budgeting. The growth in container demand did not have a positive impact on freight rates. The container transportation market has been tense throughout recent years, with freight rates remaining volatile and struggling to rise. Overcapacity leads to low freight rates and low returns with which carriers had to struggle throughout these years. Furthermore, large liner companies ordered extra-large size container ships to reduce their operating cost by achieving economies of scale. Large container ship deployment strategy may not work for each company and careless, excessive capital investment may lead the poor companies to bankruptcy way. To manage liner shipping company's growth more effectively, this paper investigates three major liner companies in Taiwan, Evergreen Marine Corp., Yang Ming Marine Transport Corp. and Wan Hai Lines Ltd. and we applied sustainable growth model (Higgins, 1977) to examine the sustainable growth rate (SGR) of these companies and to analyze their development strategies. While coordinating the growth rate with its financial resource condition, we propose the suitable development strategies to achieve sustainable growth for each company. The results show that the SGR model is effective and applicable. The proposed approach contributes to the liner shipping industry in both academic and business operations, even strategy formulation as well.

Keywords: Liner shipping, Sustainable growth rate (SGR), Strategic analysis

1. Introduction

The world GDP growth rate has only increased by 3% in 2013 (IMF, 2014), better than the growth rate in 2008 and 2009. The slow world economic growth has been affecting international trade cargo volume. As a result, container transport volume has only increased by 3.6% in 2012, lower than 2011 by 1%. In 2013, the cargo volume of westbound Asia/Europe route has increased by 3.7% and by only 2.7% growth in eastbound Asia/America route. However, the total capacity supply has a significant increase of 5.7% in 2013, which is equivalent to 1,727 million TEUs (Twenty-foot Equivalent Units). Due to the continuous downturn, liner carriers are forced to purchase larger container ships (above 7,500 TEUs) and to deploy these mega ships to the main lines in order to lower their unit operating costs. According to Figure 1, total capacity of the top 20 liner companies has increased by 63% from 2010 to 2014. In 2012, due to the increase of larger container ship delivery, total space of these ships has contributed to 34% in the total supply of market capacity.

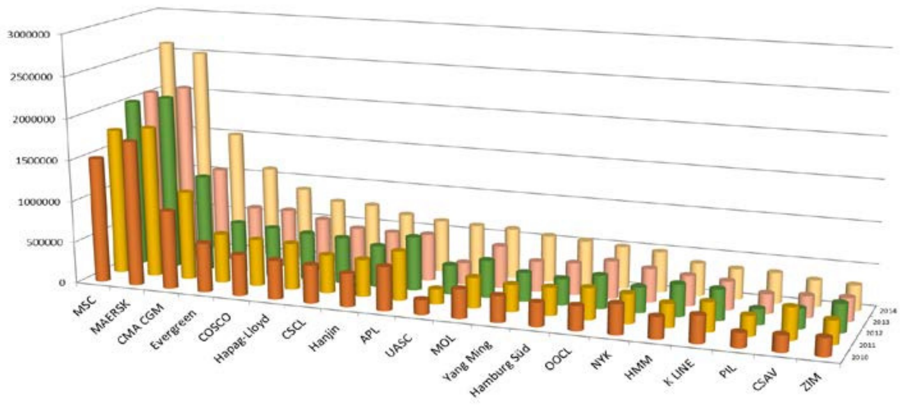

Figure 1: The Top 20 Liner Carriers' Capacity in TEUs from 2010 to 2014
Source: United Nations Conference on Trade and Development (2015)

The fierce competition has caused continuous depression in freight rates due to overcapacity, in which it also contributed to the constant low growth rate in cargo volume. Most of liner carriers realized that lowering the operating cost is going to be a long term management plan. Hence carriers have to use strategic plan such as replacing uneconomic chartered/owned ships, delaying delivery of container ships, reducing ship speed, restructuring service route network and adjusting freight rates to achieve their profit goals. As shown in Figure 2, there were only 6 carriers among the top carriers, which had positive operating margins due to the slow economic growth and too much overcapacity. All of the carriers hope to increase their growth rate in many ways. They increase their capital investment to grow their fleet and capacity but as a result, they didn't have compatible sales growth and suffered from financial deficits.

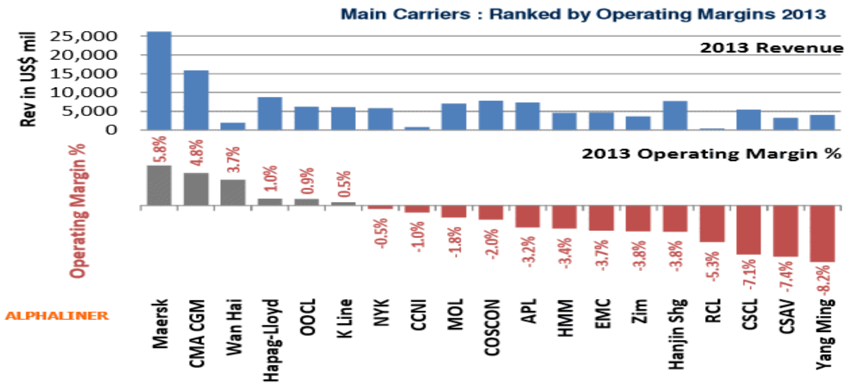

Figure 2: Revenue and Operating Margin of the Top 20 Liner Carriers in 2013
Source: Alphaliner (2015)

For liner shipping, we would say that the carriers have to control their growth to some extent. Large container ship deployment strategy may not work for each company and careless, excessive capital investment may lead the poor companies to bankruptcy way. Clark et al. (1985) warn that a desired growth rate is not simply that have positive net present value or an internal rate of return greater than the cost of capital. They assert that Higgins (1977) model provides a good starting point in long-term or strategic planning when a manager is facing growth related issues.

In Taiwan, three are three major liner companies: Evergreen Marine Corp., Yang Ming Marine Transport Corp. and Wan Hai Transport Corp. They also faced the same problems during these recent years. Evergreen reduced its total vessels to 145 in 2012 but the total capacity is more than 2011 due to delivery of large container ships. However the net profit was still less than year 2011. Evergreen and Yang Ming had a net loss although they increased their total vessels to 187 and 86 in 2013. Thus we could question if investment in bigger container ships is a suitable strategy for reducing operating cost and increasing profit growth. To manage liner shipping company's growth more effectively, this paper investigates these three companies' financial statements and we applied sustainable growth model (Higgins, 1977) to examine the sustainable growth rate (SGR) of these companies and to analyze their development strategies. While coordinating the growth rate with its financial resource condition, we propose the suitable development strategies for each company. This research will hopefully assist carriers in breaking the vicious cycle in the liner shipping industry with sustainable growth views and development strategies.

This paper proceeds as follows. The sustainable growth rate (SGR) model is described in Section 2. Section 3 analyzes the actual growth rate and sustainable growth rate of these companies respectively. Strategic analysis is conducted for each company and some findings are discussed in Section 4, followed by concluding remarks.

2. Sustainable Growth Rate (SGR) Model

Most companies often fall into an unlimited growth situation which is caused by the reasons why most people think that "the bigger, the better" but they have forgotten that it takes money to grow business continuously (Tarantino, 2004). There are a lot of research that investigate only actual growth rate but they have disregarded the growth in sustainability in any expansion plan, in which has caused them to grow too quickly(Seens, 2013). The sustainable growth rate (SGR) model (Higgins, 1977, 1998) aims at analyzing if a company's actual growth rate is able to achieve the maximum capacity without increasing any additional capital. By using SGR, managers and investors could understand if a company's future growth plans are realistic based on its current performance and policy. SGR will provide a company with better insights into the levels of corporate growth. Furthermore, industry structure, trends, and competitive positioning can be analyzed to find specific opportunities(Chang, 2012). To be concise, the model of SGR is essentially based on the old saying "It takes money to make money". Hence, a company needs to have sufficient financial resources in order to grow at its maximum capacity(Higgins, 1977). SGR model is divided into two categories: (1) accounting theory in which further divided into the Higgins model and the Van Hone model and (2) cash flow theory in which further divided into Rappaport model and Kore model. Ashta (2008) pointed out that there are 41% of corporate financial reports have discussed SGR. This has further enhanced the usefulness of the concept. Additionally, the Deloitte research, which is one of the major accountant firms, has used the SGR model to evaluate the potential growth of their major American enterprises. In the Deloitte research, they have also indicated that SGR is particularly valuable because its ability to combine company's operating situation (profit margin and asset efficiency) and financial elements (capital structure and retention rate) into one comprehensive measure (Sampath and Kambil, 2007).

The sustainable growth model is used to illustrate the relationship between the growth rate and the financial resources of a company. While the function is developed in an academic research environment, Higgins (1998) has suggested the following assumptions due to the unstable environment in reality:

(1) The company will grow rapidly with the permission of the market,
(2) The company is not allowed or permitted to sell new shares,
(3) The company has to maintain the predetermination capital structure and dividend policy.

The function of SGR model is as follows:

$$g^* = P \times R \times A \times T \,, \tag{1}$$

where g* is sustainable growth rate (SGR) expressed as a percentage; *P* is the profit margin after taxes; *A* is sales to assets ratio (i.e. asset turnover). These two ratios represent the growth of the company's operating performance. *R* is the retention ratio, and the percentage of total net profit after paying a dividend. *T* is the assets to equity ratio or leverage, which also reflects the debt and asset ratio of the company.

The actual growth rate (g) can be obtained from:

$$g = \frac{Current\ period's\ sale\ volume - \Pr evious\ period's\ sale\ volume}{\Pr evious\ period's\ sale\ volume}, \tag{2}$$

The comparison of g*(SGR) and g (AGR) will result into two situations. Firstly, when the company's g* is greater than its g, this indicates that sales are growing too slowly (Higgins, 1998) due to management have not utilized their resources efficiently to maximize the full potential growth. Alternatively, if g* is smaller than g, this indicates that sales are growing too rapidly and the company may not be able to sustain such growth.

After comparison between g* and g, we illustrate the yearly composition of a company with a four-quadrant diagram in which the vertical axis measures the growth rate (g, %) of the company and the horizontal axis measures the return on assets (ROA, %). The best positive situations will appear on the first quadrant and the worse will appear on the third quadrant. By the moving average of g*, a straight line can be depicted to indicate the best direction for a company in future development plans.

3. Analysis of Actual Growth Rate (AGR) and Sustainable Growth Rate (SGR)

3.1 Evergreen Marine Corp.

The result is shown as Figure 3. The SGRs of this company keep stable by years, in which varied within 1% to 5% due to this company's conservative policy. On the contrary, the AGRs have much higher fluctuation. From the net profit point of view, there is facing growth rapidly in 2005 and 2006 and the 2006's net profit decreased rapidly. This company has increased the number of fleet from 127 to 176 although their net profit recorded a sharp decrease in 2006. After increasing the number of fleet, the actual growth rate has decrease in 2007 whereas the net profit has increased and faced growth slowly problem in 2007. In 2008, it has lower net profit than 2007 since there has global financial crisis, and it was facing growth slowly problem during 2007 to 2009. Increasing the capacity to 629,610 TEU in 2009 although didn't increase the actual growth rate but the net profit increased. The net profit has increased rapidly in 2009 due to the cost reduction strategic success. From 2010 to 2012, this company has faced growth rapidly problem, except the European debt crisis in 2011. We found that this company has decreased theirs capacity from 629,610 TEU to 592,732 TEU during the global economic recovery period. The global economic recovery in 2010 made the actual growth rate has increased rapidly and has a higher net profit. In 2012, the capacity more than 2011, there are became 624,005 TEU and the actual growth rate more than SGR, and the net profit was lower than 2011.

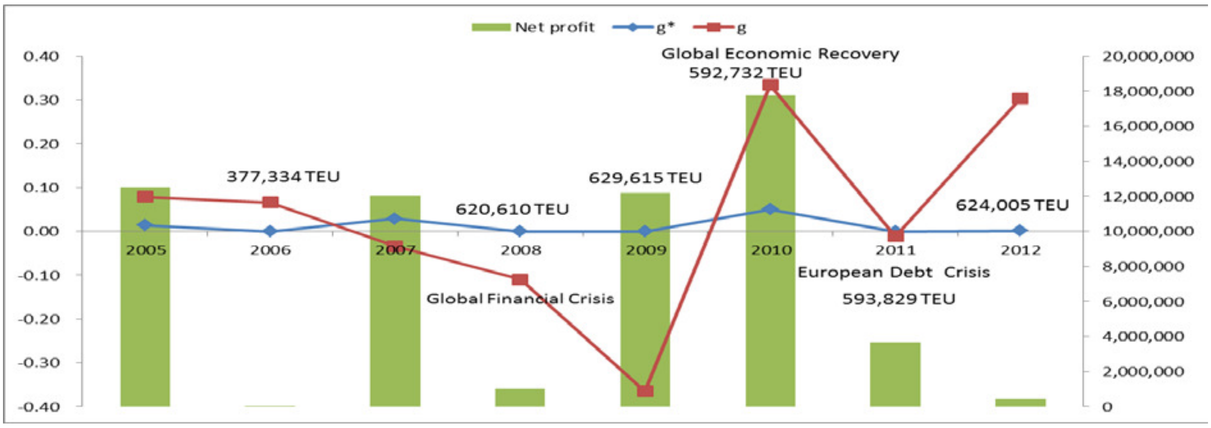

Figure 3: Net Profit, g* and g of Evergreen Marine Corp. from 2005 to 2012

Figure 4 illustrates the SGR result of Yang Ming Marine Transport Corp. The SGRs of Yang Ming have much more variance than Evergreen, which fluctuated from -4% to 23% during 2003 to 2012. According to the SGR model, closer SGR and actual growth rate represent that the company financial situation is sufficient to support the growth. In 2004, the SGR and actual growth rate of Yang Ming are closer so that the growth is coordinated with its financial resource condition. However, this company has faced rapid growth problems from 2003 to 2008. It has increased its fleet from 125,207 TEU to 240,433 TEU during 2002 to 2006. This company's net profit decreased rapidly in 2006, it is same as Evergreen. After the global financial crisis, this company has increased its capacity from 276,016 TEU to 343,476 TEU; there is dramatic growth from 2009 to 2011, except the global economic recovery year 2010. This quick growth resulted in net losses in 2009 and the European debt crisis in 2011. In 2012, this company faced rapid growth problems again and its total capacity increased to 343,476 TEU and finally this company has turned the net loss to net profit in 2012.

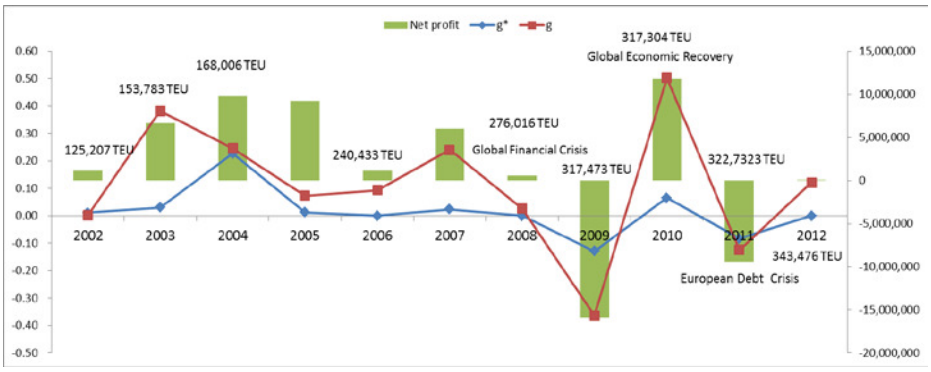

Figure 4: Net Profit, g* and g of Yang Ming Marine Transport Corp. from 2002 to 2012

Since only the number of fleet is presented in Wan Hai's annual report, we used total vessel number to illustrate their SGR result instead of total capacity TEU. Its SGR is more stable than Yang Ming's, which fluctuated form 12% to 4%. In these recent years, there was only one year 2009 in net loss situation. Wan Hai also had a good result in 2006; there was exactly 3% in SGR and actual growth rate as well. The SGR was a good inspiration for managers to plan long term development strategies. This company has faced rapid growth problems during 2007 to 2008. After the global financial crisis, this company has decreased the number of vessels from 75 to 56; however it still had net loss in 2009. The 61 vessels are deployed to gain very good profits in rapid growth year 2010 of the global economic recovery. From 2011 to 2012, this company still has been facing slow growth problems however it has increased total vessels to 73.

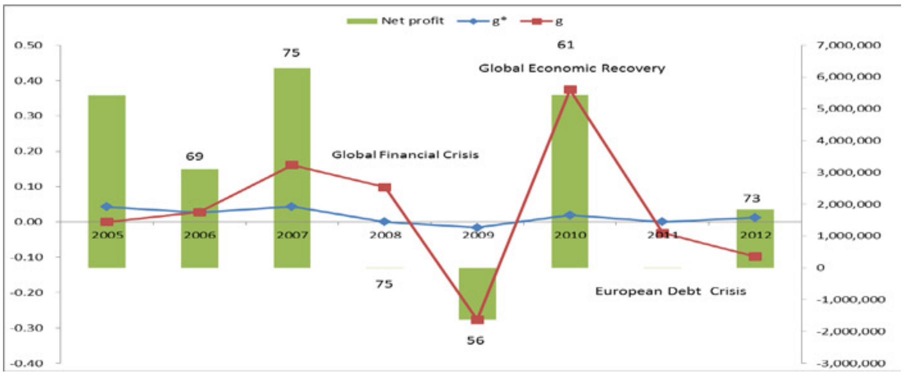

Figure 5: Net Profit, g* and g of Wan Hai Lines Ltd. from 2005 to 2012

4. Strategic Analysis of Taiwan Liner Shipping Companies

In this paper, we use four-quadrant financial curve to analyze the company's strategy. The combination of ROA and actual growth rate (g, %) located at the first quadrant means this company has positive growth in actual growth rate and ROA. However, the financial combination located at second quadrant means that this company has negative ROA and positive actual growth rate. With negative ROA and positive growth rate, the company should utilize cost reduction strategies to increase the net profit in turn to increase ROA. The worse combination of ROA and actual growth rate is located at the third quadrant with double negatives. To get rid of this worse situation, the company should re-evaluate its financial status in order to fully utilize its financial resources to improve its operation performance. When the combination locates at the fourth quadrant, the company may do very well in cost reduction strategy; but the sales growth rate hasn't increase a lot.

4.1 Evergreen Marine Corp.

The financial combination of this company should move along with the average sustainable growth rate in order to coordinate the growth rate with its financial resource condition. According to the Figure 6, the company's joint services with other companies to enlarge its service scope, therefore, the financial combination of 2005 located at first quadrant. Unfortunately, the financial combination moved to left-hand side since the oil price increased during the year 2006. In 2007, this company increased the freight rates and used hedging strategy to reduce costs and last the financial combination of 2007 moved to right-hand side. This represents that the ROA has increased due to the successful strategy of bunker cost down. The financial combination of 2008 and 2009 located at the fourth quadrant due to the negative growth rate in ROA. The oil price has increased dramatically such that the profit has decreased during 2008. This company has implied cost reduction strategy in 2009 hence the financial combination moved to the first quadrant during 2010. In 2011, the European crisis made the global shipping industry face risks of a capacity glut. Therefore, the financial combination of 2011 moved down to the fourth quadrant. This company increased the capacity to 624,005 TEU to expand the chance of raising the actual growth rate in 2012. This strategy didn't work since the net profit of 2012 was lower than 2011's. According to the Higgins theory, this company should utilize more cost reduction strategies instead of increasing capacity and ordering new building vessel strategies during 2012 so as to move the financial combination to right-hand side with closer location to the average of sustainable growth rate.

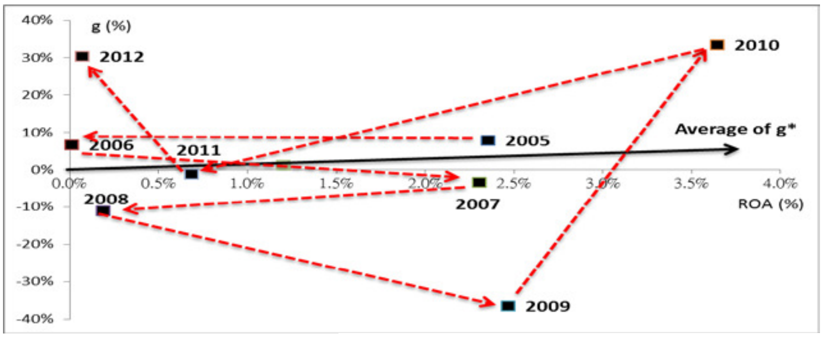

Figure 6: Evergreen Marine Corp.'s Growth and Honorarium from 2005 to 2012

4.2 Yang Ming Marine Transport Corp.

As shown in Figure 7, for Yang Ming, the financial combination of 2002 was closer to the average of sustainable growth rate with expanding the niche market strategy. Another good year for this company is 2005 due to the cost reduction strategy working well. New-building ship delivery in 2006 made the financial combination moved to left-hand side since the vessel depreciation costs increased. Unfortunately, this company faced the ASEAN Plus one tariff problems in 2009 and the ship economic speed strategy still did not get enough bunker savings to cover the loss. During the global recovery year 2010, this company took the opportunity to expand the intra-Asia market share, therefore the financial combination located at the higher place in first quadrant. In the European debt crisis year 2011, in addition, the general rate increase led actual sales growth rate to decrease rapidly. This company utilized strategic alliance in which enlarge its joint service scope with other alliance shipping companies to expand the market shares in turn and to increase the actual sales growth in 2012. Finally, the financial combination of 2012 returned to first quadrant. According to the Higgins theory, this company should apply cost reduction strategy so that the financial combination moves to right-hand side and coordinates with its financial resources to achieve sustainable growth.

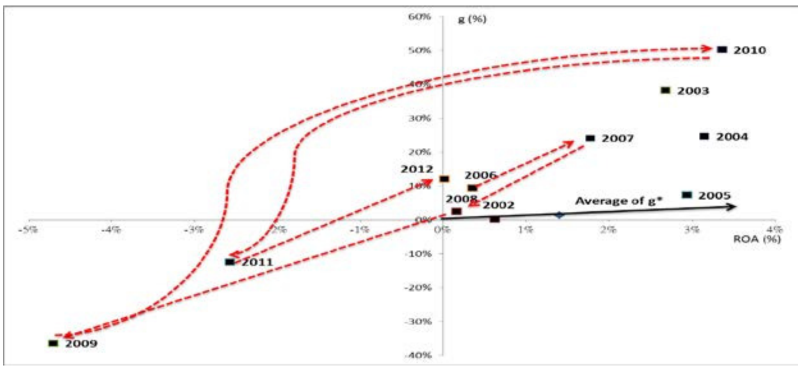

Figure 7: Yang Ming Marine Transport Corp.'s Growth and Honorarium from 2005 to 2012

4.3 Wan Hai Lines Ltd.

As shown in Figure 8, Wan Hai was the similar to the above two shipping companies which have good results in 2005. During the world economic crisis year 2008, Wan Hai ordered new vessels and increased the proportion of self-owned vessels, both of the strategies increased capital investment and vessel depreciation costs and it located the financial combination 2008 towards to left-hand side. After experiencing the recession, this company reduced the vessel number to 56 and phase out the fleet of losing-money routes in turn to increase net profits. Unluckily, this strategy didn't work well such that the financial combination located at the third quadrant to the worse situation. The world economic recovery year 2010 let this company's financial combination move to first quadrant with increasing freight rates, capacity and reducing bunker cost strategies. This company has also cooperated with other shipping companies to enlarge its service routes and to decrease the proportion of chartered vessels. These strategies helped Wan Hai decrease the loss during European debt crisis year 2011. During 2012, the strategy such as vessel sharing with other shipping companies reduced the company's slot costs and let the financial combination move to the right-hand side. However, general rate increase in 2012 decreased the actual sales growth. This company should increase cooperation chance with other shipping companies or provide other main-line carriers with contract intra-regional feeder services to increase the market shares in Asia short sea routes and then the financial combination would move up and go nearer to the average growth rate to achieve sustainable growth.

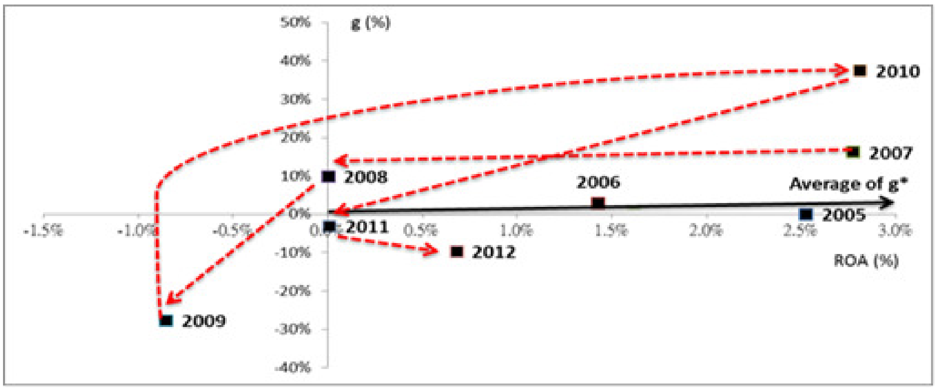

Figure 8: Wan Hai Lines Ltd.'s Growth and Honorarium from 2005 to 2012

5. Conclusions and Recommendations

Generally, a company which grows too rapidly is not necessary and not a good example; too much growth can probably exhaust all a company's resources, which then causes a company to face bankruptcy. In 2013, there were a lot of liner companies having great losses but their sales revenue was much higher than the year before. This is the problem coming from too much growth such as increase capital investment and seducing sales for lower rates. In order to manage liner companies' growth more effectively, this research uses Higgins (1977, 1998) sustainable growth rate model to derive the Taiwan three liner companies' SGR and AGR by years so as to examine whether mutual coordination with their financial resource condition, and to propose the suitable development strategies to achieve sustainable growth for each company. The results show that the SGR model is effective and applicable. The proposed approach contributes to the liner shipping industry in both academic and business operations, even strategy formulation as well. We conclude several remarks as follows:

(1) For the Evergreen Marine Corp., the results show that Evergreen had stable SGR by years and increased capacity when it faced slow growth problems and decreased capacity while facing rapid growth problems from 2008 to 2012. According to the four-quadrant analysis, this company's strategy by increasing capacity to expand the market share in 2012 did not work well due to too much growth. According to the Higgins theory, this company should utilize more cost reduction strategies instead of increasing capacity and ordering new building vessel strategies during 2012 so as to move the financial combination to right-hand side with closer location to the average of sustainable growth rate.

(2) For the Yang Ming Marine Transport Corp., the results show that SGRs of Yang Ming are much more

fluctuated than Evergreen and it has faced rapid growth problems from 2003 to 2008. This company had increased its capacity since 2002 except 2010; however it had net loss in 2009 and 2011. After the crisis of 2009 and 2011, it utilized several strategies such as expanding the intra-Asia market share and joint services with other alliance companies to reduce slot costs and to increase its profits. After examining the result of 2012, according to the Higgins theory, Yang Ming should apply cost reduction strategy so that the financial combination moves to right-hand side and coordinates with its financial resources to achieve sustainable growth.

(3) For Wan Hai Lines Ltd., the results show that its SGR is more stable than Yang Ming and Evergreen. Wan Hai also had a good result in 2006; there was exactly 3% in SGR and actual growth rate as well. The SGR was a good inspiration for managers to plan long term development strategies. During the world economic crisis year 2008, Wan Hai faced rapid growth problems however it still ordered new vessels and increased the proportion of self-owned vessels. After examining the result of 2012, Wan Hai should increase cooperation chance with other shipping companies or provide other main-line carriers with contract intra-regional feeder services to increase the market shares in Asia short sea routes and then the financial combination would move up and go nearer to the average growth rate to achieve sustainable growth.

(4) For the liner shipping industry, companies should increase their capacity or market shares when they face slow growth problems and utilize cost reduction strategy while facing rapid growth problems. In addition, this research also suggested that the companies have to refer to the recent years' SGR before planning the long-term development strategies in order to coordinate the capacity and sales growth with the companies' financial resources.

(5) For the liner shipping industry, the strategy such as ordering extra-large size container ships to reduce their operating costs by achieving economies of scale, may lead to too much growth and dramatic overcapacity, low freight rates and low profits, even losses. Obviously, most carriers have been struggling out of deficits throughout these years. Furthermore, large container ship deployment strategy may not work successfully for each company and careless, excessive capital investment may lead the poor companies to bankruptcy way.

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Evaluating the Supply Chain Resilience Capability in Container Shipping Services — A Partnership Perspective

Meng-Tsung Lee[1], Ching-Chiao Yang[2] and Wei-Lin Hsu[3]*

[1]Department of Marine Leisure Management, National Kaohsiung Marine University No.142, Haijhuan Rd., Nanzih District, Kaohsiung City 81143, Taiwan (R.O.C.)
[2]Department of Shipping and Transportation Management, National Kaohsiung Marine University No.142, Haijhuan Rd., Nanzih District, Kaohsiung City 81143, Taiwan (R.O.C.)
[3]Department of Shipping and Transportation Management, National Kaohsiung Marine University No.142, Haijhuan Rd., Nanzih District, Kaohsiung City 81143, Taiwan (R.O.C.)

Abstract

Increasing the risk of interruptions or shutdowns of supply chains, the development of multiple security initiatives to enhance supply chain security and resilience without affecting efficiency has become an important issue for multinational firms. This study thus aims to examine the supply chain resilience in container shipping services from a partnership perspective. Data collected from a questionnaire survey and a two-step structural equation modeling (SEM) was subsequently performed to test the research hypotheses. Results indicate that relationship orientation is positively related to supply chain security management and supply chain resilience capability, whereas supply chain security management is positively associated with supply chain resilience capability and operational performance. Moreover, result reveals supply chain resilience capability is positively associated with operational performance. However, the impact of relationship orientation on operational performance was not found in this study.

Keywords: Relationship orientation, Supply chain security management, Supply chain resilience capability, Operational performance, Container shipping service

1. Introduction

The globalization has forced enterprises to move their factories overseas and outsource their logistics activities in order to reduce operating costs and risk. As industry chains grow in length, long supply chains often cause companies to face greater environmental uncertainty and complexity. It is therefore imperative for firms to adopt more effective and active measures to deal with the different situations encountered by their supply chains (Thun and Hoening, 2009). Given an open system, the globalization has caused supply chain risk to increase. For instance, the 911 terror attacks in 2001 caused immeasurable damage to international trade; a 2010 volcanic eruption in Iceland caused tremendous disruption to air transport; Japan's 2011 tsunami and Fukushima nuclear disaster interrupted the supply of key parts to numerous automakers worldwide (WEF, 2013). Apart from risk of natural disasters and extreme climate conditions, supply chains also face a steady stream of problems such as management system fragility, political and economic turbulence, and steadily rising trade and insurance costs (Forbes, 2013). According to the report published by McKinsey (2011), more than two-thirds of respondents expressed that supply chain risk has increased steadily throughout the past three years, and expect that it will continue to increase during the coming five years; the senior managers also point out that supply chain risk is the largest threat faced by companies (FM Global, 2007).

The issue of supply chain security management has gradually increased in the wake of the 2001 911 terror attacks in the United States, which prompted the World Customs Organization (WCO) to draft its Framework of Standards to Secure and Facilitate global trade in June 2005, and promote its authorized economic operator (AEO) program worldwide. This program aims to facilitate the sharing of information among customs authorities in different countries and the increasingly close partnerships between customs and companies in a supply chain. The adopting of supply chain security management has facilitated prevention of theft, damage, smuggling, malicious actions, terrorist activities, and reduce the probability of injurious supply chain events (Closs and McGarrell, 2004).

If companies cannot quickly respond to and effectively deal with ongoing supply chain incidents, they will face even greater and difficult-to-estimate losses, and may even be at risk of bankruptcy. A survey performed by the Zurich Insurance Company in 2012 discovered that a single supply chain crisis will have an average cost of €230,000, and this total does not include management and time costs, loss of customers, and damage to image. As a consequence, apart from needing to possess effective supply chain security capabilities, companies facing today's dynamic marketplace must also have resilience capability. Fiksel (2006) defined resilience capability as the ability of a company to survive, adapt, and grow when encountering changes in the business environment. This suggests that one of the major challenges currently faced by corporate managers is how to reduce the incidence of supply chain risks and ease the impact of possible supply chain crises, and thereby ensure that their companies can quickly adjust and adapt to supply chain incidents, and even achieve overall corporate growth and improved competitiveness.

Companies must often depend on more than 1,000 vendors located in different countries, and rely on business partners from the raw materials end to the shipment and service at the final customer (WEF, 2013). Approximately 90% of international goods were carried by maritime transport and thus container carriers play a key role in the global movement of goods and services. Unfortunately, the frequency of global transport network interruptions has increased since 2012, and 26% of companies worldwide have reported losses from delayed international shipments of goods (WEF, 2013). In particular, maritime transport had been regarded as the most fragile point in supply chain security after 911 terrorist attacks (Lee and Whang, 2005). Therefore, container carriers must strengthen their supply chain security management capability, prevent and ease the impact of transportation system interruptions and other unforeseen incidents, and thereby enhance their capability to respond to and recover from unpredictable incidents.

In the era of supply chain management, enterprises must seek to cooperate with other supply chain members through the establishment of trust, communication, and information sharing. A relationship orientation can thus boost overall operating efficiency, achieve consistent mutual decisions, and cement cooperative relationships with other supply chain members. Panayides (2007) has suggested that the highly cooperative corporate cultures of supply chain members make them willing to share information, which can improve overall supply chain operating efficiency and the resulting benefit. Deloitte (2013) similarly points out that the cooperative relationships among supply chain members will thrive when the companies can base their relations on mutually benefit and trust, which will enable them to better avoid and prevent supply chain incidents and achieve common business goals. In summary, companies must rely on a relationship orientation to forge close, active cooperative relationships with supply chain members, which will allow them to enhance their supply chain interruption and recovery capabilities.

Most previous studies on relationship orientation and supply chain security management mainly focused on manufacturing industries (Johnson and Sohi, 2001; Williams et al., 2008; Hintsa et al., 2009; Cheng et al., 2014). Moreover, supply chain resilience capability was mainly in the fields of ecology, psychology, and manufacturing (Holling, 1973; Carpenter et al., 2001; Li et al., 2009; Jüttner and Maklan, 2011; Gligor, 2013). Considering supply chain security management and supply chain resilience have been regarded as crucial to sustain competitive advantage, this study aims to examine the relationships among relationship orientation, supply chain security management, supply chain resilience, and security performance in container shipping services from a partnership perspective.

There are five sections in this study. Section 1 introduces the motivation and purpose of the research. Section 2 reviews the literature on relationship orientation, supply chain security management, and supply chain resilience capability. A conceptual framework and research hypotheses are also provided in this section. Section 3 describes the research methodology, including questionnaire design, sampling technique, and research methods. Section 4 presents the results of analysis. The conclusions and implications are discussed in the final section.

2. Literature Review and Hypotheses Development

2.1 Relationship Orientation

Companies have treated relationship orientation as a driver to maintain positive relationships with their supply chain members. When supply chain partners can provide valuable resources and information to each other, this can achieve the effective integration of supply chain partners, and enable supply chain members to develop closely cooperative relationships (Morgan and Hunt, 1994). Thus, a relationship orientation can be defined as the corporate strategy or operational core of the relationship between two trading parties, and also as a business philosophy embedded in an organizational culture or organizational values (Sin et al., 2002; Panayides, 2007). Robert et al. (2008) also defined a relationship orientation as the expectation that a company can establish closer relationships with existing or potential partners for the purpose of cooperative operation.

Deshpande et al. (1993) pointed out that relationship orientation was a company's core values and beliefs and could enhance employees' understanding of cooperative actions, and would increase a company's competitive advantage. In the era of supply chain management, a relationship orientation is the wish of companies to establish even closer relationships with their supply chain partners through mutual cooperation, interchange, and meeting commitments based on the need to obtain profit (Grönroos, 1990). It is apparent that a relationship orientation is an attitude or psychology that can influence companies' ways of thinking (Kumar et al., 2003; Pillai and Sharma, 2003).

A large number of previous studies has concluded that relationship orientation can help a firm achieve long term relationship with their partners and further to enhance its performance and competitive advantage (Larson, 1992; Deshpande et al., 1993; Cheng et al., 2014). When firms have an organizational culture to develop closely cooperative relationships, they are willing to share information and cooperate with each other on management activities (Palmatier et al., 2008). In other words, an organizational culture with relationship orientation is positive to the development of supply chain security management across the shipping container supply chain. Hoyt and Huq (2000) also noted that a closer relationship between supply chain partners could help firms more agile, flexible and speedy to respond to the unforeseen events in a supply chain. Grounding on the base of trust, commitment, and mutual benefit, supply chain members are willing to sharing information and collaborating with each other. Thus, this study hypothesizes that:

H_1: Relationship orientation is positively related to supply chain security management in container shipping supply chain

H_2: Relationship orientation is positively related to supply chain resilience capability in container shipping supply chain

H_3: Relationship orientation is positively related to cargo operation performance in container shipping supply chain

2.2 Supply Chain Security Management

Globalization has caused supply chains to growth in length and complexity, and has also increased the mutual dependence among companies, and these trends have increased the fragility of supply chains in the face of unforeseeable incidents (Wagner and Bode, 2006). Supply chain disruption may occur when natural disasters, strikes, vendor bankruptcy, terrorist attacks, war, or political turbulence caused the interruption in the shipment of raw materials or goods (Wilson, 2007). Since the supply chain disruptions can have a negative impact on companies' supply chain performance, supply chain security management is therefore been regarded as one of important issues (Hendricks and Singhal, 2005; Thai, 2009). Closs and McGarrell (2004) defined supply chain security management as supply chain policies, procedures, and technological applications adopted to protect supply chain assets (products, facilities, equipment, information, and personnel) from theft or damage, and prevent terrorist attacks, unauthorized smuggling of goods or persons, and the large-scale entry of destructive weapons. Banomyong (2005) defined supply chain security management as involving the flow of physical goods and information from the raw materials stage to the final users. Therefore, security risks may occur at different supply chain nodes, including cargo, factories, supply chain partners, supply chain facilities, transport, personnel, and information. Through supply chain security management, firms can successful control and manage product, transportation, information, and personnel safety.

Ocean carriers played an important intermediary role in supply chains, bear responsibility for loading, unloading, and caring cargo shipped by sea, and link cargo consignors and recipients. In research on threats to Israel's maritime transport, Lorenz (2007) suggested that ships, ports, and containers are often fragile links in maritime transportation systems, and are prone to terrorist attacks and other disturbances. Furthermore, because cargo containers are often used to smuggle goods, people, and weapons, containers are also often seen as key links in supply chain security management. Barnes and Oloruntoba (2005) pointed out that the complexity of maritime transport often creates supply chain gaps, and international supply chain security measures are therefore needed to ensure the security of the maritime trade system, and can also serve as key indicators of the development of international trade.

Supply chain security management has been viewed as an important part of risk management. The implementation of supply chain security management can help multinational firms reduce the probability of injurious supply chain events and which in turn increase their supply chain resilience capability (Closs and McGarrell, 2004; Sheffi and Rice, 2005). Thus, an effective supply chain security management procedure can increase firms' agility, flexibility, and speed to respond to unforeseen events in a supply chain (Jüttner and Maklan, 2011; Matook et al., 2009). Moreover, Peleg-Gillai et al. (2006) noted that third party logistics service providers can increase operational efficiency and safety by implementing security management. Accordingly, this study hypothesizes that:

H_4: Supply chain security management is positively related to supply chain resilience capability in container shipping supply chain

H_5: Supply chain security management is positively related to cargo operational performance in container shipping supply chain

2.3 Supply Chain Resilience Capability

The concept of supply chain resilience capability was first proposed by the Canadian ecologist Holling (1973), who asserted that ecosystems possess both recovery capability and adaptive capability. Resilience capability determines whether a system is able to withstand environmental changes, while adaptation represents the ability to restore a balance when a system encounters disturbances. The faster a system's recovery speed, the greater the system's stability. When the concept of resilience capability is used in social and economic contexts, it is typically employed to describe the behavioral responses of groups, national economies, and systems (Ponomarov and Holcomb, 2009). Thus, in a supply chain context, when a supply chain system receives an internal or external impact, resilience capability allows the system to reorganize itself and continue to provide core functions (WEF, 2013).

Ponomarov and Holcomb (2009) summarized perspectives in the fields of ecology, socioeconomics, psychology, and risk management, and proposed that a supply chain's resilience capability represents the supply chain's adaptive capability, which allows it to respond to unforeseeable incidents, such as power or transport interruptions caused by attacks on vendor networks or poor climatic conditions (Blackhurst et al., 2011). Christopher and Peck (2004) and Peck (2005) define supply chain resilience capability as a firm's capability to restore its original or a changed state of operations, and even attain improved operation, after it suffers and unforeseeable risk incident. Blackhurst et al. (2011) argued that supply chain resilience capability constitutes a company's ability to recover from a risk incident.

Several studies have proven the importance of resilience capability. Pettit et al. (2013) noted that manufacturing firms can enhance their competitiveness and financial performance by establishing supply chain resilience capability management systems, which implies that an effective supply chain resilience capability can potentially improve a company's overall operating performance, and allow it to quickly respond to changes in the environment and actively adjust its response strategies to prevent major disruption to its supply chain. Wieland and Wallenburg (2012) found that a firm can reduce the unforeseen events in a supply chain through its speed, flexibility, and agility. That is a frim can decrease the cargo loss and damage and frequency of accidents by its resilience capability in terms of agility, flexibility, and speed. Accordingly, this study hypothesizes that:

H_6: Supply chain resilience capability is positively related to cargo operational performance in container shipping supply chain

To summarize, a conceptual model portraying the relationships among relationship orientation, supply chain security management, supply chain resilience capability for container shipping services is proposed in Figure 1.

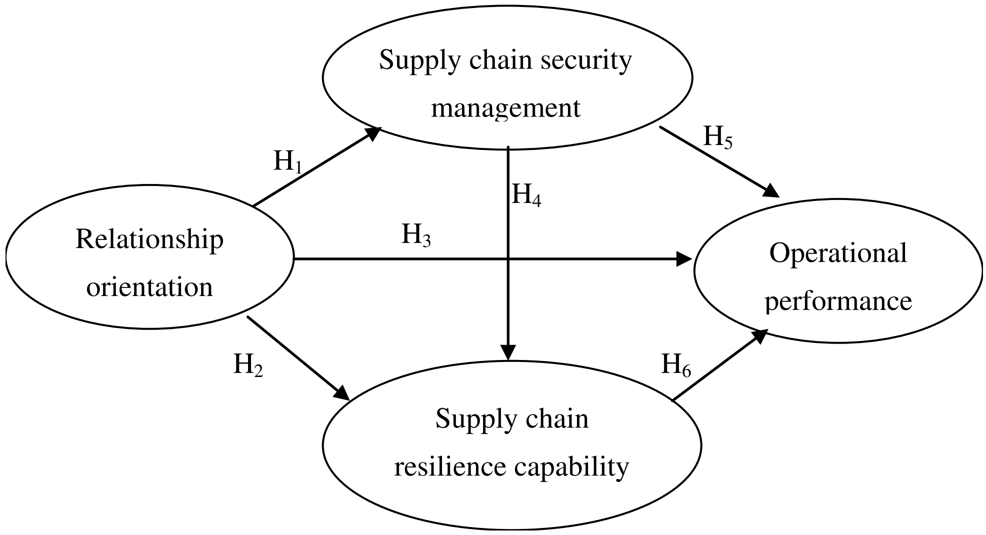

Figure 1: Research framework

3. Methodologies

3.1 Questionnaire Design and Measures

A self-administered questionnaire was designed to collect empirical data in this study. The step-by-step stages of questionnaire design based on Churchill and Iacobucci's (2010) study were employed for improving the reliability and validity of the survey data. All variables and measures of the questionnaire were adapted from literature review (Johnson and Sohi, 2001; Hintsa et al., 2009; Li et al., 2009; Gligor, 2013; Yang and Wei, 2013; Cheng et al., 2014) and are illustrated in Appendix A. To ensure the content validity of the construct, a practical interview with five shipping experts and executives were made for their opinions on the questionnaire. The final version of the questionnaire comprises five parts. Part 1 was the profile information of respondents and their companies. Parts 2 to 5 were for surveying respondents' perceptions on their company's performance in terms of relationship orientation, supply chain security management, supply chain resilience capability, and cargo operational performance. All the question items in our survey were measured using a 5 point Likert scale, ranging from "1= strongly disagree" to "5=strongly agree"

3.2 Sample Techniques

The major members of container shipping supply chain typically include liner shipping companies, shipping agencies, freight forwarders, and terminal operators. Thus, the sample for this study was based on the *Directory of the National Association of Chinese Ship Owners and Shipping Agencies*, the *Members of the International Ocean Freight Forwarders and Logistics Association* in Taiwan published in 2014. The questionnaire with a cover letter and postage-paid return envelope was sent to 700 container shipping executives in March, 2015. The initial mailing elicited 250 usable responses. A follow-up mailing was sent one month after the initial mailing. An additional 77 usable responses were returned. Since 42 returned questionnaires were disqualified due to incomplete responses, the total number of usable responses was 285, yielding an overall response rate of 40.7 percent.

Though the response rate is high, the potential problem of non-response bias maybe existed. A comparison of early and lately responses across 13 measures by performing a t-test was carried out (Armstrong and Overton, 1977). Results indicated that there were no statistical differences across the 113 measures at the 5% significance level, implying non-response bias was not a problem, since late group's responses were similar to those of the earlier one.

Since the data were collected from single informants, common method variance (CMV) bias could be a threat to the validity of research results (Podsakoff et al., 2003). Firstly, respondents were assured of anonymity and the confidentiality of their response to encourage them to answer as honestly as possible. Second, Moreover, over 50% of respondents were directors or above, and 73.3% of respondents had at least six-year tenure; therefore, they were knowledgeable and knowledgeable about the operations of their companies. Finally, a Harman's one-factor test was used to ensure that no single factor accounted for the majority of covariance between the predictor and criterion variables. Results indicated six factors with an eigenvalue greater than one, which identified and explained 66.94% of the total variances. Apparently, the first factor only accounted for 16.28% of the total variances, indicating no one general factor accounted for the majority of the variances of the items. The common method variance problem therefore can be mitigated in this study (Podsakoff and Organ, 1986).

3.3 Research Methods

This study performs a two-step structural equation modeling (SEM) approach to evaluate the effects of supply chain security management on supply chain resilience and logistics operational performance in container shipping services. Firstly, a confirmatory factor analysis was conducted to assess the validity of the measurement model. Once the measurement is purified, the structural equation model was subsequently performed to test the research hypotheses. All analyses were carried out using the *SPSS 18.0 for Windows* and *AMOS 18.0* statistical packages.

4. Results of Empirical Analysis

4.1 Characteristics of Respondents and Their Companies

The profile of respondents and their companies showed that 53.0% of respondents were in the position of director or above. Basically, managers are actively involved in and anchor operations in their businesses, and since 73.3% of respondents had worked in the container shipping industry for more than six years, suggesting that they had abundant practical experiences to answer the questions appropriately. With respect to the types of responding firms, 42.8% were from liner shipping firms, 21.8% from liner shipping agencies, 25.6% from ocean freight forwarders, and 9.8% from terminal operators. Moreover, 78.9% of respondents were local firms, and nearly 70% (69.5%) of responding firms had been in operation for more than 16 years. Around 25% of the responding firms had fewer than 50 employees, while 34.4% had more than 501 employees. Results also showed that 31.8% of the respondents reported that their firms' annual revenue was below NT$100 million, while 29.2% reported revenue of more than NT$10 billion. Finally, 69.1% of responding firms had licenses pertaining to supply chain security management.

4.2 Measurement Validation and Reliability

The descriptive statistics of 13 constructs were displayed in the Table 1. Relational predisposition (mean=4.371) was perceived as the most agreeable dimension of relationship orientation construct, and cargo management (mean=4.378) was perceived as the most agreeable dimension of supply chain security management construct, whereas speed was perceived by the respondents as the most agreeable dimension of supply chain resilience capability.

The Cronbach's alpha statistics was used to assess the internal consistency and reliability of the constructs. A suggested threshold of alpha value was 0.75 (Churchill and Iacobucci, 2010; Hair et al., 2010). Results, shown in the Appendix A, indicated that all alpha values were well met the criteria, and considered adequate for confirming a satisfactory level of reliability in research. Noting that the aforementioned techniques do not allow either for the assessment of convergent validity and discriminant validity, a confirmatory factor analysis suggested by Anderson and Gerbing (1988) was therefore conducted in this study to ensure the validity of measures. The CFA results were summarized in the Appendix A and showed that the comparative fit index (CFI), the incremental fit index (IFI), and the Tucker-Lewis index (TLI) values were well above the recommended cut-off value of 0.90, and the root mean square residual (RMR) values bellowed the recommended threshold of 0.05, confirming all the constructs exhibit a good fit of the data (Hu and Bentler, 1999).

The convergent validity of the construct was assessed by the critical ratio (CR) values that are statistically significant for the factor loadings and average variance extracted (AVE) (Anderson and Gerbing, 1988; Hair et al., 2010). Results, shown in Appendix A, indicated that all indicators in their respective constructs had statistically significant factoring loadings from 0.5 to 0.9, effectively suggesting that all the indicators measure the same construct and providing satisfactory evidence of their convergent validity. In addition, a complementary measure used alongside convergent validity is the average variance extracted (AVE) showing directly the amount of variance captured by the construct in relation to the amount of variance due to the measurement error. Results also revealed the AVE of each construct exceeds the recommended cut-off value of 0.5, providing evidence of convergent validity of the constructs (Fornell and Larcker, 1981).

The discriminant validity was assessed by comparing the average variance extracted (AVE) with the squared correlation between constructs. Discriminant validity exists if the items share more common variance with their respective construct than any variance that the construct shares with other constructs (Fornell and Larcker, 1981; Koufteros, 1999). Table 1 showed that the square root of AVE of all the constructs is greater than the correlation between any pair of them. Accordingly, the results demonstrate evidence of discriminant validity for the study constructs.

4.3 Structural Equation Modeling: Hypotheses Testing

After confirming the fitness of the proposed model, this study established a structural equation model to test research hypotheses. Results indicated that the structural equation model of relationship orientation, supply chain security management, supply chain resilience capability, and cargo operational performance provide a reasonable fit of the data with fit indices χ^2=217.765 (84); GFI=0.899; CFI=0.961, NFI-0.938; IFI=0.961; TLI=0.951; RMR=0.018; RMSEA=0.075. The testing results of hypotheses can be summarized in Table 2 and revealed that relationship orientation is positively associated with supply chain security management (ß = 0.680, C.R. =11.068) and supply chain resilience capability (ß = 0.235, C.R. =2.538) in container shipping services. Results also show supply chain security management is positively associated with supply chain resilience capability (ß = 0.763, C.R. =7.875) and cargo operational performance (ß = 0.315, C.R. =2.522), and supply chain resilience capability is positively associated with cargo operational performance (ß = 0.650, C.R. =7.480). However, the impact of relationship orientation on cargo operational performance (ß = 0.090, C.R. =0.841) was not found in this study.

Table 2: Results of structural equation modeling

Relationships	Estimate	S. E.	C.R.	P	Sign	Supported
RO ->SCSM	0.680	0.061	11.068	0.000	+	Supported
RO -> SCR	0.235	0.092	2.538	0.011	+	Supported
RO -> OP	0.090	0.107	0.841	0.400	+	Not Supported
SCSM-> SCR	0.803	0.096	8.366	0.000	+	Supported
SCSM-> OP	0.315	0.125	2.522	0.012	+	Supported
SCR-> OP	0.650	0.087	7.480	0.000	+	Supported

Fit indices: χ^2=217.765, d.f=84, P=0.000, RMR=0.018, GFI=0.899, AGFI=0.856, NFI=0.938, RFI=0.923, IFI=0.961, TLI=0.951, CFI=0.961, MRSEA=0.075.

Table 1: Mean, standard deviations, and correlations of the constructs

	Mean	S.D.	Alpha	RB	RP	RC	CM	FM	IM	HRM	PRM	AP	AG	FL	SP	OP
RB	4.309	0.531	**0.791**	**0.778**												
RP	4.371	0.526	**0.827**	0.730**	**0.813**											
RC	4.060	0.596	**0.821**	0.517**	0.596**	**0.764**										
CM	4.378	0.523	**0.837**	0.451**	0.497**	0.404**	**0.778**									
FM	4.365	0.549	**0.894**	0.420**	0.486**	0.383**	0.776**	**0.813**								
IM	4.218	0.573	**0.850**	0.375**	0.447**	0.356**	0.608**	0.666**	**0.725**							
HRM	4.352	0.540	**0.835**	0.434**	0.525**	0.445**	0.691**	0.702**	0.631**	**0.792**						
PRM	4.240	0.568	**0.873**	0.422**	0.496**	0.517**	0.617**	0.599**	0.576**	0.693**	**0.809**					
AP	4.304	0.543	**0.887**	0.466**	0.534**	0.485**	0.653**	0.640**	0.621**	0.727**	0.764**	**0.798**				
AG	4.052	0.669	**0.932**	0.455**	0.457**	0.421**	0.537**	0.468**	0.559**	0.569**	0.572**	0.588**	**0.907**			
FL	3.953	0.720	**0.873**	0.420**	0.417**	0.466**	0.456**	0.413**	0.532**	0.536**	0.596**	0.577**	0.823**	**0.856**		
SP	4.055	0.662	**0.901**	0.463**	0.471**	0.511**	0.486**	0.452**	0.506**	0.553**	0.614**	0.603**	0.774**	0.828**	**0.850**	
OP	3.936	0.675	**0.893**	0.408**	0.432**	0.453**	0.500**	0.504**	0.484**	0.539**	0.554**	0.536**	0.639**	0.645**	0.648**	**0.869**

5. Conclusions and Discussions

This study empirically from a partner relationship view examines the relationships among relationship orientation, supply chain security management, supply chain resilience capability, and operational performance for container shipping firms. The main findings are summarized below.

Deriving from the results of structural equation modeling, a positively relationship was found between relationship orientation and supply chain security management for container shipping services (H_1), implying that container shipping firms can improve their security management capability by establishing closer relationships with their supply chain partners. Results also reveal that relationship orientation is positively associated with container shipping firms' supply chain resilience capability (H_2). It is apparently that a firm with a closer relationship with their supply chain partners can significantly improve their security management and which in turn enhance supply chain resilience capability. The findings are consistent with findings reported in previous studies (Whitfield and Landeros, 2006; Park, 2013; Cheng et al., 2014).

In addition, supply chain security management is positively associated with a container shipping firm's supply chain resilience capability (H_3). This suggests that a container shipping firm can enhance its resilience capability, namely agility, flexibility, and speed through the implementation of security management activities. In other words, this study suggests a container shipping firm should compliance with security initiatives such as CSI, AEO, and C-TPAT for increasing its supply chain resilience capability. The finding is consistent with previous studies (Matook et al., 2009). Supply chain security management was also found to have a positively impact on cargo operational performance (H_4), suggesting a container shipping firm can improve its operational performance by performing security management activities such as cargo, facility, information, and human resource management. The finding is consistent with previous studies (Peleg-Gillai et al., 2006; Yang and Wei, 2013).

However, the direct impact of relationship orientation on cargo operational performance was not found in this study. This is because relationship orientation is an attitude or psychology that can influence companies' ways of thinking. Thus, the relationship orientation can't impact directly a container shipping firm's cargo operational performance but directly through the establishment of supply chain security management and supply chain resilience capability. Thus, a long-term and closer relationship with supply chain partners can help a firm share instant and accurate information with partners for making decision across the supply chain. Through the establishment of partner relationship, a firm can enhance its supply chain security management capability and which in turn improve its resilience capability and operational performance.

This study has a number of practical implications for container shipping firms. First, this study provides empirical evidence that a higher level of relationship can help supply chain partners trust each other and further to facilitate the implementation of supply chain security management across the container shipping supply chain. Thus, it is imperative for container shipping firms to establish a closer relationship with their partners for improving resilience capability and which in turn improve operational performance. Typically, a container shipping firm can build a closer relationship with their supply chain partners through relational benefit, relational predispositions, and relational connectedness.

Second, relationship orientation was also found to be the crucial factor driving the development of supply chain resilience capability. Thus, a firm was suggested to build closer relationship with its partners for sharing information and collaborative making decision. In this way, a firm can enhance its resilience capability in terms of agility, flexibility, and speed for dealing with the unforeseen events in a supply chain.

Finally, supply chain security management was demonstrated to have positively impacts on supply chain resilience capability and operational performance. Thus, this study suggests a container shipping firm should compliance with security initiatives such as AEO and C-TPAT to increase its supply chain security management capability based on the closer relationship with it partners. Through the implementation of supply chain security management, a firm can respond to unforeseen events more agile, flexible, and speedy, and which in turn decrease the loss and damage of goods.

From a theoretical perspective, this study contributes to the literature by the theoretical development of the relationship orientation theory to examine the relationship among relationship orientation, supply chain security management, supply chain resilience capability, and operational performance. Findings also contribute to demonstrate that relationship orientation and supply chain security management are two of the antecedents to the successful enhance supply chain resilience capability.

However, it suffers from several limitations. First, though the direct impact of relationship orientation on operational performance was not found in this study, security management and resilience capability may mediate the relationship between relationship orientation and operational performance. Therefore, future research could examine the mediating effect of supply chain security management and resilience capability, respectively. Another worthwhile direction for future research might be examined the moderating effect of relationship orientation on the relationship between supply chain security management and operational performance, and the relationship between resilience capability and operational performance. Finally, the data was collected at one point in time and therefore the hypothesized relationships were examined in a static fashion. Longitudinal research could be employed to indicate how perceptions of supply chain security management capability and resilience capability change over time.

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Appendix A

Results of confirmatory factor analysis

Constructs and reflective indicators	Loadings
Relationship orientation (RO) (Sources: Johnson and Sohi, 2001; Cheng et al., 2014)	
Relational benefit (RB) ($\chi 2$=N/A, df=N/A; CFI=N/A; RMR=N/A; IFI=N/A; TLI=N/A; Cronbach's α=0.791; CR= 0.814; AVE= 0.604)	
RB1: A closer relationship with our partners offers a major advent in doing businesss.	0.777
RB2: On average, the expected market shares of our firm am dour partners are good.	0.951
RB3: On average, the expected satisfaction of our firm and our partners is good.	0.552
Relational predispositions (RP) ($\chi 2$=N/A, df=N/A; CFI=N/A; RMR=N/A; IFI=N/A; TLI=N/A; Cronbach's α=0.827; CR= 0.833; AVE= 0.627)	
RP1: Our firm is committed to maintaining a closely relationship with our partners.	0.869
RP2: Our firm and partners seek to maintain a long-term and sustainable relationship.	0.844
RP3: Working closely with our partners allows us to be more effective.	0.644
Relational connectedness (RC) ($\chi 2$=16.061, df=2; CFI=0.972; RMR=0.019; IFI=0.972; TLI=0.916; Cronbach's α=0.821; CR=0.845; AVE=0.584)	
RC1: There are alternative channels for sharing information and communicating with partners.	0.739
RC2: When the need arises, our firm can share and exchange security information with partners without formal channels.	0.551
RC3: It is easy for our firm to understand the needs of security management from partners	0.849
RC4: Our firm shares accurate and timely security information with partners.	0.874
Supply chain security management (SCSM) (Sources: Hintsa et al., 2009; Yang and Wei, 2013)	
Cargo management (CM) ($\chi 2$=16.568, df=2; CFI=0.972; RMR=0.012; IFI=0.972; TLI=0.916; Cronbach's α=0.859; CR=0.859; AVE=0.606)	
CM1: Our firm records and controls the stock.	0.791
CM2: Our firm stores goods in a safety area and protects against unauthorized acess.	0.867
CM3: Our firm stores goods in different types separately.	0.737
CM5: Our firm inspects the cargos during the shipping process and reports the anomalies.	0.709
Facility management (FM) ($\chi 2$=1.315, df=2; CFI=1.000; RMR=0.003; IFI=0.999; TLI=0.999; Cronbach's α=0.885; CR= 0.886; AVE= 0.660)	
FM1: Our firm protects facility and clearly makes control areas.	0.822
FM2: Our firm monitors and controls the access procedures.	0.870
FM3: Our firms records the entry/exit of the people and vehicles	0.775
FM4: Our firm instals a 24hr camera system or CCTV.	0.780
Information management (IM) ($\chi 2$=7.642, df=2; CFI=0.985; RMR=0.013; IFI=0.985; TLI=0.955; Cronbach's α=0.810; CR=0.814; AVE= 0.526)	
IM1: Our firm encrypts and codes information.	0.648
IM2: Our firm protects business information from unauthorized access and usage.	0.767
IM3: Our firm frequently tests computer systems against unauthorized access.	0.832
IM4: Our firm regularly backs up all commercial data and programs.	0.636

Constructs and reflective indicators	Loadings
Human resources management (HRM) (χ2=5.521, df=2; CFI=0.994; RMR=0.007; IFI=0.994; TLI=0.982; Cronbach's α=0.861; CR=0.867 ; AVE= 0.627)	
HRM1: Our firm provides adequate training program on supply chain security issues.	0.851
HRM2: Our firm distributes security issues and information throughout the organization.	0.877
HRM3: Our firm runs security training programs in the workplace.	0.840
HRM4: Our firm removes computer access and return of security pass when staff leaving.	0.556
Partner relationship management (PRM) (χ2=0.9525, df=2; CFI=1.000; RMR=0.003; IFI=0.999; TLI=0.999; Cronbach's α=0.878; CR= 0.882; AVE= 0.654)	
PRM1: Our firm carefully selects low risk and high security business partners.	0.811
PRM2: Our firm regularly evaluates business partners.	0.920
PRM3: Our firm has a good system for recording and controlling commercial intercourse.	0.814
PRM4: Our firm encourages supply chain partners to enhance supply chain security.	0.671
Accident prevention and processing (AP) (χ2=1.496, df=2; CFI=1.000; RMR=0.004; IFI=0.999; TLI=0.999; Cronbach's α=0.870; CR= 0.874; AVE= 0.636)	
AP1: Our firm regularly conducts security analysis to improve security performance.	0.778
AP2: Our firm investigates security incidents and clearly defines the response for them.	0.786
AP3: Our firm provides security incidents statistical data for modifying security policy.	0.899
AP4: Our firm quickly shares information with all employees in the case of security incidents.	0.717
Supply chain resilience (SCR) (Sources: Li et al., 2009; Gligor, 2013)	
Agility (AG) (χ2=N/A, df=N/A; CFI=N/A; RMR=N/A; IFI=N/A; TLI=N/A; Cronbach's α=0.932; CR= 0.933; AVE= 0.823)	
AG1: Our firm can detect the business opportunity in container shipping in a timely manner.	0.940
AG2: Our firm can detect threatens in container shipping in a timely manner.	0.926
AG3: Our firm can detect changes in container shipping in a timely manner.	0.854
Flexibility (FL) (χ^2=N/A, df=N/A; CFI=N/A; RMR=N/A; IFI=N/A; TLI=N/A; Cronbach's α=0.889; CR= 0.891; AVE= 0.733)	
FL1: Our firm's logistics operation model is flexible to respond to the dramatic changes.	0.893
FL2: Our firm enhances the short-term response ability to respond to the sudden changes.	0.885
FL3: Our firm can provide customized or sudden logistics services to customers	0.786
Speed (SP) (χ^2=N/A, df=N/A; CFI=N/A; RMR=N/A; IFI=N/A; TLI=N/A; Cronbach's α=0.886; CR= 0.887; AVE= 0.723)	
SP1: Our firm cam make decision quickly to respond to the disruptions of logistics operations	0.833
SP2: Our firm can timely restore its original state of operations from the disruptions.	0.847
SP3: Our firm can modify business strategy in timely to respond to changes in container shipping	0.870
Operational performance (OP) (Sources: Yang and Wei, 2013) (χ2=N/A, df=N/A; CFI=N/A; RMR=N/A; IFI=N/A; TLI=N/A; Cronbach's α=0.893; CR= 0.901; AVE= 0.755)	
OP1: Decrease in cargo loss and damage	0.930
OP2: Decrease in frequency of accidents	0.957
OP3: Increase in cargo flow	0.696

A New Model for Piracy and Robbery Risk Assessment

Sascha Pristrom[1], Zaili Yang[1], Xinping Yan[2] and Jin Wang[1]*

[1]Liverpool Logistics, Offshore and Marine (LOOM) Research Institute, Liverpool John Moores University, United Kingdom
[2] National Engineering Research Center for Water Transport Safety, Wuhan University of Technology, China

[*]*Corresponding author: j.wang@ljmu.ac.uk*

Abstract

Internationally, more than 55,000 merchant ships carry more than 8.4 billion tonnes of goods each year. It is important to understand how to use the current capabilities to identify, assess and address maritime security issues, and how to improve the ability to do so in future through the most efficient use of available resources. It is also necessary to carefully assess and prioritise the maritime risks and opportunities we face and allocate our resources rationally. In this research, an analytical model incorporating Bayesian reasoning is proposed to estimate the likelihood of a ship being hijacked in the Western Indian or Eastern African region. Available data collected from the Global Integrated Shipping Information System (GISIS) together with expert judgement is used to demonstrate and validate the proposed model. This model can be used by maritime stakeholders to make cost-effective decisions in their operations under high uncertainties.

Keywords: Maritime security, Maritime piracy, Hijacking, Best management practice, Bayesian networks

1. Introduction

The shipping industry and international organisations have made enormous effort in the resolution to the menace of piracy. Several States have sent naval assets to the high risk areas (HRA) to protect merchant shipping from attacks and several UN organisations have dedicated expert teams to improve the situation. The International Maritime Organization (IMO) supported the setting up of a regional cooperation agreement, the Djibouti Code of Conduct, aimed at assisting littoral States that are affected by Somali piracy to implement a set of measures to suppress piracy using their own resources. The IMO was also instrumental in establishing the framework for collaboration among the littoral states of the Straits of Malacca and Singapore and the South China Sea, the so-called Regional Cooperation Agreement on Combating Piracy and Armed Robbery against Ships in Asia (ReCAAP) agreement (IMO, 2012). A major step in addressing maritime crime in the Gulf of Guinea region was made in June 2013 when Heads of States or their representatives from 25 West and Central African countries signed the Code of Conduct concerning the repression of piracy, armed robbery against ships, and illicit maritime activity in West and Central Africa.

The positive development in the suppression of piracy and armed robbery against Somalia-based piracy can be attributed to the fact that many organizations have made efforts to address maritime piracy activities in Somali waters and the wider Western Indian Ocean. For example, the United Nations Political Office for Somalia (UNPOS) started developing and implementing the National Security and Stabilization Plan through active engagement with the Federal Government of Somalia.

Modern piracy became a significant threat in the late 1990s and early years after the Millennium in South East Asia and in particular the Malacca Strait whereas the current piracy hot-spots are the waters off the coasts of West and East Africa. However, incidents in the Malacca Strait are rising and siphoning oil cargo from product tankers – similar to incidents in the Gulf of Guinea – has been reported in 2014 also for this region. High occurrences of piracy incidents during the period from 1 January 2007 to 1 December 2014 are in the waters off the East African coast; this was by far the most dangerous area for ships to become a victim of piracy (Pristrom, 2013). The statistics of incidents show three other piracy hotspot areas: the South East Asia region comprising the South China Sea and its adjacent waters, the Indian Ocean and West Africa (Source: IMO GISIS database).

2. Literature Review

Most research findings on maritime security involving piracy and robbery have been reported over the past decade. The reported research has targeted two main research topics. One is about the study of the nature of maritime piracy and robbery related activities while the other focuses on technical modelling of them with a view to making decisions on which risk control options to select.

Some useful studies have been reported. A quantitative risk assessment was conducted on Somali-based maritime piracy through judgemental data with respect to the threat's capability, intent and likelihood of exploiting a ship's vulnerability (Liwang *et al.*, 2013). Based on the collected description of the threat, the study analysed, the probability of successful boarding, an influence diagram describing the probability of successful boarding was given although no detailed analysis was demonstrated. An agency-based model of maritime traffic in piracy-effected waters was developed for simulating pirate activities and piracy countermeasures (Vanek *et al.*, 2013). The complex dynamics of the maritime transportation system threatened by maritime piracy were investigated in order to assess a range of piracy countermeasures. A spatial analysis of shipping routes was conducted to assess shipping safety at the South China Sea through considering many influencing factors such as extreme weather and piracy (Wang *et al.*, 2014). The annual and seasonal navigation risk was evaluated along the shipping routes using a fuzzy analytic hierarchy process and geographic information science, and validated by comparison to actual incident reports. A novel fuzzy rule-based Bayesian reasoning approach was proposed to facilitate quantitative implementation of the International Shipboard and Port Facility Security (ISPS) Code (Yang and Wang, 2009). It can be used either as a stand-alone technique for prioritising vulnerable systems or as part of an integrated decision making method for evaluating the effectiveness of security control options. A Bayesian network (BN) to manage piracy risks of offshore oil fields was proposed to provide a solution to the problem of offshore piracy from the perspective of the entire processing chain covering the detection of a potential threat to the implementation of a response (Bouejla *et al.*, 2014). The BN model was used to investigate attack scenarios of offshore installations associated with a number of influencing parameters and identify appropriate countermeasures. It is noted that such influencing parameters' dependency and their interactions were not fully modelled in the study.

The conducted literature review indicates that one of the most powerful tools to analyse risk and to ease the decision-making process can be achieved by utilizing a method of evidence-based reasoning. A BN is a method to reason probabilistically (Korb and Nicholson, 2003) while, at the same time, describing the state of the world. A BN model itself consists of variables which can have different states, e.g. variable A 'Maritime Crime' may take the state of a1: 'Piracy' or a2: 'Human trafficking' and so on. If a node (variable) in a BN has a parent node, it is accompanied by a Conditional Probability Table (CPT) for each of its states. If a node does not have a parent node, it is accompanied with an unconditional probability table. One of the great advantages of BNs is the easy adaptability of the model so that with any new information the model can be up-dated so as to reflect the real world without too much requirement on the modification of the existing networks.

3. A Proposed Model for Estimating Occurrence Likelihood of Successful Hijacking of a Ship

The variables/nodes in risk based BNs are normally identified through a hierarchy process. The first level events influencing hijacking of a vessel in the Western Indian/East African region are identified through both literature review and expert judgement as follows (Pristrom, 2013):

i. Defence measures. There are a wide range of defence measures which may vary considerably from ship to ship. Some ships may deploy only passive measures such as barbed wire mounted on the bulwark, 'bumping drums' attached to the ship's hull close to the waterline or electric fences. This variable has two states of 'Yes' and 'No'.

ii. MSCHOA (Maritime Security Centre Horn of Africa). MSCHOA is the coordination centre of the European Naval Force (EUNAVFOR) which is assigned to coordinate the naval forces in their mission to suppress acts of piracy in the Gulf of Aden, the Somali Basin and off the Horn of Africa. Its role is not limited to coordinate the assets provided by the EUNAVFOR operation 'Mission Atalanta' (the US-led Combined Task Force (CTF 150)) alone but to liaise with other cooperation centres and naval forces in the region such as the NATO Combined Task Forces 151 (CTF 151) and ships operating independently. This variable has two states of 'Registered' and 'Unregistered'.

iii. Lookout. This variable reflects the probability of having extra personnel on board to function as lookouts. Their main duty is to detect possible pirates at an early stage. This variable has two states of 'Additional' and 'No Additional'.

iv. Time. Piracy and armed robbery incidents follow a pattern according to the obtained statistics. This variable has two states of 'Daytime' and 'Night'.

v. Visibility. The visibility variable is less important for this sea area but this model may be modified to apply to other sea regions where the visibility is more significant and thus has been retained here. This variable has three states of 'Good', 'Moderate' and 'Poor'.

vi. Season. The monsoon season is known for winds and high waves and thus poses restrictions on the operation of the small twin-engine fishing skiffs pirates use (Bevege and Hassan, 2009). This variable has two states of 'Monsoon' and 'Calm'.

vii. Freeboard. The freeboard is defined in the International Convention on Load Lines, 1966 as the distance measured vertically downwards amidships from the upper edge of the related load line (IMO, 1966). This variable has three states of 'High', 'Medium' and 'Low'.

viii. Speed. The speed of a ship is a significant factor to assess the risk of a ship when under attack. It is known that ships which are capable of making a speed of 15 knots or more have not been successfully attacked unless gross negligence of good seamanship had been the root factor.

ix. This variable has three states of 'At anchor', '< Fifteen knots' and '≥ Fifteen knots'.

x. Guards. The estimation of this parameter can be carried out based on the consultation with ship owners and other sources (Leander, 2010). This variable has three states of 'Armed', 'Not armed' and 'No guards'.

xi. Naval Support. This variable stands for the military response time (i.e. the time necessary to render assistance to the ship under threat). This variable has three states of 't15', 't30' and '> t30'. The first state (t15) reflects situations where military support is rendered within 15 minutes, the second state (t30) reflects assistance rendered between 16 and 30 minutes and the third state (> t30) is for all other situations.

Secondly, the intermediate level events are identified in a way that each of them is influenced by a combination of some first level events.

i. Ship type. This variable has 2 parent nodes, the variables 'Freeboard' and 'Speed'. This variable has two states of 'High risk' and 'Low risk'.

ii. Environmental condition. This variable has 3 parent nodes, the variables 'Time', 'Visibility' and 'Season'. This variable has two states of 'Favourable' and 'Poor'.

iii. BMP (Best Management Practices). This variable has 3 parent nodes, the variables 'Defence measures', 'MSCHOA' and 'Lookout'. This variable has two states of 'Yes' and 'No'.

Thirdly, a third level event ‘Attack’ is determined by the second level events. This variable has three parent nodes, the variables ‘Ship Type’, ‘Environmental Condition’ and ‘BMP’. It describes the status of a vessel in the HRA being attacked given the application of BMP, the prevailing weather conditions and the vessel’s characteristics. This variable has two states, i.e. ‘Yes’ and ‘No’.

Fourthly, the last (fourth) level events are identified. They can be explained as follows:

i. ‘Hijacked’. This variable has three parent nodes, the variables ‘Naval Support’, ‘Guards’ and ‘Attack’. This variable describes the status of the vessel in the HRA being hijacked given the available naval support, the use of guards on the ship and the status of the ship being attacked. This variable has two states of ‘Yes’ and ‘No’.

ii. ‘Unsuccessful Attempt’. The variable ‘Attack’ either leads to the vessel being hijacked or to an unsuccessful attempt. This variable has two states of ‘Yes’ and ‘No’.

A model for predicting the probabilities of a ship being attacked, hijacked and unsuccessful attempt in the Western Indian/East African region is developed as shown in Figure 1 by considering the events at the four levels and their relationships. The CPTs and unconditional probability tables associated with the first level events are developed largely based on the scenario to be investigated due to the significant difference in piracy statistics across various regions”. The detailed quantitative analysis of the proposal BN is therefore seen in Section 4 where a numerical case study is conducted.

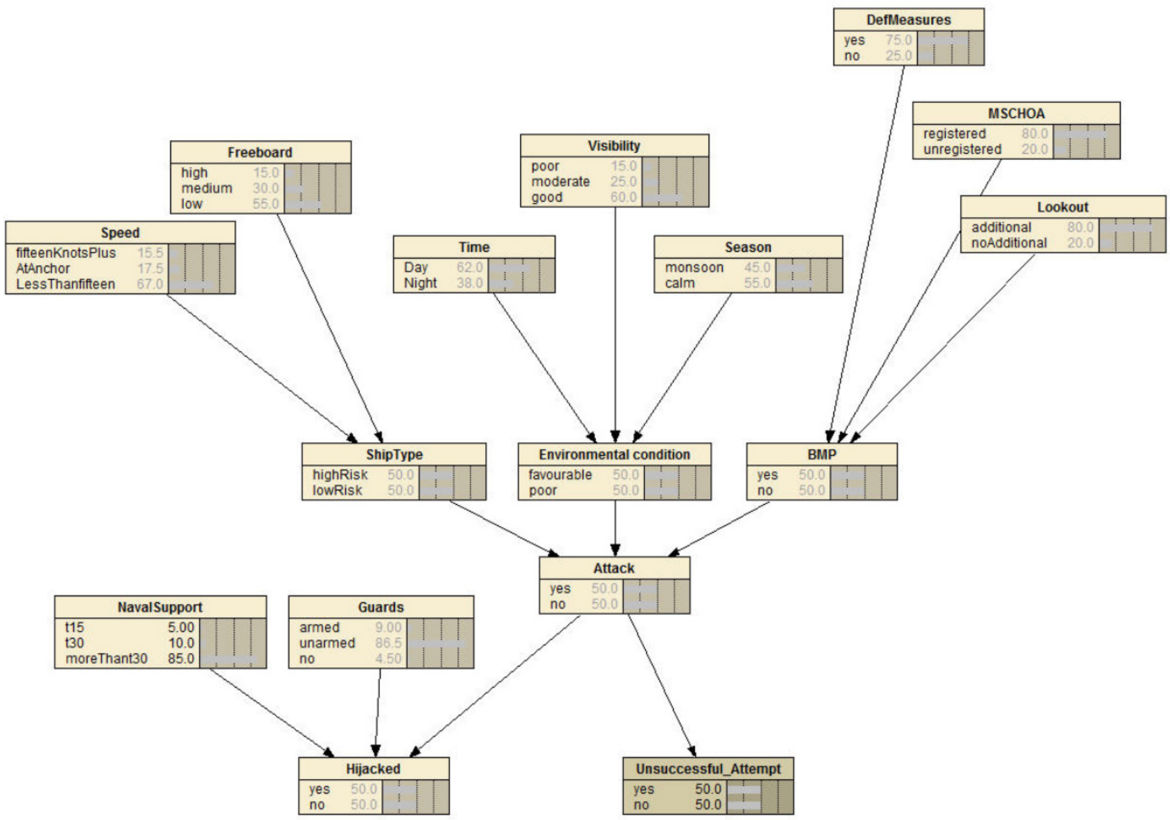

Figure 1: BN model of pirate attack and hijacking

A sensitivity study (SA) is used to provide a degree of confidence that the model has been built correctly and is working as intended. SA is essentially a measure of how responsive the output of a model is to variations in the inputs. If the model shown in Figure 1 is reasonable, then the following listed axioms must be satisfied (Jones *et al*., 2009):

i. Axiom 1. Given the variation of probability distributions of each parent node, its influence magnitude to the child node values should keep consistency.

ii. Axiom 2. The total influence magnitudes of the combination of the probability variations from x attributes (evidence) on the values should be always greater than the one from the set of x-y (y ϵ x) attributes (sub-evidence).

4. An Example

The likelihood of a ship transiting through the Western Indian/East African region is used to demonstrate and validate the proposed BN model. Both expert judgement and statistical data from sources such as the IMO Global Integrated Shipping Information System (GISIS) are used to provide quantitative inputs into the BN model. For example, the base root node, 'Defence Measure' can be modelled using expert judgement. Its 'Yes' and 'No' states are assigned probabilities of 0.75 and 0.25 respectively through expert judgements (Pristrom, 2013). The intermediate nodes and leaf nodes can also be modelled in a similar way. For example, 'Ship Type' can be modelled as follows. Through investigating the data in GISIS reported for three and a half years, 554 incidents have been analysed to produce the CPT for "Ship Type" as shown in Table 1. It is worth noting that the freeboard values for 'High' and 'Medium' are merged as one value in GISIS while in the proposed BN model, 'Freeboard' has three states 'High', 'Medium' and 'Low'. It is also worth noting that the statistical data may present a paradox here as the data suggests that the risk of being involved in a piracy accident might be higher when steaming than at anchor. The simple reason for this lower risk is due to the very limited number of ships at anchor in the region as this would contradict the BMP. For analysing the general risk this fact, however, reflects reality.

Table 1: CPT for 'Ship Type'

Speed	Fifteen knots plus			Less than fifteen			At anchor		
Freeboard / Ship Type	High	Medium	Low	High	Medium	Low	High	Medium	Low
High risk	0.103	0.103	0.2	0.063	0.063	0.455	0.047	0.047	0.132
Low risk	0.897	0.897	0.8	0.937	0.937	0.545	0.953	0.953	0.868

'Attack', 'Hijacked' and 'Unsuccessful attempt' can be modelled using domain experts as shown in Tables 2, 3 and 4 respectively (Pristrom, 2013). Detailed information for all other nodes in Figure 1 can be found in (Pristrom, 2013).

Table 2: CPT for 'Attack'

Ship Type	High risk				Low risk			
Environmental Condition	Favourable		Poor		Favourable		Poor	
BMP / Attack	Yes	No	Yes	No	Yes	No	Yes	No
Yes	22.1	24.9	12.5	15.7	19.6	23.9	5.5	7.7
No	77.9	75.1	87.5	84.3	80.4	76.1	94.5	92.3

Table 3: CPT for 'Hijacked'

Attack	Yes									No								
Naval Support	t15			T30			>t30			t15			T30			>t30		
BMP / Hijacked	Armed	Unarmed	No	Armed	Unarmed	No	Armed	Unarmed	No	Armed	Unarmed	No	Armed	Unarmed	No	Armed	Unarmed	No
Yes	0.06	0.22	0.3	0.14	0.3	0.36	0.22	0.41	0.47	0	0	0	0	0	0	0	0	0
No	0.94	0.78	0.7	0.86	0.7	0.64	0.78	0.59	0.53	1	1	1	1	1	1	1	1	1

Table 4: CPT for 'Unsuccessful attempt'

Attack / Unsucc. Attempt	Yes	No
Yes	0.9	1
No	0.1	0

5. Results and Model Validation

Figure 2 shows the results for the BN example. According to the model, the general likelihood of a ship being attacked in the Western Indian/East African region is 11.8% for a generic ship on the condition that pirates exist and are ready to attack. Such an attack may be abandoned at an early stage when the attackers become aware of the defence measures on board or the attack is not successful because the ship is out-manoeuvring the attacking skiffs. The variable 'Hijacked' then reflects the risks of being hijacked when under attack. The BN then suggests that the likelihood of a ship being hijacked is about 4.4% in the area given circumstances of the influencing factors such as naval support and use of guards. The above results may be best interpreted as follows. If a ship is attached by pirates in the region, the likelihood of being hijacked is 4.4% given the particular circumstances of the influencing factors and their relationships.

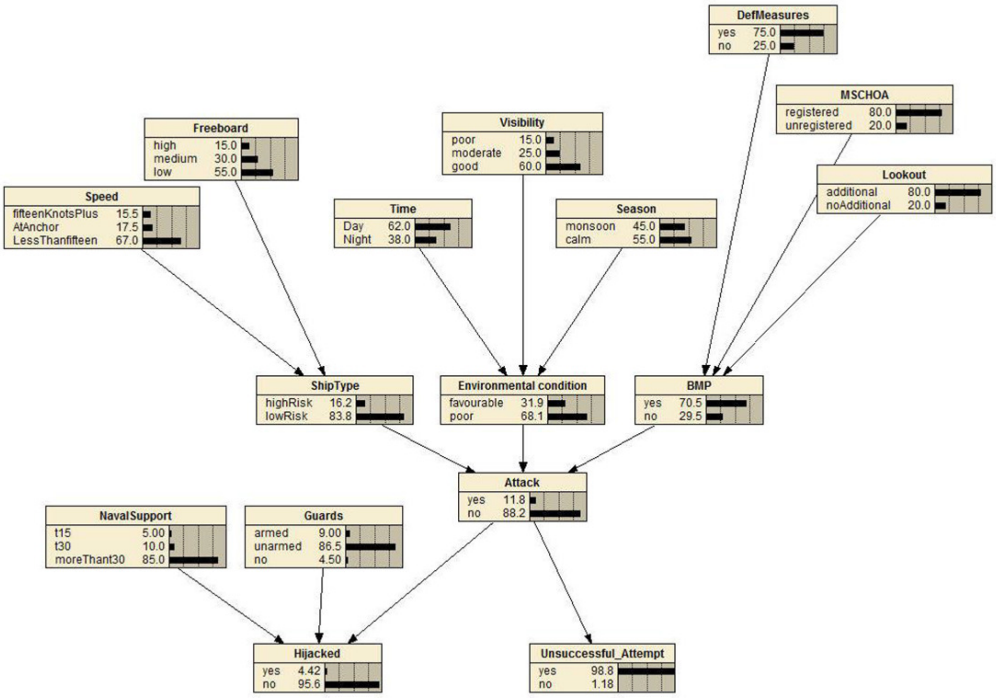

Figure 2: The results from the BN model

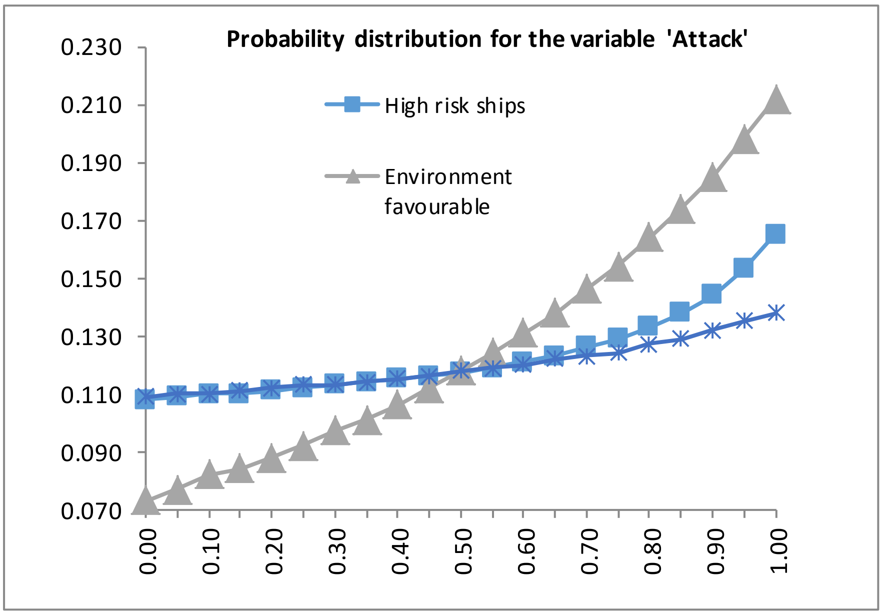

Figure 3: Validation using Axiom 2 for the node 'Attack'

Figure 3 shows the change of probabilities for the node ‘Attack’ in accordance to changes made to its parent variables ‘Ship Type’, ‘Environmental Condition’ and ‘BMP’. The shapes of the curves indicate that there are no outliers or sharp-kneed features. A consistent change of probabilities for ‘Attack = Yes’ due to change of probabilities of ‘Ship Type = High risk’, ‘Environmental Condition = Favourable’ or ‘BMP = No’. This is in line with Axiom 1.

Axiom 2 requires that sub-evidence should have less influence on the values of a node than evidence received from the parent nodes. Figure 4 show the validity of this requirement for the node ‘Attack’ where, for example, the maximum likelihood of having an attack given sub-evidence (e.g. Visibility) is lower than the one under the full evidence (i.e. a combination of Time, Visibility and Season).

The model proposed is generic in nature. More variables can be added to the developed model in order to help improve the accuracy of maritime piracy and robbery risk estimates. This would not need to significantly change the existing model, making it easy for the model to be improved. Application of the developed model would need further case studies for testing its applicability.

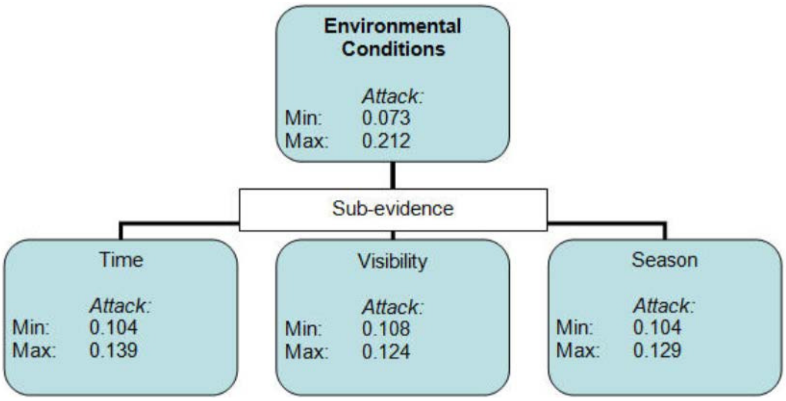

Figure 4: Validation using Axiom 3 for the node ‘Attack’ depending on ‘Environmental Condition’

6. Conclusion

Commercially operated ships are at high risk of becoming a victim of piracy unless robust security measures are taken to prevent such attacks. This paper analyses previous maritime piracy related incidents in the major piracy hotspot areas. Due to the highly complex environment a ship is operating in, the likelihood of a successful hijacking depends on many factors such as wind and weather conditions, ship characteristics such as freeboard and speed, the presence of naval forces in the sea area, and the security measures taken by the crew.

A model incorporating BN is proposed for estimating the likelihood of a ship being hijacked in the Western Indian/East Africa region, taking into account the associated influencing factors with high uncertainties. The model is demonstrated and validated through a case study with data obtained from both report data records and expert judgement. The model can be used to update the estimation of the probability of ships being hijacked in the Western Indian/East Africa region when any new information becomes available. More influencing variables can be easily added to the model if considered necessary without having to re-design it entirely. The proposed model can be used by maritime stakeholders such as ship operators to make security-based operational decisions. In the current difficult economic climate for ship operations with low freight rates and tonnage overcapacity for many cargoes a ship owner is reluctant to invest in unnecessary security measures. The cost of a professional private armed security team is a great expenditure that has to be well thought through and to be based on a realistic and profound risk analysis in order to balance the risk, costs and benefits.

7. Disclaimer

This paper is the opinion of authors and does not necessarily represent the belief and policy of their employers.

8. Acknowledgements

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Understanding Power Relationships in Chinese Hub Seaports

Wenrui Ma, Stephen Pettit, Robert Mason and Jane Haider

Cardiff Business School, Cardiff University, United Kingdom

Abstract

The development of global trade and logistics chains has reshaped the market environment of the seaport and liner shipping sector. Against this background, there is no consensus regarding the relative market position between terminal operators (TOs) and global liner shipping companies (LSCs). Using the theory of power, this paper aims to investigate this issue in the context of Chinese hub seaports. To fulfil this purpose, this paper adopts a qualitative case study research design. Whereas the findings about power relationships in Chinese hub seaports are multi-dimensional, TOs appear to be in a more powerful position compared to LSCs. This paper contributes to the literature in several ways: it clarifies the market position between TOs and LSCs in the Chinese hub seaport sector, and it contributes to the development of the power theory with empirical findings from an underdeveloped research context. The overall findings are beneficial for TOs and LSCs to form business strategies and ultimately achieve business success.

Keywords: Terminal operators, Liner shipping companies, Power patterns

1. Introduction

Maritime transportation has been a fast growing and changing market over the last few decades. The total world containerised trade reached 160 million TEUs in 2013 (United Nations Conference on Trade and Development (UNCTAD), 2014). The development of seaborne trade has resulted in significant organisational and technological changes in seaports, which has enabled them to improve their transportation services from a port-to-port level to a door-to-door level (Paixao and Marlow, 2003). Even so, the seaport sector has often been regarded as being 'reactive' to the shipping industry's development (Paixao and Marlow, 2003; Bichou and Gray, 2004).

On the one hand, the development of the liner shipping sector has brought significant challenges to seaports. Vertical and horizontal integration strategies are widely adopted by LSCs. The industrial structure of the liner market has become increasingly concentrated, and seaports are facing intensified competition. These issues have significantly shaped the business environment of the maritime industry in which seaports are dealing with increasingly powerful liner customers (Notteboom, 2008; Woo et al., 2011).

On the other hand, the trend of power development has shown that this transportation node is playing an increasingly important role in supply chains (SCs). The role of the seaport has evolved from being an isolated interface between land and sea transport focusing on cargo handling to being an integrated logistic platform in the international distribution channel providing various value-adding transport activities (Beresford et al., 2004). Global expansion and consolidation has granted TOs a stronger negotiating position with regard to LSCs (Heaver et al., 2001; Pallis et al., 2008; Martin and Thomas, 2001).

Therefore, the relative market position between seaports/TOs and LSCs is unclear in view of the current development of the maritime industry. This paper collects data from four Chinese hub seaports, namely, Xiamen Port, Shanghai Port, Qingdao Port, and Ningbo Port (see Figure 1), and investigates this issue by virtue of the theory of power. As an essential attribute of social systems, power is central to all business-to-business relationships (Cox, 2001a). In light of the research gap and the significance of power theory for understanding business relationships, this paper investigates the power relationship between TOs and LSCs in the context of Chinese gateway seaports.

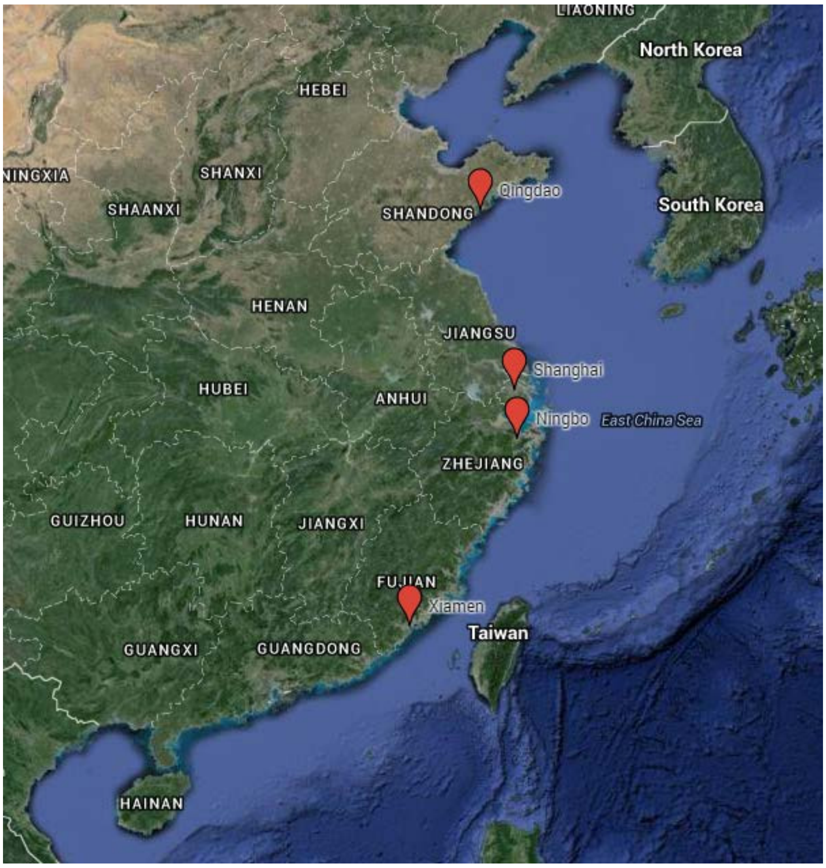

Figure 1: Four Chinese hub seaports covered in this study

The rest of this paper is organised as follows. Section 2 reviews the market environment of the maritime industry and introduces the concept of power patterns. Section 3 describes methodological issues. Then, the presentation and discussion of findings are provided in section 4. The last section concludes the whole study.

2. Literature Review

The evolution of the seaport market has been significantly shaped by the development of seaborne trade, logistics chains, and the liner shipping industry. Thus, it is argued that the seaport sector is located at the end of the changing sequence of the maritime industry (Woo et al., 2011). In view of this sequence, this section firstly reviews key factors that have contributed to the restructuring of the seaport sector, based on which the research gap is further clarified. Then, the focus moves to the examination of the theory of power, which lays down the theoretical grounds for the investigation of the vested business relationship.

2.1. The Market Environment

2.1.1. Globalisation and Containerisation

Globalisation has always been closely related to the development of the maritime industry (Reynaud, 2009). The rapidly globalising marketplace has shaped the geography of seaborne trade and poses a challenge to both seaports and LSCs. Driven by the trend of globalisation, production sites are widely dispersed (Organization for Economic Cooperation and Development (OECD), 2008). This dispersed source of production has increased the difficulty for seaports regarding gathering cargos and attracting ship calls, given their physical immobility.

Containerisation is another influential factor that has shaped the maritime industry. Since the utilisation of the first container in the 1960s, the trend of containerisation has swept the liner shipping sector (Stopford, 2009). Containerisation has significantly improved the performance of logistics chains and standardised port operations and port services (OECD, 2008). As a result, ports have become very similar in terms of their core services. Although the development of a port hierarchy and a hub-and-spoke system has largely defined the role of the port in a regional port group, ports in proximity to each other are highly substitutive.

While port competition has been increased due to globalisation and containerisation, the challenge to attract port calls is further intensified by the 'foot-loose' feature of liner operators and supply chains (Heaver et al., 2001). On the one hand, LSCs are highly mobile. They act footloose to find a better deal in terms of port service and port charge. On the other hand, the mobility of liners and the global search for economic production sites have rendered SCs footloose as well (Robinson and Malhotra, 2005). These two factors have further intensified the port competition and placed seaports in a disadvantageous position when dealing with LSCs.

2.1.2. The Existence of Strong LSCs

The development of seaborne trade and logistics channels has also posed challenges for the liner shipping sector. Carriers bear the pressure of offering abundant shipping services at a lower cost. This pressure has significantly affected the conduct of carriers and the market structure of the liner industry. Shipping companies have used increasingly large ships in the liner trade so as to gain economies of scale. According to the statistics, the average size of a container ship has shown a continuously increasing trend since the 1980s (UNCTAD, 2008). The increase of ship size has a significant impact on the maritime industry, as large ships call at fewer ports. The reduction in the number of port calls has decreased the dependence of carriers on a particular port and intensified the competition among seaports, especially those that are able to accommodate large vessels (OECD, 2008).

In addition, LSCs have engaged in various types of cooperation, which also improves their negotiating position in relation to seaports/TOs. Strategic alliance is currently the most popular form of cooperation adopted by carriers. It usually covers a wide scope of cooperation agreements including operating joint services, slot and information sharing, shared terminals, and pooled containers (Stopford, 2009). The formation of an alliance implies the control of cargos by a group of liner operators. However, it has raised concerns about the dominant position of LSCs over other SC members. Since carriers bring more business volume to the negotiating table, ports have become more dependent on LSCs (Heaver et al., 2000).

In addition to the cooperation at the intra-industrial level, carriers are keen to engage in vertical integration and to cooperate with parties across the logistics chain. As the 'through service provider', LSCs wish to participate in terminal operating and inland transportation in order to maintain the smooth operation of the logistics chain (Notteboom and Rodrigue, 2005). In the maritime industry, vertical integration is commonly adopted by carriers to seize the control of terminals (Van de Voorde and Vanelslander, 2009). They establish subsidiaries that specialise in terminal operations business and/or form joint ventures with pure terminal operators or with other liner operators (Kaselimi et al., 2011). Through these methods, carriers have strengthened their control over seaports on a global scale.

2.1.3. The Uncertainty About the Relative Market Position Between TOs and LSCs

To deal with the restructured logistics chain and extensively consolidative activities within the liner shipping sector, TOs have also engaged in cooperative activities on the horizon. In addition, the trend of privatisation in the seaport sector has created a sound environment for the expansion of TOs' business on a global scale. Consolidation and the expansion of global coverage can help TOs to exploit economies of scale, develop network economies, and optimise the terminal's function within logistics networks (Midoro et al., 2005). From the perspective of inter-organisational relations, consolidation has contributed to TOs' stronger negotiating position. Global expansion has increased the flexibility of service supply and limited the liner's alternatives of port choice (Heaver et al., 2001). These two factors have also led to an increasingly concentrated seaport sector despite the involvement of integrated shipping lines (Pallis et al., 2008; Martin and Thomas, 2001). Therefore, the market position of TOs has increased over the last few decades.

Overall, the development of logistics chains and the maritime industry has implied a seaport sector that is 'reactive' to the shipping industry and a competitive terminal operating market. Even so, TOs and shipping lines behave actively to improve their position in the SC and in the dyadic inter-organisational relation. The review of these market features has revealed a complex and uncertain relative market position between LSCs and TOs, which calls for further investigation.

In maritime studies, terms including 'market power', 'buyer power' and/or 'monopoly power' have been widely used (e.g. Heaver et al., 2001; Song and Panayides, 2002; Van de Voorde and Vanelslander, 2009; Woo et al., 2011) to describe the vested business relationship. This popularity implies the importance of the concept of power for the 'knowing of reality' in the maritime industry. In addition, the theory of power has been an essential theory for the understanding of inter-organisational relations (Kaselimi et al., 2011). Accordingly, the next section reviews the power literature and attempts to form the theoretical basis for the investigation of the relative market position of TOs and LSCs.

2.2. The Pattern of Power

Power in an SC can be defined as one SC member's ability to influence or control the decisions and behaviour of another member (Narasimhan et al., 2009). The issue of power is an essential area of study in business research. Although there is already a significant amount of literature on power, investigation into power remains underdeveloped in the field of maritime research. The concept of power has many dimensions. Whether a power relationship is balanced or unbalanced represents the basic understanding of power (Casciaro and Piskorski, 2005). This issue is referred to as power patterns in this paper.

From the standpoint of the resource dependence theory, power imbalance refers to the difference in mutual dependence (Lawler and Yoon, 1996). Adopting a resource-based view, Cox et al. (2002) developed a power matrix based on four possible power relationships between buyer (A) and supplier (B): interdependence (A=B), buyer dominance (A>B), supplier dominance (A<B), and independence (A0B). The illustration of the power matrix can be seen in Figure 2. These four types of power relationship are formed according to the relative amount of power held by the two parties involved in a power relationship. Whereas A>B and A<B refer to an imbalanced power pattern, A=B and A0B represent situations whereby A and B have largely equal amounts of power.

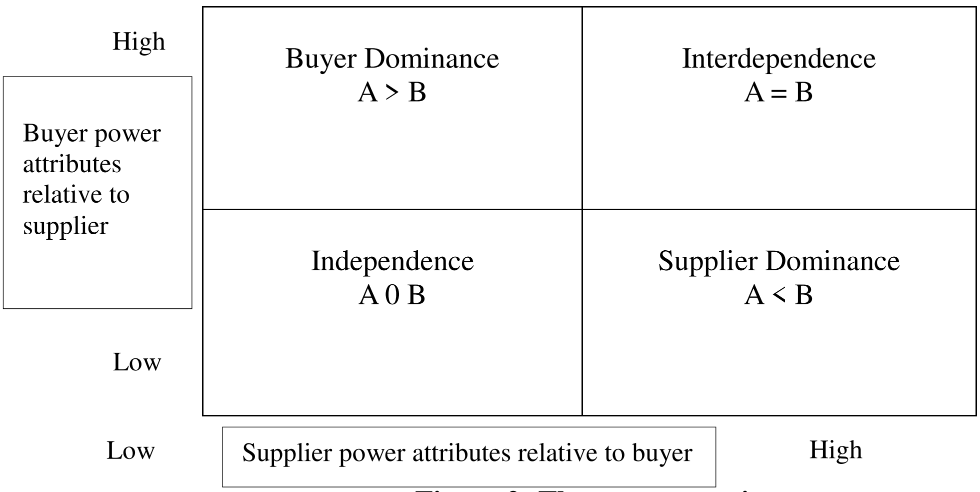

Figure 2: The power matrix
Source: Cox. (2001a)

From a dyadic inter-organisational perspective, power imbalance is a common relationship in business world as seen in many studies, including Byrne and Power (2014), Kahkonen (2014), and Lin et al. (2013). The reason lies in the benefit of having power, which is the acquisition of surplus value (Casciaro and Piskorski, 2005; Cox, 2001b; Hingley, 2005). Although a buyer-supplier transaction can never be solely about power, and there is always some sort of mutual interest between two contracting parties, not all of the interest between suppliers and buyers is mutual (Cox, 2001a). Given that SC members are primarily motivated by self-interest and strive to acquire and keep surplus value (Cox, 1999; Williamson, 1975), the pursuit for power is logically a primary pattern of organizational behaviour.

The desire for a favourable power position thus offers one explanation for the conduct of TOs and LSCs as reviewed in the previous section. Furthermore, section 2.1 has revealed an unclear status regarding the relative market position between TOs and LSCs. Although this issue has been assessed in a number of maritime studies, it has seldom been studied systematically. The description of the idea of power patterns shows that this concept is closely related to the relative market position of SC actors. In addition, power has been an underdeveloped concept in SCs (Canieels and Gelderman, 2007). Therefore, the study of the power relationship between TOs and LSCs tends to be advantageous not only for understanding these two actors' relative market positions but also for the development of power theory in the context of maritime logistics chain.

3. Research Setting and Methods

3.1. Research Context

The area of Chinese gateway seaports was selected as the research context due to the increasingly important role of China in international seaborne transport and the unique characteristics of the market. Since the application of the open-door policy in the late 1970s, the economic regime of China has undergone significant changes. The remarkable economic growth over the last few decades has made China a major global economy. Accompanied by strong economic growth, international trade has boomed in China and has significantly changed the maritime industry. Having developed from a semi-closed state with poor infrastructure, China has become the most accessible nation in the world to the global liner shipping network (UNCTAD, 2014). In 2013, 7 out the top 10 world container ports in terms of throughput were Chinese ports (including Hong Kong Port) (UNCTAD, 2014).

In addition to the essential role of China in international maritime transportation, the special political regime of this nation has had a significant impact on the governance structure of the seaport sector. The concept of governance has greatly benefited the examination of power issues among institutions involved in collective actions (Griffin, 2012). It is particularly relevant for studying power issues in countries like China, since the central and local government are still playing essential roles in the port sector (Wang and Slack, 2004). The administrative system of Chinese ports has gone through several phases. The most recent port reform that has helped establish the current port governance structure in China took place in 2003 when the Port Law of the People's Republic of China (PLC) was implemented. Port reform after 2003 has been characterised by two principles: the corporatisation of port authorities and the establishment of the municipal port administration system under the supervision of the provincial and central government (The National People's Congress of the People's Republic of China, 2004). Besides, PLC has encouraged the involvement of private funding in the port sector (PLC, 2003).

In view of these changes, Qiu (2008) summarises three costal port governance models in mainland China: the general model, the Shanghai model, and the Shenzhen model. Despite their differences, all three models are characterised by the control of port operations by state-owned port corporations/groups to varying degrees. Joint ventures and/or subsidiary companies are established as TOs. Thus, in the context of the Chinese seaport sector, TOs seem to have a strong affiliation with their respective port group, which acts as the operators of the port. Therefore, the operator of the seaport and of the terminals within a seaport may behave as one party depending on the extent of the TOs' autonomy. Accordingly, the term 'port/terminal operator' (P/TO) is used in the selected research context of this paper, and the power pattern under study is between P/TOs in China and global LSCs.

3.2. Research Design

A qualitative case study research design was adopted to fulfil the research aim. On the one hand, the selection of a qualitative approach was because of the contextual-embedded feature of the concept of power (Kasabov, 2007; Kim, 2000) and the research approach's strength to appreciate the richness, depth, and complexity of the social reality (Bryman and Bell, 2011). On the other hand, the purpose of this research is to explore, describe, and understand the vested power relationship, and the case study design was considered suitable for the fulfilment of these types of research purpose (Blaikie, 2010).

Semi-structured interviews, participant observation, direct observation, and documentation were used to gather data. The data collection took place between May and July 2014. Seaports involved in the case study are Xiamen Port, Shanghai Port, Qingdao Port, and Ningbo Port (see Figure 1). These ports are not only essential gateways for China's international trade, but also are among the top ranked container ports in the world (see Appendix 1 for a brief description of these ports). The main data collection method of this study was interviews. The aim of interviewing in this paper was to gather data about power patterns. This means the interview topics were largely pre-determined. Thus, a semi-structured interview with open-ended questions was adopted to collect the data. An interview protocol was used in all cases to improve the reliability of the research.

In terms of the application of the interview strategy, the summary can be seen in Table 1. Firms participating in this research consist of six TOs from four port groups in these selected seaports and eight global shipping lines that have established business relationships with these seaports. In the case of Ningbo Port and Shanghai Port, key informants from the port group were also approached for information. The eight carriers in this study are Maersk (involved in two cases), Evergreen, Hapag-Lloyd, APL, MOL, Cosco, CMA-CGM, and Zim. These carriers cover key global alliances in the current shipping industry, including G6, CKYHE, 2M and O3.

Table 1: Interview summary

Case studies	Interview summary			Field work time (2014)
	Total No.	Party involved	No. of interviewees (Code)	
Xiamen Port	9	TO1	7 (XM1-7)	April
		LSC1	2 (XMS1-2)	
Shanghai Port	11	TO2	6 (SH1-6)	May
		TO3		
		Shanghai Port Group	2 (SH7-8)	
		LSC1	3 (SHS1-3)	
		LSC2		
		LSC3		
Qingdao Port	12	TO4	9 (QD1-9)	June
		TO5		
		LSC4	3 QDS (1-3)	
		LSC5		
		LSC6		
Ningbo Port	7	TO6	2 (NB1-2)	July
		Ningbo Port Group	3 (NB3-5)	
		LSC7	2 (NBS 1-2)	
		LSC8		
Total	39	6 TOs and 8 LSCs (one LSC is involved in two case seaports)		

Thirty-nine interviews were conducted involving ten respondents from the shipping sector and the rest from the port sector. All of these respondents were from the level of director and above, which guarantees the quality of the data collected. All the interviews were recorded and subsequently transcribed. The name of the respondents was not revealed in order to preserve anonymity. For the convenience of referencing, each was given a code; for example, [XM 1] means number 1 interviewee in the case of Xiamen Port.

The level of analysis in this paper is bilateral. Whereas P/TOs are the focus of this study, respondents from both sides of the relationship, that is, P/TOs and LSCs, were interviewed to acquire accurate and unbiased data about the power relationship. Template analysis was adopted as the data analysis method. This method generates a list of codes to facilitate the analysis of the qualitative data set (King, 1998). The coding process started with a line-by-line reading of the whole transcript and the marking of possible codes. The transcripts were read several times in order to assure all possible codes and themes were marked. During this process, some higher-order categories seemed to emerge. The identification, organisation and further categorisation of these higher-order nodes generated the whole coding system. To facilitate the analysis and presentation of the power patterns in the Chinese hub seaport sector, Cox's (2001a) power regimes were adopted.

4. Findings and Discussion

The data collected from four Chinese hub ports are analysed with reference to the theory of power patterns. For the inter-organisational relationship between LSCs and P/TOs, the former party are regarded as buyers of the port services that are supplied by the latter party. In general, two types of power relationships from Cox et al.'s (2002) power regimes are most relevant in these four cases: interdependence and supplier (P/TO) dominance. On the one hand, respondents recognised the close relationship between the port sector and the shipping sector and felt that P/TOs and LSCs are highly interdependent. On the other hand, interviewees indicated the powerful position as being taken by P/TOs rather than LSCs. Based on the interview findings, the details and evidence concerning these two dominant types of power patterns can be seen in Table 2.

4.1. LSC-P/TO Interdependence

Interdependence is, unsurprisingly, a notable pattern of the power relationship between P/TOs and LSCs. At the inter-industrial level, the operation of the seaport sector and the shipping sector only make sense with the existence of the other party (Talley, 2009). As adjacent actors in the logistics chain, these two sectors form the transportation nodes and lines that make maritime trade possible. Shipping lines need a seaport to accommodate ships and load/unload cargos whereas the assets of a seaport are highly specific to the carriers. The interdependence power pattern thus stems from the 'mutual indispensability' of these two sectors, as one operational manager from TO3 mentioned.

On the other hand, a high level of mutual dependence was also perceived at the inter-organisational level. The LSCs covered in this paper are top-ranking global carriers. All of them have established a business relationship with these four Chinese hub ports to varying degrees. With reference to the resource-dependence view, this means the existence of an interdependent relationship, which stems from the mutual demand for the other party's resources. Furthermore, the mutual dependence was further strengthened by the contractual form of the business relationship between P/TOs and LSCs. Often renewed on an annual basis, the formation of a contractual relationship implies the existence of mutual interest (Cox et al., 2002) and has been regarded by previous power researchers (e.g. Frazier, 1983; Kasabov, 2007; Moore et al., 2004) as an indicator of mutual dependence.

In addition, the evidence for the interdependent power pattern in Table 2 reveals that the relationship between P/TOs and LSCs was also perceived as 'cooperative' and 'integrated'. These types of business relationship, which can reduce uncertainty, improve efficiency, and increase the possibility of business success, are also advocated by the resource dependence theory (Gundlach and Cadotte, 1994; Crook and Combs, 2007). From the perspective of power patterns, it adds additional evidence for the highly interdependent relationship between LSCs and P/TOs.

Table 2: Interview evidence for the dominant power patterns between LSCs and P/TOs in four hub ports

Power patterns	Cases	Illustrative quotations
Power interdependence	Xiamen Port	'From the perspective of relationship, they (LSCs and P/TOs) complement each other…I feel it is more about mutual influence.' [XM1] 'I see more and more cooperation, and their relationship is a kind of coexistence.' [XMS1]
	Shanghai Port	'These two sectors are dedicated to reach other, so they must tie together.' [SH2] 'No party can survive without the other; it is mutual dependence.' [SHS3]

	Qingdao Port	'Carriers and terminal operators have integrated. They are as close as fish and water.' [QD2]
	Ningbo Port	'Each party is an indispensable part of another. So they rely on each other and adjust themselves to fit the other party's need.' [NB2] 'For the relationship, they depend on each other, though it (pattern) may manifest differently in different time periods.' [NBS2]
P/TO dominance	Xiamen Port	'In China, port groups all have a strong capability to influence LSCs.' [XM3] 'If the carrier does not call at the Group's terminals, it has nowhere else to berth. So we have the advantageous position when negotiating.' [XM7]
	Shanghai Port	'Carriers can only influence the liner market. They cannot influence P/TOs, whereas P/TOs can affect them.' [SH3] 'P/TOs in Shanghai Port are more powerful.' 'There is only one operator in this port (Shanghai Port Group). If they (carriers) want to berth, they have to listen to me.' [SH7] 'Costal resources are scarce resources and are controlled by state-owned port groups. This tilts the scales in favour of the port side.' [SHS1]
	Qingdao Port	'The port group is a monopoly. (….) We have no power to require the P/TO to make any changes.' [QDA1] 'The terminal operator takes the significant (power) position for sure. It is a monopoly' [QDS2]
	Ningbo Port	'Speaking of the current stage, the port group is more powerful.' [NBS1] 'No carriers can give up the market in Ningbo.' [NB1]

4.2. P/TO Dominance and LSC Dominance

The power pattern of interdependence identified in these four cases does not mean that the power between P/TOs and LSCs is strictly balanced. The multidimensional perception about power patterns has been witnessed in these four cases. In addition to interdependence, P/TO dominance was reported in all cases. A number of reasons for this perception were offered by interviewees. In Table 2, noticeable factors that contribute to P/TO dominance include the liners' lack of any alternative port choice, the monopoly management structure of the port group, and the scarcity of costal resources controlled by P/TOs.

Exceptional findings were reported in the case of Xiamen, where the port representative of LSC1 felt the P/TOs in the Port of Xiamen were 'a little weak' despite the interdependent relationship between the two parties being studied. This was agreed by one director from the business department of TO1, who claimed LSCs were more powerful, as they are international corporations. Evidence from the interviews indicates that the reasons for the perception of LSC dominance were related to the governance structure of Xiamne Port Group and the level of inter-port competition.

From the perspective of power theory, the explanations offered by the respondents for the power pattern regarding LSC/TO dominance were related to the source of power. Theoretically, this factor determines the amount of power held by social actors. As a power pattern is a reflection of the relative amount of power, power sources can be regarded as an essential indicator of the pattern of power relationships.

4.3. The Mapping of Power Patterns in Chinese Hub Seaports

The analysis of power patterns makes possible the mapping of these four seaports' power positions based on Figure 2. In Cox's (2001a) power matrix (Figure 2), the four types of power relationship are formed based on the relative amount of power held by supplier and buyer. The location of the vested inter-organisational relationship in Figure 2 can be determined by the findings about the power patterns between LSCs (buyers) and P/TOs (suppliers) in sections 4.1 and 4.2.

However, the original power matrix needs to be revised to fit the power patterns in the Chinese seaport sector. More specifically, the four power positions in Figure 2 are theoretically exclusive. However, evidence from the case study indicates that there is a multidimensional perception about vested power patterns. This means the power pattern in one Chinese hub seaport may be characterised by more than one type of power position in

Figure 2. In order to address this feature, the mapping of power patterns in Chinese hub seaports is presented in a coordinate system (Figure 3) based on Cox's (2001a) power matrix. In Figure 3, the horizontal axis represents the change of power imbalance from buyer (LSC) dominance to supplier (P/TO) dominance, and the vertical axis indicates the evolution of mutual dependence from buyer/supplier independence to buyer/supplier interdependence. Scale is omitted in the coordinate system because of the qualitative nature of the data collected. The positioning of these four ports in Figure 3 is based mainly on interviewees' perception about power patterns.

In general, P/TOs and LSCs are highly interdependent in all these seaports. However, this does not mean these two parties' power is balanced. Interview evidence has indicated that in addition to the interdependent relationship, the power patterns in the case of Shanghai Port, Ningbo Port, and Qingdao Port were also characterised by P/TO dominance. In terms of Xiamen Port, both buyer dominance and supplier dominance were demonstrated. The characteristics of the power relationship in Xiamen Port are illustrated in the figure by virtue of its relative location in relation to the other three ports. Based on these four ports' location in Figure 3, it is noticeable that the power position of P/TOs in Xiamen Port is less advantageous in comparison to P/TOs in the other three hub ports.

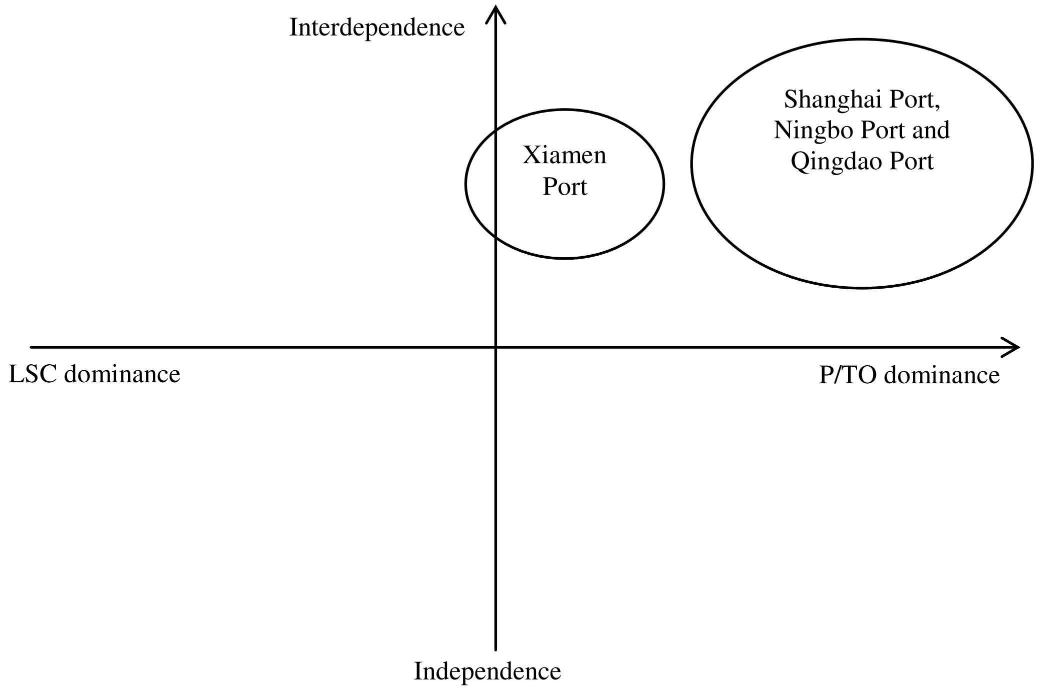

Figure 3: The mapping of power patterns in Chinese hub seaports

5. Conclusions

By studying power patterns in the Chinese seaport sector, the relative market position between P/TOs and LSCs has been clarified. In general, the vested power pattern is multidimensional. In addition to the wide consensus about LSC-P/TO interdependence, the power patterns in the case of Shanghai Port, Ningbo Port, and Qingdao Port were characterised by P/TO dominance, whereas both P/TO dominance and LSC dominance were demonstrated in Xiamen Port. Therefore, a broad conclusion can be drawn regarding P/TOs' powerful status in relation to LSCs in the context of Chinese hub seaports.

This paper has applied the theory of power to the seaport and liner shipping industry. It attempts to raise more awareness about the study of power in the maritime sector. The paper adds empirical findings to the flourishing Chinese maritime market. It contributes to the power literature by applying Cox's (2001a) power regimes to an underdeveloped research setting. The multidimensional perception about the vested power patterns implies that the four possible power positions may not be exclusive when a qualitative research design is adopted.

Since social actors tend to pursue a favourable power position, the identification of power patterns has suggested directions for P/TOs and LSCs to achieve such a purpose. In addition, it is also important for these two parties to form a business strategy and ultimately achieve business success. However, respondents' explanations about their perception of power patterns imply a contextual-embedded feature of this concept. Therefore, the extent to which the findings of this paper can be generalised to seaports in other regions of the world remains to be seen. The complexity of the concept of power and its underdeveloped status in SC studies calls for the attention of future researchers.

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Cabotage Policy and Development of Short Sea Shipping in Korea, China and Japan

Yong An Park[1 2] and Francesca Romana Medda[2]

[1]Korea Maritime Institute, Korea
[2]UCL QASER Lab, University College London

Abstract

Coastal shipping and short sea shipping both play a significant role as branches in the larger global transport networks. Different from the European Commission, however, which integrates coastal shipping for liners of member countries, countries in North East Asia, specifically Korea, China and Japan, maintain principally strict cabotage policy for protecting their domestic coastal shipping. In the present paper we review the role and status of coastal shipping for Korea, China and Japan and examine the development of short sea shipping in the region. We find that cabotage policy is a crucial element in the formation of hub-and-spoke networks in the region, and highlight the importance of common policy on cabotage for developing and integrating short sea shipping in the region through a common policy tool, e.g. allowing foreign flags and deep oceangoing national liners to transport empty containers.

Keywords: Coastal shipping, Cabotage, Short sea shipping, Hub-and-spoke, Korea, China, Japan

1. Introduction

North East Asia is a leading region in the global shipping industry. Container throughputs for three major shipping countries in the area show more shares than elsewhere in the world: in 2010 China contributed 25% and 125 million twenty foot equivalent unit (TEU); Korea 4% with 19 million TEU; and Japan 3.6% with 18 million TEU (Informa UK, 2012). Furthermore, the slot capacity of main liners of Korea, China and Japan, which are in the top 20 of the world ranking, comprises about 28% of world fleets (NYK Line Research Group, 2014). North East Asia has also played a pivotal role in introducing and implementing new trends and a new maritime policy in liner shipping due to its increasing market power. For example, as a leading global shipping country, the Chinese government in 2014 rejected the P3, an alliance between Maersk, MSC and CMA CGM, which rank 1, 2 and 3, respectively, worldwide in liner shipping (Wall Street Journal, 2014). That decision dismantled the alliance in Asia-Europe routes and also curtailed growth on other routes.

Another concern in the state-of-play between global shipping giants Europe and North East Asia is the policy on cabotage and short sea shipping in the Asian territory. When the European Community completed the integration of its shipping market in 2004 to allow shipping companies of member countries to participate in cabotage activity, European liners were thereafter able to deploy the same vessel in short sea shipping and domestic coastal shipping for the same shipper within member countries. More recently, short sea shipping in Europe includes cabotage activity. However, North East Asian countries maintain a strict cabotage rule of exclusion operation and the principle of separation between short sea shipping and cabotage activity – coastal shipping – even within regional areasand in spite of significant increase of trade flows at regional level. The exploration of oil and gas offshore, and conflict over marine territories in Far East and South East Asia also make the cabotage issue even more complicated with respect to the spatial range of cabotage and the concept of coastal shipping (Aspinwall, 1987).

As part of the global network, coastal shipping is affected by cabotage policy and domestic logistic systems, domestic transport policy, trends in short sea shipping and deep sea-going shipping, and other internal and external circumstances. In addition, each network of short sea shipping feeder has its own unique historical background and characteristics of development. In an agreement in the early 1960s between the governments of Korea and Japan after Korean independence and remuneration for Korea's losses, the shipping network between Korea and Japan was run mainly by Korean companies in the aim to normalise diplomatic relations between the two countries.

We find evidence for decisive discussion on the liberalisation of shipping services and efficiency of global shipping networks in an international service agreement, as well as the assertion that international shipping also includes domestic feeder services – coastal shipping – for foreign trade cargoes. The Trade in Service Agreement (TISA), a new international service agreement was recently initiated by the EC after the World Trade Organization/Doha Development Agenda (WTO/DDA) in 2013: with a focus on the liberalisation of maritime services including coastal shipping activities (Sauve, 2013; Park and Cho, 2013). Main countries in Asia, North America and South America including China, Japan, US, Canada, and Mexico, sustain cabotage for national flag ships and domestic coastal shipping companies. If we conclude a new trend in cabotage policy and short sea shipping in North East Asia, we may evaluate the possibility of integration of short sea shipping in North East Asia and draw a futuristic view of global shipping network.

The present paper is aimed at reviewing cabotage policy and its implementation, discussing the trend of short sea shipping between Korea, China and Japan, analysing the connection between coastal shipping and these short sea shipping networks, and extracting a possible common policy of the three. The paper also tries to uncover new trends in liner shipping through examining cooperative shipping policy and strategy in North East Asia.

Next in section 2, we review the literature on cabotage policy and explain the methodology for the present paper in which we reconsider the relationship between cabotage policy and domestic logistics systems. Section 3 describes the role of coastal shipping in the three countries and scrutinises legal schemes and policy changes of cabotage within them. Section 4 discusses the development of short sea shipping and connectivity between costal shipping and short sea shipping in the North East Asian region. Section 5examines the benefits and disadvantages of strict cabotage policy, and discusses how different common policy on cabotage may lead to the integration of short sea shipping in the region. Conclusions are drawn in section 6.

2. Literature Review and Methodology

2.1 Literature Review

Cabotage is directly related with coastal shipping and feeder services of global liners. We can differentiate between the two concepts *coastal shipping* and *short sea shipping*, as defined by the British government: coastal shipping is shipping between two or more points of a country; short sea shipping is shipping between a country and the other country in the same region within the same continent (Saldanha and Gray, 2002). In order to discuss a geographical coverage of services generally, we can identify *shipping* as coastal shipping, short sea shipping and deep-sea going shipping in a global shipping network.

On the one hand, we observe that cabotage may restrict the operations of hub-and-spoke networks from the view of global liners, especially European liners. In an analysis of global liners, Zheng et al. (2014) argue that feeder networks around a hub port can be affected by cabotage policy of neighboring countries. In particular, Hong Kong port is able to handle transshipment cargoes of regional ports in China where only Chinese coastal shipping companies transport cargoes between Chinese ports. However, Busan port has collected transshipment cargoes from the neighbouring countries, e.g. Japan and China.

On the other hand, cabotage in shipping is a vital part of a country's sovereignty and green logistics. The United States maintains a strong cabotage rule for marine sovereignty through the laws: Merchant Marine Act of 1920, Passenger Shipping Act of 1886, and Vessel Documentation Act of 1980 (Aspinwall, 1987). Coastal shipping in the US must be serviced by the US flag, US seafarers, and equipment and parts made in the US). In Europe, the use of short sea shipping and coastal shipping can reduce toxic emissions, increase economic efficiency for cargo movement, and result in lower social costs (Saldanha and Gray, 2002; Medda and Trujillo, 2010; Lazarus and Ukpere, 2011).

Cabotage in shipping has both positive and negative aspects in relation to policy, according to different scholars, as in the case of New Zealand (Cavana, 2004). In New Zealand, for instance, among domestic transport modes, coastal shipping is exposed to the choice behaviour of shippers (Brooks, 2008; Yuen et al., 2012). In general we can observe that shippers tend to have different views on cost efficiency of cabotage policy against coastal shipping companies (Cavana, 2004). Through investigating cabotage policy in Korea, China and Japan, the paper tries to capture future trends in global liner shipping.

2.2 Methodology

Global liners have been eager to optimise their fleet deployments by building hub-and-spoke networks and also by integrating the three shipping services into a single shipping network. In North East Asia the deep sea-going shipping market is run by global liners. There are diverse types of players, liner conferences and alliances in short sea shipping. We therefore assert that a business entry registry and a legal structure for foreign direct investment for the three shipping services would be decisive factors for global liners supplying global services. Small and medium sized liners willing to expand service networks would also benefit from a shipping structure that seamlessly connects coastal shipping, short sea shipping and deep sea-going shipping.

Since cabotage policy is implemented by each country which has independent right to decide their coastal shipping and each country has its own geographical peculiarities, we can surmise that policy makers in each country can build policy tools on entry registry, foreign investment and allowance of national flag in coastal shipping. These policy tools are framed in relation to market performance are related with other shipping policy, port policy and domestic transport policy.

Against this background, in this work we will compare the market and legal schemes of cabotage operations in three North East Asia countries, Korea, China and Japan, in order to verify the changes that can produce increase in market share through cabotage systems and operations and the relation with short sea shipping systems. The analysis will be structured according the following steps. In a first step, we review the present status of coastal shipping in North East Asia by describing the volume share and average distance of coastal shipping in Korea, China and Japan. We include long-term trends of all domestic transport modes, including short sea shipping.

Thereafter in our second step we will compare the legal system of business definition and registry of business entry for coastal shipping, short sea shipping and deep oceangoing shipping for Korea, China and Japan. The legal institutions of Korea, China and Japan mirror the geographical characteristics of each country; China for example, has the broadest coastline in North East Asia and therefore has more detailed businesses in coastal shipping. After a discussion of each country’s legal and business structure, we examine the restrictions, if any, on foreign direct investment and discuss whether foreign liners are permitted to invest in coastal shipping. Some countries prohibit such investment.

Lastly, we examine the connection between coastal shipping and short sea shipping in Korea, China and Japan. The cargoes of short sea shipping in North East Asia can be categorized as either direct export and import cargoes or transshipment cargoes.

3. Markets of Coastal Shipping in the Region

3.1 Korea

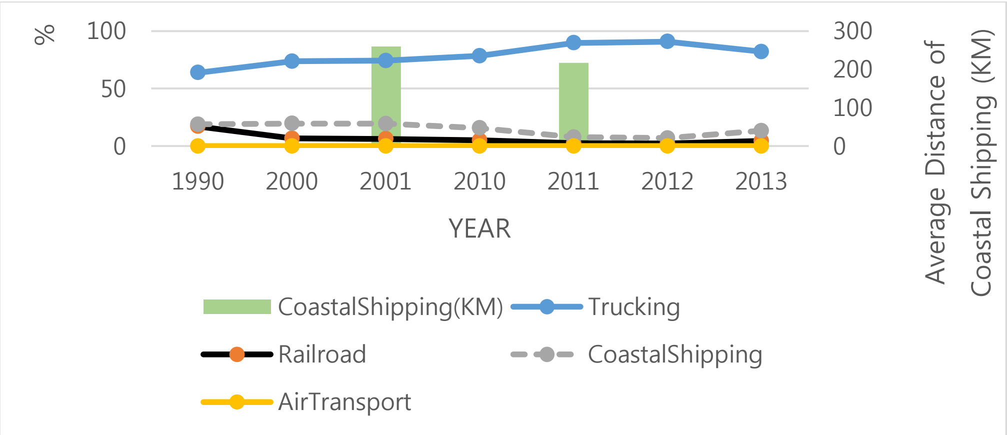
3.1.1 Role of Coastal Shipping

The coastal shipping shares 13.4% of total domestic cargo movement in Korea in 2013. The share of cargo tonnage indicates a decrease in the trend since 2000, when it recorded 19.6%. The main mode of domestic transport is trucking, sharing 82% in 2013. The share of railroad transport also shows a decreased trend since 1990. The average distance of coastal shipping in Korea is 217 km in 2011, shorter than both China and Japan. This characteristic is likely due to the geographical position of Korea: in the southern part of the Korea Peninsula the maximum distance between cities is about 500 km, and the distance between main industrial complexes is less than 400 km.

3.1.2 Business Entry and Cabotage Rule

The Law of Shipping Business of Korea identifies the cargo shipping business into three types: coastal cargo shipping, deep oceangoing cargo shipping, and irregular cargo shipping business (Ministry of Government Legislation of Korea, 2015). The law requires a coastal cargo shipping company to obtain a license from a competent maritime authority. In addition, the Ship Act regulates the restriction of coastal cargo shipping from one port to another port in the Korean business territory and permits only national flags in cargo shipping and oceangoing cargo shipping to transport cargoes between ports in Korea, with exceptional cases under treaty, or any such case as permitted by the Minister in Ministry of Oceans and Fisheries (MOF) (Ministry of Government Legislation of Korea, 2015). Direct investment by foreigners in coastal shipping is allowed but it is restricted on the condition that Korean parties in the company should be controlling shareholders.

Figure 1: Share of each domestic transport mode and average distance of coastal shipping in Korea



Source: Ministry of Land, Infrastructure and Transportation of Korea, Statistical yearbook, at each year

3.1.3 Change of Cabotage Policy

In the 2000s, the Korean government changed its cabotage rule. First, the MOF allowed national deep oceangoing shipping companies to participate in coastal container shipping starting in 2003. Then in 2005the MOF permitted foreign flag shipping companies to participate in domestic feeder networks for a temporary period in order to boost transshipment activity in Gwangyang port (MOF, 2005) (MOF, 2005; Park and Medda, 2015).

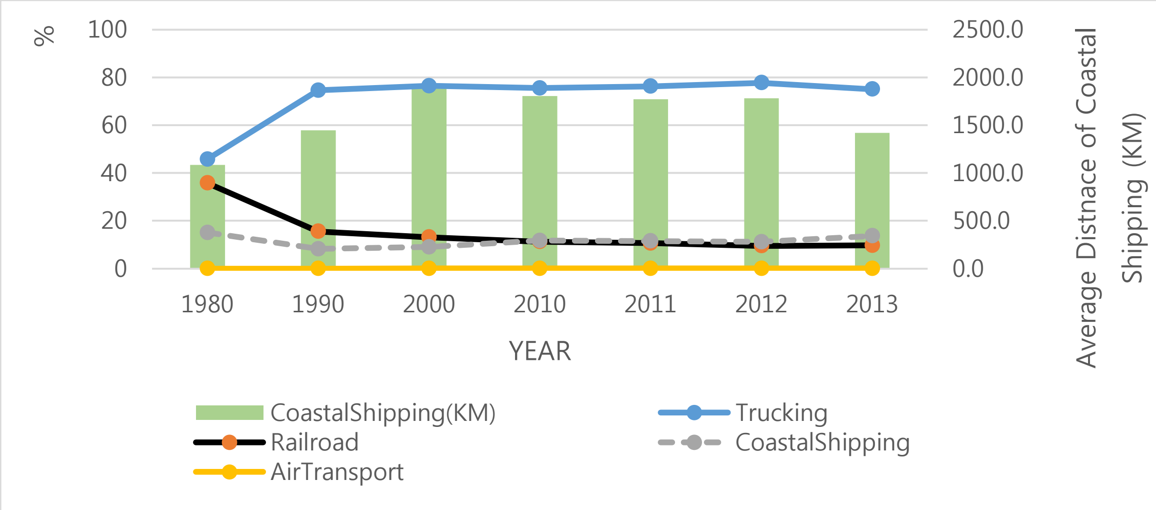
While Korea has taken a liberal position in international agreements on maritime services such as the General Agreement on Trade in Services (GATS) in 1994 and Trade in Service Agreement (TISA) after 2013, Korea did not make a commitment on cabotage issues such as coastal feedering of cargoes and passengers, coastal shipping of transport equipment including empty containers, and offshore maritime services in the GATS.

3.2 China

3.2.1 Role of coastal shipping

The share of coastal shipping in China showed an increasing trend,of 9% in 2000,rising to 13.7% in 2013. In China, trucking is the main mode of domestic transport, with a share of 75.1% in 2013. However, the percentage of railroad decreased from 15.5% in 1990 to 9.7% in 2013. The average distance of coastal shipping in China is 1,419 km in 2013, about seven times of that of Korea. Coastal shipping in China seems to play a main artery for bulk cargoes between ports beyond a distance of 1,000km.

Figure 2: Share of each domestic transport mode and average distance of coastal shipping in China



Source: Year Book House of China Transportation & Communication (2014), Year Book of China Transportation & Communications

3.2.2 Business entry and cabotage rule

The Maritime Code of China discusses that maritime transport and towage services between the ports of China shall be undertaken by Chinese flag ships except as otherwise provided for by laws or administrative rules and regulation.

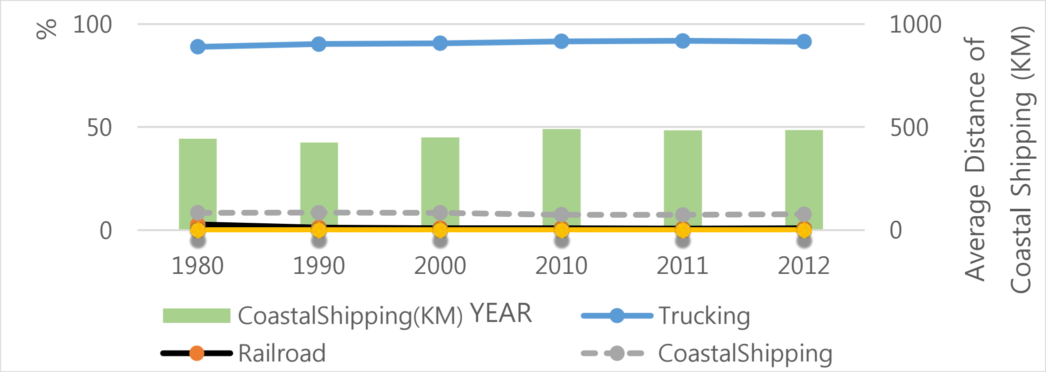
The Chinese regulation on coastal cargo shipping specifies categories of business into three types: inland waterway transport, coastal shipping within a province, and inter-province coastal shipping.
The Catalogue of Industries for Guiding Foreign Investment (2011 Amendment) describes the encouraged industries and the restricted industries for foreign direct investment (Ministry of Commerce of China, 2011). Foreign Direct Investment in coastal shipping is allowed but is restricted on the condition that Chinese parties of a company should be controlling shareholders. Foreign ships may engage in maritime transport and towage services only by gaining permission from the competent authorities of transport and communications. China did not implement the cabotage activities drawn up in the 1994 GATS agreement.

3.3 Japan

3.3.1 Role of coastal shipping

Japan has a slightly lower proportion of share in coastal shipping in its domestic transport, compared to Korea and China. The share of coastal shipping in Japan showed a similar level of 8.4% from 1980 to 2000, but recorded a slight decrease from 8.4% in 2000 to 7.7% in 2012. Trucking is the main mode of domestic transport, sharing 91.4% in 2012. The average distance of coastal shipping trips is 485 km in 2011, about two times longer than that of Korea. There are many liner shipping routes by ferry and full container ships between the main islands of Japan (Ocean Commerce Ltd., 2012; Port and Harbor Association of Japan, 2014).

Figure 3: Share of each domestic transport mode and average distance of coastal shipping in Japan



Source: Statistical Bureau, Ministry of Internal Affairs and Communications of Japan (2015), Japan Statistical Yearbook 2015

3.3.2 Business entry and cabotage rule

The Ship Law of Japan describes the conditions for the Japanese flag ships and regulates that only Japanese flag ships can supply maritime services between the ports of Japan. Nevertheless, there are exceptions of this cabotage for those treaties, with regard to most favoured nations (MFN) treatment, and with permission from the Japanese government: Anglo-Japanese Treaty of Commerce and Navigation of 1894, Treaty of Commerce and Navigation of 1896 between Norway and Japan and MFN treatment for seven countries including France, Germany, Denmark, Sweden, India, Thailand, and Haiti (University of Tokyo, 2012).

The right to engage in coastal shipping by foreign flag ships is available on treaties of friendship, of commerce and navigation with Japan and on a reciprocal basis. In addition, the minister of Ministry of Land, Infrastructure, Transport and Tourism can permit foreign flag ships to participate in coastal shipping on the condition that their participation is not harmful to national safety, does not hinder domestic shipping companies in coastal shipping, and on reciprocal basis. The permission is valid only for a certain voyage, port and period. Every year about 3,000 permissions for coastal shipping are issued to foreign flag ships to transport empty and full containers (University of Tokyo, 2012). In addition, the Japanese government has allowed Japanese deep oceangoing shipping companies to participate in coastal container shipping between Okinawa and other regions in Japan since 2010, and foreign flag shipping companies to participate on that route on a reciprocal basis from 2010.

Japan also takes a liberal position in the GATS international agreement on maritime services. However, it is noteworthy that Japan did not make any commitment with regard to the cabotage issues in GATS.

4. Development of Short Sea Shipping in the Region

4.1 Short sea shipping between Korea and China

Prior to 1989, the main routes between Korea and China were so-called feeder routes between Korean ports and the port of Hong Kong and Chinese coastal shipping routes after transshipment in Hong Kong Port. Jang Geum Shipping Lines, a joint venture of Korean and Chinese liners, began direct shipping services between Korea and China in 1989;this opening of direct routes largely increased the trade volume between them (Baik and Park, 2002). In addition, a bi-lateral shipping agreement between Korea and China in 1993 further propelled the enlargement of the shipping routes.

Although Korea and China agreed that the shipping market between them should be operated on the free market principle, liner shipping between Incheon port and Chinese ports by container ships has been restricted by both governments since2002 (Yoo, 2011). As a result, routes between Korea and China have developed mainly at Busan port rather than Incheon port, which is nearer to Chinese ports at the Bohai Rim than Busan port. The Chinese government has thus far allowed Korea liners to move empty containers only on the Shanghai-Ningbo route since 2005 (Korea Shipowner's Association, 2005).

If foreign liners besides Korean flag and Chinese flag ships were to build feeder networks in the Chinese northern ports located at the Bohai Rim, they would choose hub ports among the main ports in Korea, Taiwan and Japan. Shipping between China and Taiwan is considered as cabotage by the Chinese government (Chiu, 2007). Foreign liners will choose main Korean ports as their hub choice because Japan is too far from Chinese ports. These factors of Chinese cabotage policy, geographical location of Busan port, and agreement between the Korean and Chinese governments has helped Busan port construct a broad hub-and-spoke network in North East Asia. From the view of shipping networks, Busan port could combine short sea shipping networks with China and other networks with Japan and North America countries. Busan port could improve its connectivity for short sea shipping with China (and also other routes) as a result of restrictions put in place on routes by both governments as well as China cabotage policy.

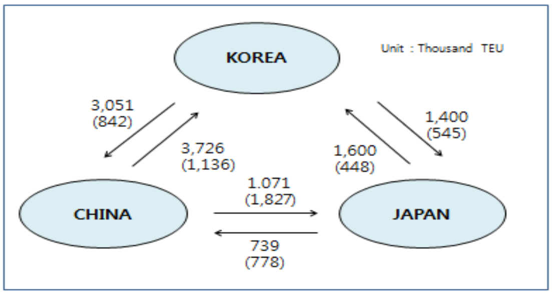
Table 1: Nautical distance table between ports of Korea, China and Japan Unit (nautical mile)

	Korean ports		Chinese ports			Japanese ports		Taiwan
	Incheon	Busan	Tianjin	Dalian	Tangku	Kobe	Hiroshima	Kaoshiung
Incheon	-	406	500	288	469	753	601	980
Busan	406	-	723	549	711	363	253	913
Tianjin	500	723	-	245	31	1046	1010(e)	1234
Dalian	288	549	245	-	203	957	743	1043
Tangku	469	711	31	203	-	1015	906	1203
Kobe	753	363	1046	957	1015	-	36	1121
Hiroshima	601	253	1010(e)	743	906	36	-	1062
Kaoshiung	980	913	1234	1043	1203	1121	1062	-
Average distance	571.0	559.7	629.8	575.4	648.3	755.9	600.2	1079.4

Source: Japan Shipping Exchange Inc., Distance Tables for World Shipping, 1975. Note: nautical miles in the shortest route

While each of the two governments sustains its own cabotage policy with allowance of empty container transport in a specific route by Chinese government, the short sea shipping between Korea and China was developed around Busan port in Korea. Nevertheless, from the view of global liners, Busan port could build a vast networks with Chinese regional ports due to cabotage rule of China. Hence, the cabotage policy of Korea has very little impact on building short sea shipping networks between Busan port and Chinese ports.

Figure 4: Container volume between Korea, China and Japan in 2004 and 2013



Source: MOF (www. spidc.go.kr, 2015) Ocean Commerce Ltd (2015)
Note: figures in parentheses indicate container volumes in 2004; non-parentheses show volumes in 2013

Nowadays, the volumes shipped on the Korea/China routes represent the main source of container throughputs in Korean ports. The total container volume in Korea/China routes has increased from 1.978 million TEU in 2004, to 6.777 million TEU in 2013, as shown in Figure 4.

4.2 *Short sea shipping between Korea and Japan*

Although the bilateral shipping agreement between Korea and Japan has not yet been concluded, both parties have been part of the Korea-Japan Shipping Working Committee since 1987. The committee was integrated into the Korea Near-sea Federation Council (KNFC) in 1989. After 1995, the committee and KNFC have worked as a kind of liner conference and have regulated the entry of Japanese liners into the short sea shipping routes between Japan and Korea. Korean cargo pooling system and cargo ceiling have implemented joint operation between the two countries in the feeder routes thus expanding the Korean regional coverage in Japan. The committee and KNFC maintained the cargo pooling system and cargo ceiling, and defined the shares of each member until the early 2000s (Maritime Korea, 2001). The Korean government however regulates the entry of foreign liners, besides Korean and Japanese liners, into the feeder routes (MOMAF, 2005). The regular yearly Discussion on Maritime Services between Korean government and Japanese government is the main body which decides on rules and regulations of the feeder routes between both countries

Although Korean liners are not permitted to transport containers between Japanese ports, they nevertheless provide Japanese shippers with feeder services at lower rates than Japanese coastal shipping and trucking between regional ports and hub ports in Japan. As shown in Table 2, the total transport cost of the Feedering service in Busan port for shippers at Hiroshima in Japan is $US 2,732; Coastal shipping $US 2,773; and for Trucking $US 3,216 in 2011.

Table 2: Comparison of transport costs between Japan/West Coast of North America

Mode	Content of intermodality	Total cost
1	Hiroshima (Trucking) → Hiroshima Port (Coastal shipping) → Kobe port → West Coast of North America	2,773 USD/FEU (344 Thousand Yen)
2	Hiroshima (Trucking) → Kobe port → West Coast of North America	3,216 USD/FEU (399 Thousand Yen)
3	Hiroshima (Trucking)→ Hiroshima Port (Feedering) → Busan port → West Coast of North America	2,732 USD/FEU (339 Thousand Yen)

Note: The exchange rate is calculated at the basic rate.

Source: University of Tokyo (2011)

The development of a feeder network between Busan and Japanese ports has been affected mainly by the liner conference on the routes and joint-fleet operations of Korean liners. Another factor that we need to consider is the expensive costs of road transport and coastal shipping in Japan, which has also promoted the expansion of feeder networks between Busan and Japanese ports. Table 2 highlights that the costs for transshipment in Busan port for Japanese shippers are lower when moving their cargoes from Hiroshima in Japan to the West Coast of North America.

The cargo pooling system, cargo ceiling, and joint operations of Korean liners in the Korea/Japan routes have all contributed to increase the relevance of Busan port thus building a broad networks of short sea shipping with Japanese regional ports. Additionally Busan has expanded its short sea shipping situation between Korea and Japan due to its short distance from the Japanese coasts. In fact, Japanese strict cabotage policy disallows foreign liners, and even Japanese deep oceangoing liners, from transporting cargoes between Japanese ports. Therefore, since Busan is nearest foreign port hub between the different North East Asia countries and Japan, Busan is chosen as the preferred port to handle transshipment cargoes with Japan.

When we turn to Table 3, we can observe that during the 1970s and 1980s Japanese ports such as Kobe and Yokohama have played a role as hub. Japanese hub ports have built hub-and-spoke networks for both Korea and China.

The dynamic changes occurring in Busan port from the 1970s to the 2000s show close mutual relationships among the physical aspects of the port: trade volumes, shipping fleet, port throughput, and port status. In this context, and by considering the observation of developments of Korea-Japan shipping routes and port networks, we may imply some suggestions to predict the Korean shipping industry and port status going into the 21st century.

Table 3: Korea-Japan liner shipping routes (December 1971)

Ports in Korea	Ports in Japan	Average service time (day)	Ship type	No. of Services weekly	Shipping companies
Busan	Kobe	1.8	Traditional liner ships	12	Chon-gyong, Keumyoung, Namsung, Heung-A
Incheon	Kobe	5		2	Choyang, KMTC
Busan	Moji	1		1	Heung-A
Busan	Nagoya	3		1	KMTC
Incheon	Nagoya	6		2	KMTC, Choyang
Busan	Osaka	4		13	Chon-gyong, Keumyoung, Namsung, Heung-A
Incheon	Osaka	8		2	Choyang, KMTC
Busan	Shimonoseki	1		1	Heung-A
Busan	Tokuyama	7		1	Heung-A
Busan	Yokohama	4.5		2	KMTC, Namsung
Incheon	Yokohama	5		1	KMTC

Data Source: Korea Shipping Gazette (1971). Park and Choi (2012)

4.3 Short sea shipping between China and Japan

China and Japan secured diplomatic ties in 1972 and soon after concluded a bilateral shipping agreement whereupon liner shipping by containerships began in 1976 (Ocean Commerce Ltd., 2012). At the initial stage of liner services in the 1970s between the two countries, Japanese liners led the market and supplied deep oceangoing services and feeder services for transshipment in Japanese hub ports such as Kobe. Nevertheless, in the 1980s Chinese liners represented by COSCO raised their shares in the routes and recorded an approximately 90% share in the container movements. By late 1989, Chinese regional liners started to participate at the routes. In Japanese regional ports we observe Chinese liners such as COSCO, Ji Zhou Shipping, Minsheng, and SITC. In this short sea shipping context, cabotage policy of both parties seems not to affect the development of new hub ports or alter the shipping networks between China and Japan.

5. Discussion

5.1 Cabotage policy and connectivity at a port

Although short sea shipping by full containerships in North East Asia has developed since the 1970s, we notice a distinct separation between the markets of coastal shipping and short sea shipping due to strict cabotage rules. The markets of short sea shipping in the region have been divided into several networks on the basis of geographical coverage. Nevertheless, they are linked through transshipment and connection at ports, and may at some stage develop into global networks. Also importantly, a port faces different managerial environments including the strategy of liners, government policy, and competition from neighbouring ports. Cabotage policy in North East Asia has affected the specific process of connection between coastal shipping, short sea shipping, and deep oceangoing shipping.

The Korean government takes a more liberal position in cabotage policy than China and Japan. It has allowed deep oceangoing Korean flag ships to participate in coastal shipping since 2004 and has also temporarily permitted foreign flag ships to handle containers of coastal shipping along specific shipping routes. It is reasonable therefore, to consider that the main container ports in Korea such as Busan and Gwangyang could supply efficient connectivity between coastal shipping, short sea shipping and deep oceangoing shipping. Nevertheless, in the early 2010s, Hanjin Co., the main coastal shipping entity since the 1990s, exited from the market due to severe competition and financial deficit in its operations. Nowadays, it is possible for Korean deep oceangoing liners to supply coastal shipping and short sea shipping as well as deep oceangoing shipping for the same shippers. In addition, foreign flag liners can supply the connection between coastal shipping, short sea shipping and oceangoing shipping by its fleets along restricted routes in Korea.

In China, the Regulation on the Administration of Domestics Water Transport is responsible for coastal shipping. The regulation specifies the coastal shipping into three activities: inland waterway shipping, shipping within a province, and shipping in inter-province. Foreign providers may participate in coastal shipping only by leasing Chinese flag ships and slots of Chinese flag ships. Hence, the providers of coastal shipping in China are Chinese shipping companies registered as domestic water transport companies. We can find many coastal shipping companies in China. In addition, coastal shipping companies are the branches for domestically-traded goods moved over distances greater than 1,000 km.

Japan has kept a strict cabotage rule. Principally, Japanese coastal shipping providers can supply domestic feeder services between Japanese ports. Foreign flag ships in some exceptional cases can supply coastal shipping based on treaties of friendship, of commerce and navigation with Japan, and on a reciprocal basis. In the Okinawa route, Japanese oceangoing shipping companies may participate in the coastal container shipping between Okinawa and other regions in Japan from 2010, and foreign flag shipping companies may participate in that route on a reciprocal basis. In Japan we can observe large numbers of coastal shipping companies which transport containers and we also find many ferry shipping companies.

Among the three countries, Korea has more flexible cabotage policy for efficient connection between coastal shipping, short sea shipping and deep sea going shipping. Nevertheless, service providers registered as coastal shipping businesses have exited from coastal shipping due to severe competition with road hauliers, rail service, liners of short sea shipping and deep oceangoing shipping. Hence, we can distinguish between two sides with regard to cabotage policy on shipping and the port industry. On the one hand, cabotage protects coastal shipping providers from competing with short sea shipping and deep oceangoing liners and promotes environmentally friendly transport in the countries in North East Asia. On the other hand, cabotage has affected the shape of hub-and-spoke network around main ports in North East Asia, particularly e.g., the networks of Busan port.

5.2 Possibility for a single market in short sea shipping

There could be a potential progress of policy change in empty containers in a specific coastal route and under specific condition as in the cases of China government, Korea government and Japan government. Even though they presented a wide range of cabotage policy on foreign flags and deep sea going national flag, they represent us a flexibility in cabotage policy. Furthermore, if they make a common policy on cabotage, that new rule may spread world-widely through global shipping networks in main ports in in North-east Asia.

Since the regionalisation of the three big economies has promoted the integration of manufacturing and trade, we notice the potential for a single market for short sea shipping in North East Asia. Bi-lateral or tri-lateral as well as pluri-lateral negotiations of civilian or governmental sides on common shipping policy could effectively implement new rules on cabotage policy, as in the case of the P3 alliance.

6. Conclusion

Based on our review of cabotage policy in the North East Asia region, we can raise the following implications. Firstly, cabotage policy has affected the formation of hub-and-spoke networks around a main port, e.g. Busan, and impeded competition between main ports. Strict cabotage policy in mainland and routes between mainland China and Taiwan has prevented foreign flagships from developing their coastal shipping and short sea shipping networks. Secondly, geographical distance has worked beneficially to build short sea shipping networks in the region. Busan port could potentially gain, especially in relation to Japanese regional ports. Thirdly, a willingness to promote cooperation between governments could change the face of short sea shipping and the future of each port, as we have discussed in the case of bilateral shipping negotiations between Korea and China on the restriction of liner routes by containerships in Incheon port, Korea until the early 2000s.

Korea, China and Japan initiated their bi-annual ministerial conference in 2006 in order for Ministers of the three countries to discuss important cooperative issues in international transport, mainly shipping, ports and international intermodal transport. Significant issues arising include the standardisation of pallets, harmonisation of information of technology (IT) in the shipping and port industries, and efficiency in intermodal transport of trailer-chassis (trucking), widely used as the main mode in intermodal transport among the three. Although the conference has not called for the direct integration of the shipping market and common cabotage policy, it may decide on a new action plan on common cabotage policy. Towards the possibility of single market of short sea shipping, we could suggest some candidates for the initial stage of common policy.

The first candidate for common cabotage policy would be a policy to allow empty containers on foreign flagships and deep oceangoing national flag son a specific route, under the condition that such a policy change on cabotage is not a disadvantage for coastal shipping providers. The second candidate is a preparation policy against natural and social disasters such as tsunamis and earthquakes. In these types of disasters, rather than have to make a formal request, foreign flags and deep oceangoing national flags could automatically transport the cargoes. In a further step, China, Korea and Japan could develop an international recycle chain by combining coastal shipping, short sea shipping and oceangoing shipping for specific cargoes in the aim of environmental protection in remote areas on land and sea.

North East Asia is a leading region in international liner shipping with respect to container volumes, slot capacity of containerships and policy development. We could expect growing container throughputs of Chinese hub ports such as Shanghai, Tianjin and Qingdao and development of coastal shipping networks within China, and expansion of short sea shipping around Chinese ports. The expansion and development of Chinese hub ports may usher in new geographical changes to the current hub-and-spoke networks in the region.

Further study of each country's position in an international agreement and negotiation of maritime services could provide insights into changes taking place in hub-and-spoke networks and the connection between coastal shipping, short sea shipping and deep oceangoing shipping. In addition, analysis of the benefits and disadvantages of common policy in North East Asia could clarify the content and action plans of the shipping common policy. In studies of the domestic logistics system the analysis of the diverse interactions between transport modes around a port and coastal shipping activity could also yield useful insights.

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The Effect of Container Liner Shipping on Economic Growth: A Panel Data Analysis

Enna P. Hirata and Hideki Murakami

Graduate School of Business Administration, Kobe University, Japan

Abstract

In this study, unbalanced panel data are used to estimate how container liner shipping freight and liner connectivity influence economic growth for a sample of 31 countries over a seven-year period. The fixed and random effects are estimated by using the pooled ordinary least squares and feasible generalised least squares methods, respectively. The coefficients of both transport costs (using container liner freight as a proxy) and liner connectivity (liner shipping network integration level) are found to be statistically significant at the 5% level. Further, the estimated effect of liner connectivity on GDP growth is greater than that of container liner freight, which implies that an increase in liner connectivity could be more effective at stimulating trade growth. The main contribution of this study is thus quantifying the effects of the container liner shipping industry on economic growth.

Keywords: Liner Shipping, Liner Freight, Liner Connectivity, GDP, Economic Growth, Feasible GLS

1. Introduction

Liner container shipping has influenced global trade heavily over the past 50 years. Lower transport costs have allowed much lower value cargo to be traded as well as cargo from more remote areas to be sold in new markets. Consequently, container liner shipping industry has clearly contributed to trade growth in East Asia, notably in China. However, few studies have quantified these positive effects or explained their implications for the carriers and regulators in other regions.

Containerised transport has been a growing industry for the past 30 years. Between 1983 and 2006, world GDP growth was 4.8% per year, whereas container cargo growth averaged 10% per year (Stopford 2009). This trend has continued in recent years according to World Bank data with the exception of 2009 and 2011 when the industry suffered the effects of the global financial crisis. According to Alphaliner, global container volumes outstripped global GDP growth by 2.7 times during 2000 to 2009 and by 2.1 times in 2010 to 2012[1]. This long history of rapid growth in containerised cargo has led to the expectation of continuous growth in the industry. However, the lengthy delivery time for newly built vessels of several years makes the market slow to adapt to increased demand, with subsequent huge fluctuations in revenues, as seen in the aftermath of the financial crisis in 2009.

This paper uses unbalanced panel data for 31 countries over a seven-year period[i] to estimate the relationships between container liner freight, liner connectivity, and economic growth. Estimating by using panel data offers a number of advantages. Firstly, such data provide a large number of observations on individuals and time, which makes the resulting estimates more efficient and asymptotically consistent. Secondly, panel data allow us to check the individual and time effects in a regression. This approach thus provides more variance than that contained in time series alone, allows for individual system-specific heterogeneity to address the problem of omitted variable bias, and can reduce the potential for multicollinearity and aid identification.

* 'It is not length of life, but depth of life.' – Ralph Waldo Emerson
Prof. Hideki Murakami passed away on 23 September 2015 at the age of 50. He worked in the Sauder School of Business at the University of British Columbia and Graduate School of Business and Administration in Kobe University. He taught and published various papers on Econometrics and Air Transportation, especially LCC, Logistics, and Maritime Economics.

However, crucially, for the purpose of this study, the key benefit of panel data is that they allow us to derive the consistent effect of liner shipping on economic growth despite missing time periods and unobserved effects. Hence, we estimate the fixed effects (FE) and random effects (RE) of container liner freight and liner connectivity on economic growth. This statistical approach allows system-specific heterogeneity and accommodates endogenous regressors.

The rest of the paper is organised as follows. Section 2 reviews the literature on line freight. Section 3 outlines the framework and model applied. Section 4 describes the data available for the estimation. Section 5 presents the results and conclusions are drawn in the final section.

2. Literature Review

Previous research has focused on the relationship between shipping and economic growth. Many scholars have pointed out that ocean freight plays an important role in economic growth. North (1958) studied ocean freight during 1730–1913 and concluded that the radical decline in freight rates was an important part of the redirection of western resources during the vast economic development of the previous two centuries. Stopford (2009) modelled the seaborne trade–GDP relationship and suggested that these two variables move linearly. Bernhofen et al. (2013) suggested that containerisation stimulates trade in containerisable products (e.g. auto parts) and has complementary effects on non-containerisable products (e.g. automobiles).

Research has also quantified how transport costs affect economic growth. Sampson and Yeats (1977, 1978) assessed the incidence of international transport and tariff exports from Australia and the United Kingdom. The authors found that the trade barriers imposed by transport costs accentuated the role freight costs played in limiting international trade flows, which may indicate the importance of formulating measures to reduce transport costs in order to stimulate trade. Radelet and Sachs (1998) found a strong relationship between shipping costs and economic growth and suggested that geographic isolation and higher shipping costs may make it 'much more difficult if not impossible for relatively isolated countries to succeed in promoting manufactured exports'. Raballand et al. (2005) explored the role of transportation costs in weakening trade between the European Union (EU) and Central Asia. The authors argued that transport costs play an important role in causing Central Asian countries to generate far less trade with the EU than their relative location would suggest. However, research on modelling the relationship between GDP and liner transport costs has been scarce.

3. Theoretical Framework and Empirical Model

To quantify the relationship between shipping and economic growth, we use a model derived from the traditional macroeconomic literature. For any economy, GDP (*Y*) is the sum of consumption (*C*), investment (*I*), government spending (*G*), and net exports (*NX*),

$$\mathrm{Y} = \mathrm{C} + \mathrm{I} + \mathrm{G} + \mathrm{NX} \qquad (1)$$

$$\mathrm{NX} = \mathrm{EX} - \mathrm{IM} \qquad (2)$$

where EX is exports and IM is imports. Since EX and IM are composed of commodity value (CV) and transport costs (TC), we write
e

$$\mathrm{EX} = CV_e + TC_e \qquad (3)$$

$$\mathrm{IM} = CV_i + TC_i \qquad (4)$$

By substituting (3) and (4) into (2), we have

$$\mathrm{NX} = CV_e - CV_i + TC_e - TC_i \qquad (5)$$

Since 75% of international transport is containerised (Notteboom and Rodrigue 2008), we take the container liner freight index as a proxy of transport costs. Although there is a trade imbalance between inbound and outbound liner freights, they are proportional in the long-term. For instance, Asia/Europe east-bound freight is about 25% of west-bound freight based on the World Container Index (WCI). We denote liner freight as *fr* and define it thus:

$$f(fr) = TC_e - TC_i \tag{6}$$

By substituting (5) and (6) into (1), we have

$$\mathrm{Y} = \mathrm{C} + \mathrm{I} + \mathrm{G} + CV_e - CV_i + f(fr) \tag{7}$$

In this research, we aim to estimate the partial impact of liner freight on GDP; as the effects of the other factors (C, I, G, $\mathrm{CV_e}$, $\mathrm{CV_i}$) are unobserved, we use GDP growth to eliminate possible omitted variable bias. We also introduce another variable, namely *liner service connectivity* (see the description in Section 4.3), to estimate the impact of liner service on economic growth as well as bound (*bound*), country (*country*) and year (*yr*) dummies.

Let *gr* denote GDP growth. Hence, the estimated FE model has the following form:

$$gr_{it} = \gamma_0 + \gamma_1 fr_{it} + \gamma_2 lcdi_{it} + \eta bound + \theta_i \sum_{i=1}^{30} country_i + \tau_t \sum_{t=1}^{6} yr_t + \varepsilon_{it} \tag{8}$$

for *i* =1,…,30 and *t* =1,…,6 (*t* is the annual observation[ii] of country *i*), where ε_{it} is the error term.

Since unbalanced panel data are used, a RE regression is performed to test whether the missing time periods are systematically related to the idiosyncratic errors. The RE model using the feasible generalised least squares (FGLS) estimation corrects serial correlation in the errors of multiple regressors (Wooldridge 2002, 2003). By using RE, we can thus efficiently account for any remaining serial correlation due to unobserved time-constant factors.

To derive the GLS transformation, we first define a linear regression model with the composed error term,

$$y_{it} = \beta_0 + \beta_1 x_{it1} + \cdots + \beta_k x_{itk} + v_{it} \tag{9}$$

where $v_{it} = a_i + \mu_{it}$. Here, a_i is the unobserved effect fixed over time and μ_{it} is the idiosyncratic error serially correlated across time t and section i.

Under the RE assumptions,

$$Corr(v_{it}, v_{is}) = \sigma_\mu^2/(\sigma_\mu^2 + \sigma_\alpha^2), t \neq s \tag{10}$$

where $\sigma_u^2 = Var(u_{it})$, $\sigma_a^2 = Var(a_i)$.

Define

$$\lambda = 1 - \left[\sigma_\mu^2/(\sigma_\mu^2 + T\sigma_\alpha^2\right]^{1/2} \qquad [\mathrm{T=max(0, t)}] \tag{11}$$

which is between zero and one. Then, the transformed equation is written as

$$y_{it} - \lambda\bar{y}_i = \beta_0(1-\lambda) + \beta_1(x_{it1} - \lambda\bar{x}_{i1}) + \cdots + \beta_k(x_{itk} - \lambda\bar{x}_{ik}) + (v_{it} - \lambda\bar{v}_i) \tag{12}$$

where the overbar denotes the time averages. The RE transformation subtracts a proportion of that time average, where the proportion depends on $\sigma_u^2 = Var(u_{it})$, $\sigma_a^2 = Var(a_i)$, and the number of time periods.

The transformation in (12) allows for constant explanatory variables over time, which is one advantage of RE models over FE models. This is possible because RE assumes that the unobserved effect is uncorrelated with all the explanatory variables, whether fixed over time or not. If the full set of RE assumptions holds, the RE estimator is asymptotically more efficient than the FE one.

The autocorrelation AR(1) is applied to obtain the value of parameter $\hat{\lambda}$. The RE estimator is the GLS estimator that uses $\hat{\lambda}$ instead of λ.

Finally, Hausman's (1978) specification test is applied to test the difference between the RE and FE estimates. Hausman's test compares an estimator $\beta 1$ that is known to be consistent with an estimator $\beta 2$ that is efficient under the assumption being tested. The null hypothesis is that the estimator $\beta 2$ is indeed an efficient and consistent estimator of the true parameters. If the null hypothesis cannot be rejected, there should be no systematic difference between the two estimators. Since FE is consistent but RE is inconsistent, a statistically significant difference is interpreted as evidence against the RE assumption. This study also uses Hausman's method to test the exogeneity of the variables.

4. Description of the Variables and Data

The data available for the estimation are for 2007–2013 for 22 countries in Europe and eight countries in North America (Table 1).

Table 1: Definitions and Descriptive Statistics of the Regression Variables

Variable	Specification	Mean	St. Dev	Minimum	Maximum
gr	GDP growth	1.14	4.39	-17.96	14.16
Fr	Container Liner Freight Index	40.52	35.57	2.40	157.51
lcdi	Liner Service Connectivity Index	2495.00	652.51	1362.00	3321.00

4.1 GDP growth (gr)

GDP growth is sourced from the World Bank. It is calculated as the annual percentage growth rate of GDP at market prices based on a constant local currency. Aggregates are based on constant 2005 U.S. dollars. No deductions for the depreciation of fabricated assets or for the depletion and degradation of natural resources are made. As noted earlier, we adopt GDP growth instead of GDP or GDP per capita in our models to eliminate possible unobserved variable bias.

4.2 Container Liner Freight (fr)

We measure this variable by using the freight index reported by Drewry's WCI for the period of 2007 to 2013. This reports the actual spot container freight rates for the major East–West trade routes. The indices are reported in USD per 40 ft container, while WCI rates are reported on a container yard to container yard basis inclusive of surcharges associated with the transport of goods[iii].

In common practice, container liner freight is offered based on the main ports (MP) concept. For instance, the rates per 40 ft dry container from East Asian MP to North European MP are typically the same. By contrast, rates to non-MP or outport are often offered with a standard add-on to MP rates and fluctuate in line with the MP rate. Hence, all available container freight indices report fluctuations in the MP rate. Of the 11 route-specific indices reported by the WCI, we choose four MP-based routes of larger volumes from Shanghai: to Rotterdam (one of the MP in North Europe), to Genoa (one of the MP in the Mediterranean), to Los Angeles (one of the MP on the West Coast of the United States), and to New York (one of the MP on the East Coast of the United States). Finally, we use the outbound rate indices only, as the inbound rate is a proportion of the outbound rate, as discussed in Section 3.

4.3 Liner Service Connectivity Index (lcdi)

This index captures the extent to which countries are connected to global shipping networks. It is computed by UNCTAD based on five components of the maritime transport sector: (a) the number of ships; (b) the total container-carrying capacity of those ships; (c) the maximum vessel size; (d) the number of services; and (e) the number of companies that deploy container ships on services from and to a country's ports. For each component, a country's value is divided by the maximum value of each component in 2004. The five components are then averaged for each country, and the average is divided by the maximum average for 2004 and multiplied by 100. The index generates a value of 100 for the country with the highest average index in 2004.

Assuming that higher liner connectivity stimulates trade activities, we expect the coefficient of lcdi to be positive. Basis on the routes selected, the countries involved are China, where the load port Shanghai is located, and 30 other countries (Appendix 1) in Europe and North America where the destination ports are located.

4.4 Control variables: year (yr), country (country) and bound (bound) dummies

We control for country in the FE model to eliminate omitted variable bias. We control for the potential impact of year, taking account of liner freight cycles (Stopford 2009, Wijnolst and Wergeland 2009). We further control for bound to test the effect of the trade imbalance on economic growth. The bound dummy has a value of 0 if the country's outbound freight level is higher than its inbound freight level (or the export containerised volume is greater than the import containerised volume) and 1 otherwise.

5. Results

The Hausman statistic for fr and lcdi is 6.16 distributed chi-square with a 1 degree of freedom. Given that the 5% critical value is 3.84, the two variables are thus exogenous. Our models are therefore consistent.

The feasible GLS parameter obtained by using AR(1) is 0.496. Since the ordinary least squares (OLS) and FGLS are different estimation procedures, the parameters in the estimation results vary. The Hausman statistic for the OLS and FGLS estimates is 0.837 distributed chi-square with 9 degrees of freedom. Hence, the null hypothesis holds at 1% significance level, which indicates that both models are consistent and that the FGLS estimate is more efficient. The FGLS estimator is thus preferred to the OLS estimator since it has a smaller standard deviation and the FGLS test statistics are asymptotically valid. The RE results estimated by FGLS suggest fr (liner freight) is statistically significant at the 5% level, ceteris paribus one percentage point increase in fr increases gr (GDP growth) by approximately 0.0014 percentage points (Table 2).

The RE regression results also show that lcdi (liner connectivity) are statistically significant at the 5% level. Ceteris paribus one point increase in lcdi increases gr (GDP growth) by 0.0187 percentage points. Moreover, the coefficients of the bound dummy in both models are statistically significant at the 1% level. The positive value indicates that the effect of inbound volumes on GDP growth is 4.1502 times that of the outbound volumes.

6. Concluding Remarks

This study uses unbalanced panel data on container liner freight and liner service connectivity to estimate the responsiveness of GDP growth to changes in liner shipping factors. An unbalanced panel estimation accommodates individual system-specific heterogeneity, endogenous regressors, and measurement error. Therefore, compared with the FE model, the results from the RE model are more efficient. The empirical results reveal that the effect of liner freight on GDP growth is statistically significant at the 5% level and that the effect of liner freight (transport costs) is non-negative in contrast to the conclusions of the studies reviewed in Section 2. This non-decreasing relationship suggests that reducing transport costs does not contribute to GDP growth. Further, the coefficient of liner connectivity is statistically significant, positive, and substantially higher than that of liner freight. The implication of this finding is that an increase in liner connectivity may be more effective at stimulating economic growth.

Table 2: Estimation results (Dependent variable: *gr*)

Variable	FE OLS	RE Feasible GLS (λ=0.496)
Fr	0.0026*** (0.001)	0.0014** (0.001)
Lcdi	-0.0333 (0.045)	0.0187** (0.009)
Bound	2.9531*** (1.100)	4.1502*** (0.831)
yr08	-1.9067** (0.764)	-2.3440*** (0.602)
yr09	-4.9628*** (1.539)	-6.9051*** (1.198)
yr10	-2.6944*** (0.730)	-2.7116*** (0.749)
yr11	1.2401 (1.266)	-0.2998 (1.069)
yr12	-2.7726*** (0.949)	-3.8731*** (0.870)
yr13	-1.6537 (1.176)	-3.2079*** (1.010)
Constant	-2.6782 (3.196)	-1.0809 (2.084)
R-squared adj.	0.499	0.435
Observations	217	217

***denotes significance at the 1% level against the two-sided alternative. The estimated coefficients without a* are not statistically significant at a level lower than 10%. Standard errors in parentheses. Coefficients of the country dummies are not reported since the results of all except one country are statistically significant at a level lower than 10%.

The test results for the trade imbalance suggest that inbound (import) trade volumes have a larger impact on economic growth than outbound (export) trade volumes. This finding may be explained that in addition to the effect of logistics flows on GDP, the domestic consumption of import goods promotes economic growth. The main contribution of this study is thus quantifying the relationship between liner shipping and economic growth in terms of liner transport costs and liner connectivity.

This research has two limitations. First, the freight data used are container liner freight indices for the Shanghai–Europe and Shanghai–US routes published by Drewry. The choice of these routes is limited by data availability. Although we acknowledge that outport rates are formed as the MP rate plus an add-on, the choice may still lead to bias or measurement problems because sample countries do not have similar proportions of import and export trade on these routes. Second, we used country-level data without considering the trade volume of each country, which may bias the conclusions drawn. Future research may thus aim to deflate the weighting of a country's trade volume in the model as well as identify more independent variables.

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Appendix

List of destination countries

Continent	**Country**
Europe	Ireland
Europe	Malta
Europe	Netherlands
Europe	Finland
Europe	Germany
Europe	Poland
Europe	Bulgaria
Europe	Portugal
Europe	Italy
Europe	Romania
Europe	Lithuania
Europe	Slovenia
Europe	France
Europe	Spain
Europe	Belgium
Europe	Cyprus
Europe	Estonia
Europe	Sweden
Europe	Latvia
Europe	United Kingdom
Europe	Greece
Europe	Denmark
North America	Canada
North America	Honduras
North America	Bahamas
North America	Antigua and Barbuda
North America	United States
North America	Panama
North America	Belize
North America	St Vincent and the Grenadines

[1] http://www.scdigest.com/assets/newsviews/13-04-25-1.php?cid=6981.
[i] The maximum available period is seven years for container freight indices, as they have only been measured since 2007.
[ii] Because annual data are used, seasonal effects do not need to be modelled.
[iii] http://www.worldcontainerindex.com/index.php?mode=staticContent&id=methodology.

Stacking Sequence of Marine Container Minimizing Space in Container Terminals

Ning Zhang and Yutaka Watanabe

Graduate School of Tokyo University of Marine Science and Technology, Japan

Abstract

Heavier marine containers should be loaded first into ships at container terminals so that ship stability can be maintained during transport. It is helpful for the container terminals if lighter containers arrive earlier than heavier containers because the latter can be stacked on the former. Therefore the heavier ones can be loaded into the ships first. Shippers of marine containers do not, however, care for the matters of ships. They follow their own time schedules of supply chains sending marine containers with no relation to container weight. In addition to the conflict explained above, a ship must accommodate numerous containers sent by many shippers. Consequently, marshalling containers at container terminals before loading them into ships is necessary, although it causes inefficiencies of time and cost of cargo handling.

This paper presents a proposal of a simple sequence of stacking marine containers at container terminals, adapting to random arrival of the containers irrespective of their weight, but it naturally keeps heavier containers stacked higher together with the stacking space minimized. An algorithm related to this proposal is the following.

First, weight-ranked stacking addresses are assigned initially in a block of space at a container terminal. Second, containers are accepted and stacked up in the first block as they arrive at the terminal. Third, a lighter ranked address is sought for the next container if the number of containers on the initially assigned address for the container has already reached the maximum, which depends on the height of cargo handling equipment such as transfer cranes. Fourth, such containers are stacked up on the lighter ranked address. The address is reassigned with the weight rank of the container. Fifth, a heavier ranked address is sought for the next container if no lighter ranked address can be found. Sixth, such containers are stacked up on the heavier ranked address. Seventh, change the block to the next one if either a lighter or heavier ranked address cannot be found. Eighth, repeat the sequence above.

This paper demonstrates the algorithm run by a simulation model for which actual arrival records of marine containers to a container terminal of Port of Yokohama are applied. Six ships of different sailing routes are analyzed using the simulation model. All analysis results show that heavier containers are stacked higher with a minimum number of blocks. Therefore no marshalling of containers is necessary for loading the containers into ships.

Keywords: Cargo handling, Stability of ships, Marshalling of containers, Port Logistics

1. Introduction

A container ship loads thousands marine containers at a time at a container terminal at a port. Heavier marine containers should be loaded first into a ship to maintain ship stability after departure from the ports. Arrival of the containers to the container terminal is, however, random in time series because shippers of the containers have neither relation to nor interest in matters of container terminals, but run their own business cycles, e.g. productions of factories, sales of wholesales and retail. Consequently, the container terminals must manage stacking of marine containers until the container ship berths and starts loading of the containers stacked on the container terminals. Re-handling of the containers wastes time and costs of the container terminals if heavier marine containers are stacked lower under lighter containers.

Prevention of re-handling of the containers at the terminals can be done in two ways. One is to have a wider space in the terminals to reduce stacking of the containers, placing them as flat as possible. The other is to stack heavier marine containers as high as possible, although space in the terminals is limited. Because the former is difficult to realize in economically developed regions, the latter is the more practical solution, as argued by Sou (2015).

2. Space Limitation versus Marshalling in Container Terminals

2.1 Contradictory Problem of Container Terminals

A container terminal at a port must accommodate a huge number of marine containers from an unspecified number of shippers with various weights of the containers. Ships berthing at container terminals must load heavier marine containers at the bottom first, followed by lighter ones stacked on the heavier one, and do so accordingly so that the ships can maintain stability during travel over the oceans, as shown in Figure 1. Shippers which send their marine containers do not, however, care about such maritime matters because their priorities are centered upon minimizing their own space at their site. For example, a factory of car parts produces many shipments of marine containers daily. All the containers are sent off to container terminals as soon as possible because no space is left at the factory to maintain them, paying stock costs there. In contrast, the ability to adapt to any conditions of marine containers flexibly is a necessary service of container terminals for the shippers, as shown in Figure 2.

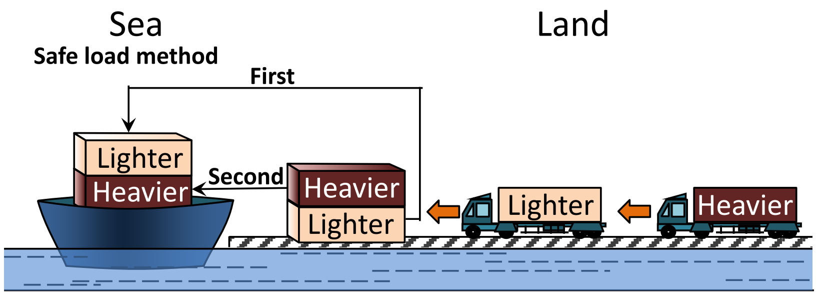

Figure 1: Ideal arrival of marine containers to container terminals

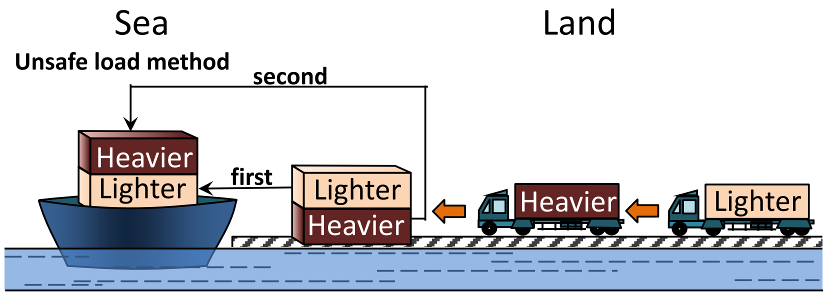

Figure 2: Actual arrival of marine containers to container terminals

2.2 Marshalling Operation in Container Terminals

If a container terminal has sufficient space for placing all containers flat, then no matter related to maritime transport occurs because heavier containers can be picked up for loading into the ships at any time. This system was actually introduced by Sea Land Inc. during the early time of containerization, as reported by Muller (1999). Today, most major container terminals are located in the heart of or in close proximity to economically developed hinterlands. Therefore land prices of the terminals are extraordinarily high, especially in economically developed countries, because marine containers are stacked more than two high at modern container terminals, as shown in Figure 3.

Figure 3: Container terminal at the Port of Yokohama
Source: Photographed by the author on July 28, 2014

The gap separating maritime matters and shipper situations argued above has engendered a unique operation at container terminals designated as “marshalling”: equivalent to “re-handling for already stacked marine containers.” Because such re-handling of containers is a costly and time-consuming operation, and because it also presents risks of damage to the cargoes inside the containers, less marshalling is done at better container terminals.

2.3 Minimization of Space and Marshalling

In this regard, this paper presents a proposal of a simple algorithm of stacking marine containers in container terminals, adapting to random arrival of the containers irrespective of their weight but naturally keeping heavier containers stacked higher together with minimization of the stacking space at terminals.

Some reports have described topics related to this paper, which were mostly operational studies such as those of Tajima (2001) and Yizhong et al. (2006). Unfortunately, such mathematically pure studies do not work well at real container terminals in ports because at a container terminal there are often more than 10 container ships arriving per week, loaded with thousands of marine containers in which are hundreds of thousands of shippers’ cargoes. An almost infinite variety of items of commodities are included in the cargoes in the container ships. Moreover, the containers arrive randomly at the container terminal every moment. All combinations described above cause a so-called “Explosion of Combinations” in the field of the operations research, by which the time needed to solve the problem turns out to be unrealistically long, although such a solver might be adopted only theoretically by mathematicians.

Actually, a terminal operator described later reported that the allowance of time to produce a stacking allocation for a marine container arriving at the gate of their container terminal was less than one second. No report in the relevant literature describes the solving speed achieved for container terminals at ports.

3. Arrival Record of Marine Containers at a Container Terminal of the Port of Yokohama

3.1 Information on marine containers arriving at a Japanese major terminal operator

A major Japanese terminal operator with activities at the Port of Yokohama appreciated the research of the authors and kindly offered arrival records of marine containers at a container terminal at the Port of Yokohama under conditions of non-disclosure of proprietary information. The information offered by the operator was presented as the following.

- Identification codes of container ships
- Sailing routes among ports of call

- Number of loaded marine containers at the container terminal in Port of Yokohama
- Weights of respective containers
- Arrival time (second, minute, and hour) and day of each container

This information was observed at the container terminal presented in Figure 3.

3.2 Arrival record details of marine containers at a container terminal at the Port of Yokohama

The information was observed during one month at some time during 2000–2010. The exact year of the observations was not notified to the authors because it is proprietary information of the company, this information was sufficient to achieve the research objectives of the authors. Table 1 presents details of the arrival record of exporting marine containers at the container terminal.

Table 1: Information on arrival record of exporting marine containers at a container terminal at the Port of Yokohama

Ship Code	Seaway	Number of containers loaded into ships in Port of Yokohama	Weight of containers	Arrival date and time of containers to Port of Yokohama
42	Yokohama→China（Dalian）→China（Qingdao）→Yokohama	154	Gross weight of containers (A box of container with cargoes inside) recorded by the kilogram.	Arrival sequence of containers recorded by date, time, minutes and seconds.
221	Yokohama→China(Hong Kong)→Italy→British→Holland→Germany→Singapore→Nagoya→Yokohama	685		
243	1. Yokohama⇄Nagoya⇄Kobe⇄Hong Kong⇄Kaohsiung 2.Yokohama⇄New Zealand⇄California⇄Mexico⇄America→Germany→Holland→Canada→America	370		
44	1. Yokohama→America→New Zealand→South Korea→Taiwan→Yokohama 2. Taiwan⇄Hong Kong⇄Singapore→Malaysia→Sri Lanka→Malaysia. 3. A man⇄Italy⇄Spanish→Canada→American→Spanish	373		
608	1.Yokohama→Kobe→Taiwan→Hong Kong→America 2Hong Kong⇄Shenzhen⇄Singapore⇄Malaysia⇄Spain→United Kingdom→Holland→Sweden→Germany→Holland→Spain	390		
926	Shanghai→South Korea→America→New Zealand→American→Yokohama→Nagoya→Shanghai	80		
958	N/A	80		
21	N/A	89		

Source: An anonymous Japanese container terminal operator in Port of Yokohama (2000–2010)

4. Algorithm of Weight Prioritized Stacking of Marine Container for Random Arrivals to Container Terminal

4.1 Weight ranks for marine containers

The maximum number of marine containers stacked at container terminals is generally five because of the yard crane height. This is, however, merely a physical limitation. Usually, the stacks should be limited to four in actual container handling operations at most container terminals to prevent inefficiency of marshaling. In this regard, the maximum number of stacking marine containers is set as four in the algorithm proposed by the authors below. There are generally six rows between the legs of the left and right side of yard cranes. Consequently, the algorithm accommodates 24 marine containers stacked in a block in which there are 6 rows and 4 marine containers stacked on each row.

It was reported during an interview by the authors to the Japanese terminal operator described above in 3.1 that the weights of marine containers were ranked by units of five or ten tons because it was sufficient for calculate ship stability and it is also better to reduce unnecessary computational loads on server computers at container terminals. Consequently, in the algorithm, the weight unit was set as five tons. Consequently, six weight groups were composed as follows.

- Less than 5 tons
- 5 to less than 10 tons

- 10 to less than 15 tons
- 15 to less than 20 tons
- 20 to less than 25 tons
- Equal to or greater than 25 tons

The legal gross weight limit of a marine container with cargoes loaded inside under the International Safe Container Convention is about 30–35 tons, which depends on the kind of structure of marine containers. Therefore the six ranks above are practical and suitable for the six rows between the legs of the yard cranes.

4.2 Pair of mutually conflicting extreme concepts

Stacking space, i.e. the number of blocks, can be minimized when marine containers are stacked solely according to the order of arrival at the container terminals. However, it would drastically worsen marshaling. No marshaling occurs when marine containers are stacked solely according the weight ranks presented above. However, it would cause the worst number of blocks there because the total number of containers in each weight rank differed, as shown in Figure 4.

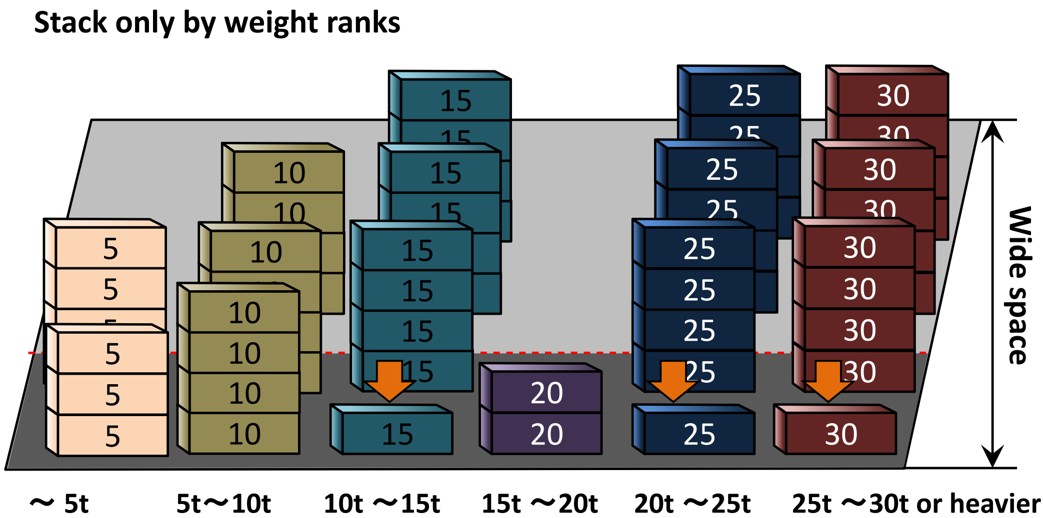

Figure 4: Consequence of stacking marine containers according only to the weight ranks

Consequently, it is readily apparent that both concepts of stacking the containers are useless. Therefore an algorithm able incorporate both must be created.

4.3 Algorithm of stacking containers enabling minimization of both the number of blocks and marshalling

To enable minimization of both the number of blocks and marshalling at container terminals, the authors proposed the following algorithm.

i) Start the algorithm.
ii) Set a block in the container terminal for stacking marine containers that have arrived.
iii) Categorize rows in a block according to the weight rank as described above.
iv) Accept an arriving marine container.
v) Identify the weight rank of the container and set it as the indicator for searching a targeted row.
vi) Search a row by the indicator with less than four marine containers stacked from the first block to the end one, i.e. at the beginning of the algorithm, the first block is the same as the end one.
vii) If the row is found by the last block, then stack the container on the row of the block and replace the category of the row of the block to the weight rank of the container stacked: no replacement of the category occurs as long as the row is found by the initial indicator. Then go to x.

viii) If the category of the row searching for the stack is not less than 5 tons, then set a lighter weight rank than the present indicator as the new indicator and go back to vi.
ix) Forward a new block and reset the new indicator as the weight rank of the container again and go back to vi.
x) If the container was the final one to be accepted, then end the algorithm; else go back to iv.

Figure 5 shows how the algorithm works. No problem arises when heavier containers are stacked on lighter containers at a row in a block, although the initial weight category of the row differs from that of stacked containers. The indicator in the algorithm allows each row to change its weight category to adopt heavier marine containers to the greatest degree possible. This algorithm might be designated as an “Algorithm of Weight Prioritized Stacking of Marine Container for Random Arrivals to Container Terminal,” which could be abbreviated to AWPSMC.

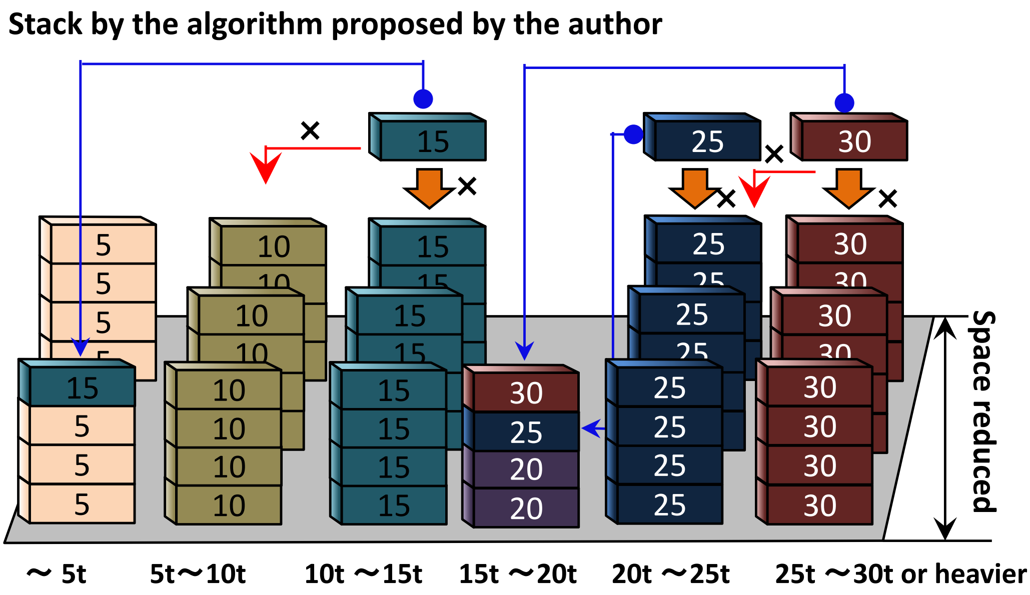

Figure 5: Mechanism of minimizing both the number of blocks and marshaling

5. Reproduction Simulation of Stacking Marine Container by AWPSMC with Real Arrival Record of Exporting Marine Containers

5.1 Simulation Overview

A computer simulation model was programmed based on AWPSMC. The real arrival record of marine containers at a container terminal at the Port of Yokohama, as shown in Table 1 was used for the simulation model. Computations related to stacking of marine containers were done not only by AWPSMC, but also according to the order of arrival and weight ranking only. Results of the computations were compared with the number of blocks needed and according to whether marshalling is needed or not. The computations were also done separately by each group of containers loaded to the six ships, as shown in Table 1.

5.2 Verification of Simulation Results

Table 2 presents results of the computations by the simulation model. AWPSMC was able to achieve the minimum number of blocks with no marshalling necessary. Whereas the algorithm according only to the order of arrival needed marshalling to achieve the minimum number of blocks, the algorithm using only the weight ranks achieved no marshalling but needed almost two times greater number of blocks compared to the result obtained by AWPSMC. These conditions of results did not differ from the ships loading the containers, although the number of containers, the sailing routes and the ports of call were substantially different from each other, as shown in Table 1.

Table 2: Simulation results for the algorithm of AWPSMC and for the order of arrival and weight ranks

Ship Code	Stack Method	Block Numbers	Marshalling
221	Order of arrival	29	YES
	Weight rank only	44	NO
	AWPSMC algorithm	29	NO
926	Order of arrival	4	YES
	Weight rank only	7	NO
	AWPSMC algorithm	4	NO
21	Order of arrival	4	YES
	Weight rank only	6	NO
	AWPSMC algorithm	4	NO
42	Order of arrival	7	YES
	Weight rank only	17	NO
	AWPSMC algorithm	7	NO
44	Order of arrival	16	YES
	Weight rank only	29	NO
	AWPSMC algorithm	16	NO
243	Order of arrival	16	YES
	Weight rank only	30	NO
	AWPSMC algorithm	16	NO
608	Order of arrival	17	YES
	Weight rank only	22	NO
	AWPSMC algorithm	17	NO
958	Order of arrival	4	YES
	Weight rank only	11	NO
	AWPSMC algorithm	4	NO

6. Conclusions

This paper introduced the algorithm of weight prioritized stacking of marine containers for random arrivals to container terminals and simulation using the algorithm to reproduce stacking of marine containers recorded at a container terminal in Port of Yokohama. The algorithm achieved the minimum number of blocks with no marshalling. The algorithm is independent of any complex mathematics such as operations research, but it follows the simple sequence as shown in 4.3. This algorithm is better for container terminals in that it does not force a computational load onto server computers of the container terminals unnecessarily. Such computers are invariably busy processing huge amounts of information related to shipping and logistics with their customers, such as shipping lines of ships and shippers of containers.

The algorithm might be applied for prioritizing not only by weight but also by other characteristics of marine containers such as sequence of ports of call, dangerous cargoes included or not, and the degree of vulnerability of cargoes inside. In this respect, the authors intend to aim their research at combining more than two priorities into the algorithm.

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Three-Dimensional Center of Gravity Detection for Trucks Hauling Marine Containers

Runan Dang and Yutaka Watanabe

Graduate School of Tokyo University of Marine Science and Technology, Japan

Abstract

Difficulty in preventing rollover accidents of marine containers derives from various load conditions of cargoes inside the containers. Heavier cargoes are widely regarded as presenting greater danger of rollover accidents. However, this presupposition is severely misleading because lighter cargoes having a higher center of gravity such as machinery with an upper mass can also cause rollover accidents. Rollover accidents are explainable fundamentally as follows.

The center of gravity of a truck loading a marine container conflicts with the centrifugal force in cornering. A truck is unstable, causing a rollover accident when the moment originating from the centrifugal force exceeds that originating from the force of gravity. Such a truck might cause a rollover accident at a lower driving speed when the center of gravity is positioned higher. The question is therefore how to find the center of gravity of trucks with marine containers. Conditions of cargoes inside the containers differ greatly. Moreover, it is practically impossible to calculate those conditions by measuring all cargoes piece-by-piece in a container unless the time and cost to do so are unlimited. Without knowing what is inside a container, there is no way to detect the center of gravity after a truck starts moving.

An important invention by the second author of this paper was produced to solve that difficulty. Detection of the Three Dimensional Center of Gravity (D3DCG) can ascertain the position of the center of gravity while trucks are moving. Soon after starting to move, vertical and rolling motions are measured onboard the trucks in half a minute. Then D3DCG is activated, instantly assessing the position of the center of gravity. D3DCG assumes that the center of gravity causes unique motions depending on its position on the truck. Therefore there is no need to know what is inside the container.

This paper first demonstrated the precision of D3DCG running an experiment by which a truck scale model was used. It was driven by remote control. Results of positions of the center of gravity delivered from D3DCG were compared to those obtained using ordinary piece-by-piece calculations. Secondly, this paper assessed examples of D3DCG installed on an actual truck loading real marine containers. Results proved that D3DCG is valuable for real-time detection of the center of gravity when driving. This achievement will greatly contribute to the prevention of rollover accidents.

Keywords: Trailer, Rollover, Road safety, Vibration of moving body, Natural frequency, D3DCG

1. Introduction

A prominent problem of transporting marine containers on roads is that truck drivers do not know conditions of cargoes loaded inside the containers because intermodal contractors have limited rights to open the containers without permission by shippers of the cargoes. Furthermore, time schedules of delivering the containers to the shippers are always tightly ordered in global supply chain networks. Consequently, severe accidents involving trailer trucks, typically rollover accidents, have increased, as reported by the Sankei Shimbun (2015) and the Asahi Shimbun (2015). The center of gravity of the trailer trucks must be ascertained to prevent rollover accidents even under the conditions above by which the drivers can neither open the marine containers nor see inside them. For example, Figure 1 shows a typical rollover accident of a trailer truck loaded a marine container caused by the higher center of gravity occurred on March 25, 2014 at Tokyo

Central. Regarding the official accidents reports by Ministry of Land, Infrastructure, Transport and Tourism of the Japanese Government, 16 cases of similar accidents occurred in Japan during 2014 and 2015.

The center of gravity of trucks can be measured using a truck scale such as that reported by Mikata et al. (2011) only in cases where the truck driver has sufficient time to go where a truck scale is available and sufficient funds to pay for the measuring service. Actually, this is unrealistic under actual conditions of logistics by which shippers and shipping lines order just in time delivery of their containers at minimum cost. No driver can waste time and money to find a truck scale somewhere during their busy business day.

The only way to overcome this difficulty is to introduce detection of the three-dimensional center of gravity (D3DCG) in trailer trucks transporting marine containers while they are traveling.

Figure 1: Trailer truck hauling a marine container in a typical rollover accident caused by a high center of gravity: March 25, 2014 at Tokyo Central

Left: Aerial view of the accident site.
Source: http://mainichi.jp/select/news/20140325k0000e040216000c.html

Right: Interior view of the marine container which caused the accident
Source: Tokyo Metropolitan Police Department

2. Detection of Three-Dimensional Center of Gravity

D3DCG can be derived as follows according to a process explained by Kawashima et al. (2014). First, as presented in Figure 2, movable bodies such as an automobile or a railcar, receive disturbance from a road surface or a track during travel. Then vertical pitching occurs on elastic structures such as the suspension and tires. This pitching is formulated as a simple harmonic motion in the following equation.

$$V' = \frac{1}{2\pi}\sqrt{\frac{2k}{m}} \tag{1}$$

Therein, V' stands for the frequency of vertical simple harmonic oscillation of a body, π represents the circular constant, k signifies the spring constant on the right/left-hand side of the body, and m denotes the body weight. This pitching tends to alleviate itself by horizontal movement. Therefore, rolling is also generated successively in the body. This rolling is expressed as a circular motion in the following equation as

$$V = \frac{\sqrt{\frac{kb^2}{2m} - gL}}{2\pi L} \tag{2}$$

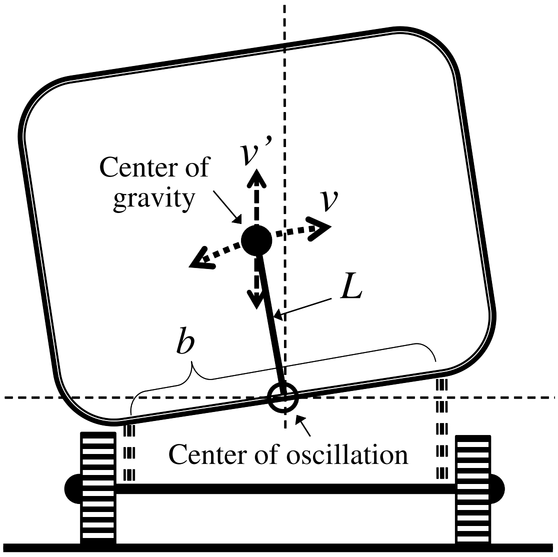

Figure 2: Concept of Detection of Three Dimensional Center of Gravity (D3DCG)

In that equation, V denotes horizontal shaking (rolling) frequency of the body, g stands for gravitational acceleration, L represents the height of the spatial center of gravity from the axis of center of oscillation of a vehicle, and b is the width of a portion supporting the weight of the vehicle from its axis of the center of oscillation. Actually, k/m can be eliminated in (1) and (2) by considering it as one variable. Therefore, they yield the following.

$$L^2 + \frac{g}{4\pi^2 V^2} L - \frac{b^2 V'^2}{4V^2} = 0 \tag{3}$$

In fact, V' and V can be ascertained by measurement with a body-mounted sensor as described later. Therefore, (3) is solvable with respect to L.

3. Accuracy of Three-Dimensional Center of Gravity Detection

3.1 Experiment Overview

Figure 3 presents a truck model to a scale of 1:14 for verification of D3DCG accuracy. First, the center of gravity of the model was measured conventionally by hanging the model from different directions. The point of intersection on hung lines represented the position of the center of gravity of the model. Secondly, a tabletop device for D3DCG was made. After the model was placed on the device, D3DCG was activated to detect the center of gravity of the model. Finally, D3DCG accuracy was verified by comparison.

3.2 Conventional measurement of the center of gravity by hanging the model

A line was attached to three parts of the model: the front, middle, and back. Then the model was hung from the line. The three traces of the line intersected at a point on the model on which the center of gravity was positioned. Figure 4 presents the procedure described above. The position of the center of gravity was measured between the point and the edge of tires of the model using a ruler as shown in Figure 4.

Tracing the intersection by hanging a targeted object provides the most accurate measurement to ascertain the center of gravity position. However, it is nearly impossible or too dangerous to hang heavier real trucks that are transporting marine containers. Therefore D3DCG is welcomed when the error is negligible compared to the trace of the intersection.

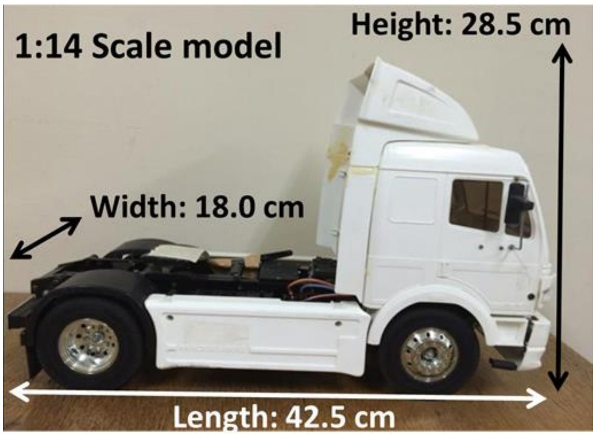

Figure 3: Model of truck to a scale of 1:14

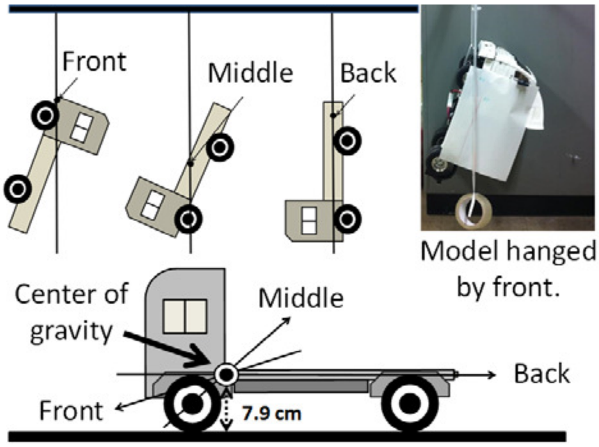

Figure 4: Measurement of the center of gravity by hanging the model

3.3 Detecting the center of gravity using a table top D3DCG device

Figure 5 shows a table top device of D3DCG in which four coil springs are attached under a platform on which a targeted object for detecting the center of gravity is placed. A motion sensor for measuring vertical accelerations and rolling angular velocity is attached underneath the platform. Their outputs are introduced to an A–D converter, and are transmitted to a PC, which computed (3) and displays the result with graphical user interface. The object starts shaking by placing it on the platform and patting its upper part softly. Then computing is conducted immediately by application of D3DCG. Figure 6 presents a display of the center of gravity of the model by the application. The measuring time was about 8 s (depending on the relation between the sampling time and FFT size).

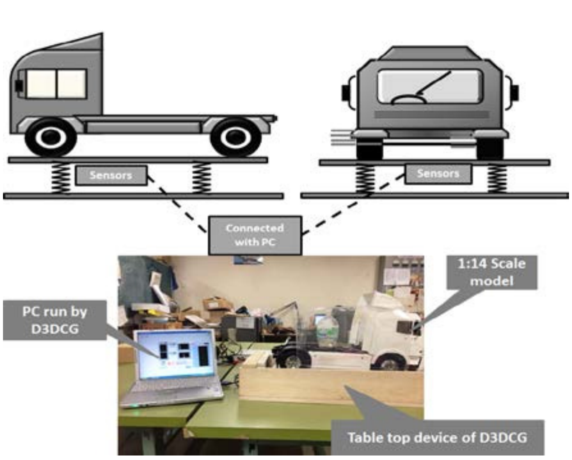

Figure 5: Table top device of D3DCG

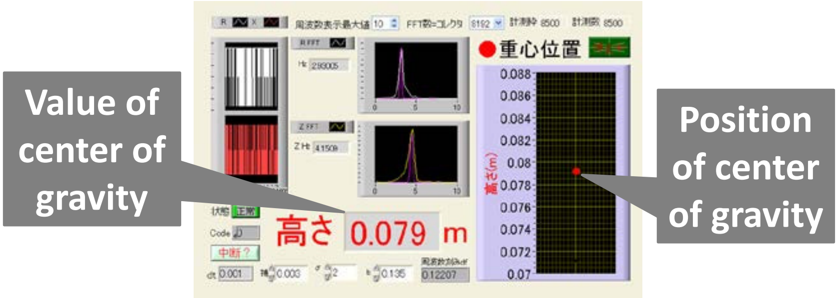

Figure 6: Application of D3DCG

3.4 Comparison with measurement of the center of gravity by the intersection and D3DCG

Table 1 presents a comparison with measurement of the center of gravity by the intersection and D3DCG argued above. The difference between them is extremely slight. It is therefore consistent in D3DCG to detect the center of gravity accurately.

Table 1: Consistency in D3DCG with accurate center of gravity detection

Way of measuring center of gravity	D3DCG	Hanging
Measurement of center of gravity	0.0787 m	0.0790 m

4. Measurement of Center of Gravity of Model of Truck During Traveling by D3DCG

4.1 Experiment Overview

Unlike the table top device of D3DCG, on which the ideal condition presented by (3) is available, measurement of the center of gravity of trucks during traveling by D3DCG might have errors because of various disturbances such as conditions of roads surfaces, driving speed, and conditions of steering. To verify D3DCG accuracy when it is activated during travel, the following experiments were conducted.

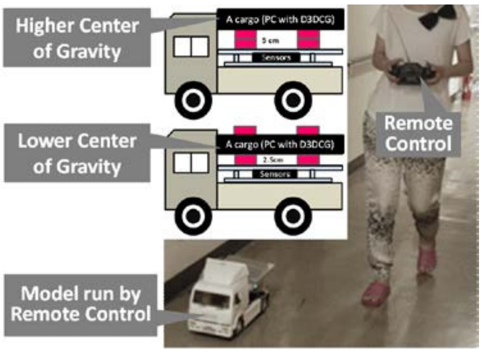

Figure 7: Mode of changing the center of gravity using a cargo and traveling the model of truck with cargo

First, a cargo in which the motion sensor with A/D converter was attached lower was loaded onto the model as shown at the left of Figure 7. A PC on which a D3DCG application was installed was placed above the sensor; both were mutually connected. The PC can be moved vertically to two positions in the cargo so that the center of gravity of the model can also be shifted accordingly. The lower position of the PC was 2.5 cm above the intermediate platform of the cargo over the sensor. The higher one was at 5 cm, as calculated similarly.

Secondly, the center of gravity of the model with the cargo was measured using the D3DCG table top device similar to that shown in Figure 5. Finally, the model with the cargo was moved by remote control as shown at the right of Figure 7. The center of gravity was measured using D3DCG installed in the cargo.

4.2 *Results obtained using the table top device of D3DCG*

Table 2 presents results of the center of gravity by the table top device of D3DCG. It is apparent that the center of gravity is higher than that of Table 1 because of the loaded cargo.

Table 2: Center of gravity measured by the table top device of D3DCG

	Center of Gravity (Number of experiments: 10)			
Position of Cargo	Average	Standard deviation	Maximum	Minimum
0.0250m	0.1134 m	0.0038 m	0.1200 m	0.1080 m
0.0500m	0.1241 m	0.0039 m	0.1280 m	0.1200 m

4.3 *Results by D3DCG during traveling*

Table 3 presents results of the center of gravity by D3DCG during motion. Compared to the results shown in Table 2, the center of gravity is about 0.2 cm lower than those shown because that D3DCG during traveling can only detect the center of gravity from the axis of center of oscillation of the model. Judging from the value of 0.2 cm with some error, the axis of the center of oscillation of the model might be positioned at a level of the center or a bit lower part of the tires of the model. Therefore, the portion of mass below the axis of center of oscillation is not involved in the measurement. The center of gravity by the table top device of D3DCG shown in Table 2 is the height of the center of gravity from the platform of the table top device of D3DCG involving all portions of the model.

Table 3: Center of gravity measured by D3DCG during traveling

	Center of Gravity (Number of experiments: 10)			
Position of Cargo	Average	Standard deviation	Maximum	Minimum
0.0250m	0.1110 m	0.0058 m	0.1236 m	0.1042 m
0.0500m	0.1225 m	0.0098 m	0.1359 m	0.1083 m

5. Demonstration Experiment of D3DCG with Real Trailer Truck

5.1 *Experiment Overview*

An experiment was conducted with an actual trailer truck transporting a marine container in which imported heavier metal products had been loaded, as shown in Figure 8. Testing was conducted in Hokkaido, Japan on March 31, 2015. A set of D3DCG measurement systems, the same one described above, was installed in the truck. The sensor was fixed on a frame of the truck. A PC was carried into the cabin of the truck as shown in Figure 9. They were mutually connected by a USB cable.

Figure 8: Actual trailer truck transporting a marine container used for a D3DCG demonstration experiment

D3DCG was activated at the cabin during traveling. The center of gravity of the trailer truck was measured in half a minute. Measurements were repeated ten times under the same driving conditions by which the truck drove straight while maintaining a constant speed.

5.2 Verification of Experimental Results

Table 4 presents results of the measurement of the center of gravity detected during traveling. The value of 0.675 m for the center of gravity can be used because the axis of the center of oscillation of the trailer truck should be positioned at a level around the middle part of the tires, as described in 4.3. Therefore the height of the center of gravity from ground level might be 1.225 m because the radius of tires for trailer trucks in Japan is generally 0.55 m. This value exceeds the level of the upper surface of the trailer onto which the marine container is loaded. The center of gravity of trailer trucks without marine containers is generally positioned lower than the level of the upper surface because the heaviest parts of a trailer truck, which are an engine, its parts, shaft, and wheel driving structure, are installed onto the wheel shaft of the tires underneath the surface. The marine container with loaded cargo has a lifted up center of gravity of the trailer truck when loaded onto the trailer bed. In this respect, the results presented in Table 4 are satisfactory.

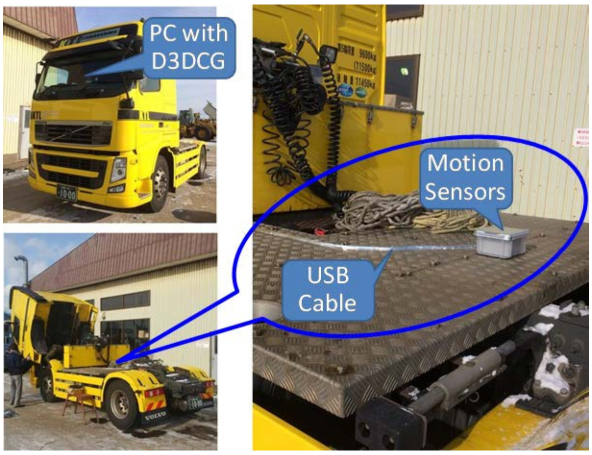

Figure 9: Installation of measurement system of D3DCG in an actual trailer truck

Table 4: Center of gravity of a real trailer truck transporting a marine container measured using D3DCG during travel

Average	Standard deviation	Maximum	Minimum
0.675 m	0.064 m	0.752 m	0.558 m
Number of experiments: 10			

6. Conclusions

This study demonstrated the accuracy of D3DCG in comparison with the measurement of the intersection by hanging a truck model. It also proved that D3DCG is applicable to the model during travel. Based on the results presented above, this study conducted a demonstration experiment of D3DCG with a real trailer truck transporting a marine container during travel. The result of the experiment was judged as reliable from the trailer structure and the results of model experiments.

The center of gravity detected using D3DCG should be used for prevention of severe accidents, such as rollovers, of trailer trucks that are hauling marine containers. The authors will strive to produce real-time rollover warning systems for use during travel for trailer trucks in which D3DCG can detect not only the center of gravity but also important conditions of steering related to rollover phenomena. For example, when D3DCG is used in conjunction with car navigation systems, the rollover critical speed limit can be told to drivers in real time. The analyses described in this paper are the first step to achieving such useful future applications.

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China–Japan Port Networks Suitable for Short Sea Shipping

Jun Tong and Yutaka Watanabe

Graduate School of Tokyo University of Marine Science and Technology, Japan

Abstract

During the last few decades, China and Japan have become mutually dependent economically. Most significantly, trade volume by container transportation between two countries has increased. However, in situations of short distance, container transportation entails the important shortcomings of costly investment for land and infrastructure at ports as well as time-consuming complex cargo-handling operations. The distances of China and Japan routes are much shorter than those transoceanic sea routes used for container transportation, e.g. between Europe and Asia.

In Europe, short sea shipping by Roll-on – Roll-off (RORO) or ferries is well networked among countries because of their proximity. There, it is difficult for container transportation to avoid the effects of cost and inefficiencies described above. Accordingly, short sea shipping should be introduced properly between China and Japan because the distances separating the countries are similar to those of existing European short sea shipping networks. This paper presents an exploration of the possibility of introducing better short sea shipping networks between China and Japan.

First, data related to short sea shipping in Europe were surveyed. The data include short sea shipping operators and regions with local ports, but also include regional populations, regional GDPs, number of regional tourists, and total regional freight tonnage. From analyzing the characteristics of short sea shipping networks, two major groups of the short sea shipping networks were found: one-to-one port networks and one-to-more port networks. Finally, geographical conditions of port locations between China and Japan were examined to ascertain whether any future port combinations can be suitable for expanding short sea shipping networks. Results show that port combinations among Okinawa in Japan, Taiwan, and southeastern China conformed to the one-to-more port networks. A short sea shipping network already exists between Okinawa and Taiwan. This paper reports means of future expansion of the network to China.

Keywords: Port networks, Short sea shipping, Regional transportation, Distance range, Tourism, Cargo handling, Container, Logistics

1. Introduction

Along with development of global production networks, marine transportation has also tended towards globalization, as described by Theo Notteboom (2007). Container transportation remains the main mode of marine transportation. However, along with construction of port networks, short sea shipping in increasingly used for shorter distance between countries.

For short sea shipping, the main ship size is 1000–10,000 tonnage, with drafts ranging from around 2.5 m to 8.8 m. Principally, transfers wet and dry bulk cargoes (grain, fertilizers, steel, coal, salt, stone, scrap and minerals etc.) are done, in addition to containers and passengers (European Shortsea Network, 2015).

Short sea shipping in Europe accounts for approximately 40% of all freight moved there. Cargo chiefly passes through the central region of Europe on rivers but not on oceans. Over the past several decades, the term of short sea shipping has broadened to include point-to-point cargo movements on inland waterways and inland to ocean ports for transshipment over oceans (European Shortsea Network, 2002).

At the same time, short sea shipping has developed to some degree in the US. From the perspective of alleviating congestion, decreasing air pollution, and overall cost savings to the shipper and a government, short sea shipping is far more efficient and cost-effective than road transport. Moreover, it is much less prone to theft and damage.

China and Japan have become mutually dependent economically as the trade volume by container transportation between the countries has increased prodigiously. Nevertheless, container transportation networking for shorter distances has not occurred because of the necessary costly investment for land and infrastructure in ports and time-consuming complex cargo-handling operations. The distances separating China from Japan are short compared to those of transoceanic sea routes used for container transportation among the US, Europe, and Asia. Consequently, César Ducruet (2006) presented the view that potential network port cities can be evaluating by consideration of micro (local environments) and macro (regional patterns) factors. The present study chooses analyses of the port networks from macro perspective and introduces better short sea shipping networks between China and Japan.

2. Data Collection of European Short Sea Shipping

2.1 Well-Developed Networks of Short Sea Shipping in Europe

Most European countries are well networked for short sea shipping because of their close mutual proximity. The salient benefits of short sea shipping in Europe portrayed in the figure are explainable by comparison with container transportation for transoceanic shipping routes. Ships used for short sea shipping are typically RORO or ferries. Therefore, ports need less infrastructure for cargo handling equipment such as cranes. It is also an important benefit of RORO and ferries that cargoes on board are wheeled as cars, trucks, or trailers. Therefore, the turnaround times of both the ships and the cargoes in ports are shorter than those for container transportation, for which containers must be stacked at container terminals in ports for days to weeks to match the timing of delivery or picking up of the containers by their shippers. Moreover, less space is needed in ports for short sea shipping because the wheeled cargoes can leave the ports soon after being discharged from the ships. In contrast, container terminals need more space in ports to accommodate a substantial number of containers, thereby meeting the timing needs of the shippers.

For China and Japan, Table 1 presents some short sea shipping routes in the Mediterranean by distance for illustration. Figure 1 shows short sea shipping networks among countries according to data in Table 1. Short sea shipping is better at producing a network among neighboring regions at close distances when local ports are available for each. However, ports are not well equipped with infrastructure such as container terminals. The distances of China and Japan approximate those in the Mediterranean, as portrayed in Figure 1. Therefore, the suitable characteristics of short sea shipping in Europe can be found for possible new port networks for short sea shipping between China and Japan.

NO.	Region	Port	Region	Port	Distance
1	Andalucia, Spain	Algeciras	Ciudad Autonoma de Ceuta(ES), Spain	Ceuta	25.56
2	Andalucia, Spain	Algeciras	Tangier-Tetouan	Tangier Med	35.74
3	Campania, Italy	Napoli	Campania, Italy	Casamicciola	60.00
4	Corsica, France	Calvi	Provence-Alpes-Cote d'Azur, France	Nice	140.75
5	Corsica, France	Bastia	Toscana, Italy	Livorno	143.57
6	Corsica, France	Bastia	Toscana, Italy	Piombino	154.18
7	Andalucia, Spain	Almeria	Oriental, Morocco	Nador	203.35
8	Andalucia, Spain	Almeria	Tlemcen, Algeria	Ghazaouet	238.35
9	Cataluna, Spain	Barcelona	IIIes Balears, Spain	Ibiza	243.35
10	Corsica, France	Bastia	Provence-Alpes-Cote d'Azur, France	Nice	250.02
11	Andalucia, Spain	Almeria	Ciudad Autonoma de Melilla(ES), Spain	Melilla	251.87
12	Cataluna, Spain	Barcelona	IIIes Balears, Spain	Formentera	295.02
13	Corsica, France	Bastia	Liguria, Italy	Savona	295.39
14	Corsica, France	Ajaccio	Provence-Alpes-Cote d'Azur, France	Toulon	309.14
15	Cataluna, Spain	Barcelona	Languedoc-Roussillon, France	Sete	319.56
16	Corsica, France	Ajaccio	Provence-Alpes-Cote d'Azur, France	Nice	335.68
17	Andalucia, Spain	Almeria	Oran, Algeria	Oran	350.03
18	Toscana, Italy	Livorno	Sardegna, Italy	Golfo Aranci	362.64
19	Corsica, France	Bastia	Provence-Alpes-Cote d'Azur, France	Toulon	387.07

Table 1: Example of Short Sea Shipping Route Mediterranean (List by Distance)
Source: RO-RO & Ferry Atlas Europe 2014/15 (2015)

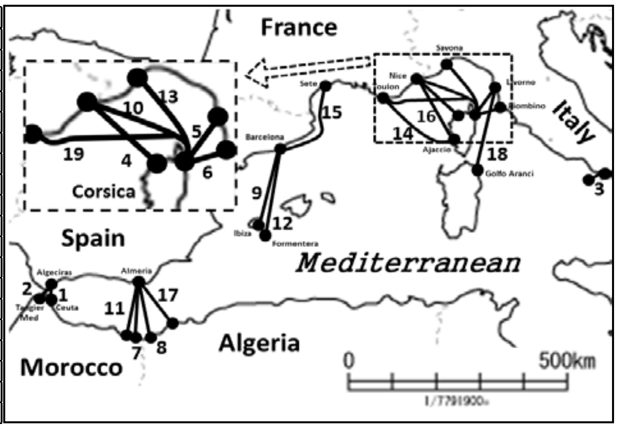

Figure 1: Map of Short Sea Shipping Route in Mediterranean
Source: Table 1

2.2 *Major Short Sea Shipping Operators in Europe*

Table 2 presents major operators of short sea shipping in Europe including all of the networks presented in Figure 1. Numbers of regions and their local ports and combinations among the ports are sufficiently varied to show characteristics that are suitable for short sea shipping between China and Japan.

Table 2: Major RORO and Ferry Operators in Europe

No.	Operators	No. Vessels	Total Gross Tonnage (2014-2015)	Total No. Passengers (2014-2015)	Total No. Cars (2014-2015)	Total No. Trucks (2014-2015)
1	Stena Line	24	749,998	23,801	6,470	151
2	P&O Ferries	16	496,495	16,448	7,288	484
3	DFDS Seaways	11	296,394	12,726	3,935	230
4	Color Line	6	246,770	10,004	2,644	0
5	Grandi Navi Veloci	6	245,429	11,893	1,744	0
6	Brittany Ferries	9	238,256	14,737	4,617	65
7	Corsica Sardinia Ferries	11	222,837	18,435	5,770	0
8	Trasmediterranea	14	214,711	12,330	3,269	0
9	Irish Ferries	5	149,250	6,300	5,385	0
10	SNAV	6	134,776	7,482	2,392	236
11	Nel Lines	10	70,179	10,601	2,519	0
12	LD Lines	2	54,318	492	195	0
13	Condor Ferries	4	11,264	2,523	625	0

Source: [1] Direct Ferries (2015), [2] Ferrylines.com (2015), [3] Marine Traffic (2015)

The prominent characteristics appearing in Table 2 are that substantial capacity of passengers as well as cars and trucks are secured by the operators. Therefore, sufficient demand exists for short sea shipping in Europe not only for pure logistics but also for passenger transportation, i.e. higher potential might exist for short sea shipping for tourism.

2.3 *Fundamental Activities in Regions Related to Short Sea Shipping*

In all, 56 regions have 86 local ports networked by the operators presented in Table 2, as shown in Table 3. Because it is natural to regard fundamental activities in regions as a driving force for short sea shipping, information related to the regional economy must be analyzed. For this study, population (inhabitants), GDP and the number of tourists per inhabitant in each region together with total freight tonnage on routes of short sea shipping connected to each local port were collected for Europe in publicly available statistics. The dataset is presented in Table 3, in which the number of tourists per inhabitant was calculated by dividing the number of tourists by the population.

3. Analysis of Characteristics of European Short Sea Shipping

3.1 *Combinations of Ports by Short Sea Shipping in Europe*

Analyses based on port of call services provided by each operator presented in Table 2 revealed 7 combinations of one-to-one port networks and 36 combinations of one-to-more ports networks. Table 4 shows the one-to-one port network. Table 5 shows the one-to-more port network. Numbers of ports were combined to produce one-to-more port networks or 2–5 destinations as presented in Table 5. Hereinafter, a port connected with more than one port is designated as a master port. A port connected with such a master port is designated as a subordinate port, as expressed in the headings of Table 5.

Table 3: Fundamental Activities in Regions Related to Short Sea Shipping

No.	Region	Port	Freight Tonnage (Thousand tonnes)	Population (Inhabitants)	GDP (Euro)	No. Tourists
1	Zuid-Holland, Netherlands	Rotterdam	404,829	3,552,407	32,000	2,079,393
2	Zuid-Holland, Netherlands	Hoek of Holland	404,829	3,552,407	32,000	2,079,303
3	Andalucia, Spain	Algeciras	119,589	8,377,810	18,300	9,584,247
4	Andalucia, Spain	Almeria	119,589	8,377,810	18,300	9,584,247
5	Andalucia, Spain	Cadiz	119,589	8,377,810	18,300	9,584,247
6	Noord-Holland, Netherlands	Amsterdam	93,453	2,709,822	36,600	3,014,630
7	East Yorkshire and Northern Lincolnshire, UK	Hull	82,990	919,611	20,100	1,143,000
8	Provence-Alpes-Cote d'Azur, France	Nice	81,595	4,927,578	26,000	11,004,030
9	Provence-Alpes-Cote d'Azur, France	Toulon	81,595	4,927,578	26,000	11,004,030
10	Sicilia, Italy	Palermo	79,053	4,999,854	16,300	2,548,463
11	Haute-Normandie, France	Le Havre	76,984	1,844,097	24,000	1,938,264
12	Haute-Normandie, France	Dieppe	76,984	1,844,097	24,000	1,938,264
13	Liguria, Italy	Genoa	69,359	1,567,339	26,700	2,215,890
14	Liguria, Italy	Savona	69,359	1,567,339	26,700	2,215,890
15	Comunidad Valenciana, Spain	Valencia	68,559	5,009,650	21,200	5,536,438
16	Cataluna, Spain	Barcelona	67,908	7,514,991	28,400	8,346,741
17	Nord-Pas-de-Calais, France	Calais	54,238	4,048,230	22,100	3,087,397
18	Nord-Pas-de-Calais, France	Dunkerque	54,238	4,048,230	22,100	3,087,397
19	Sardegna, Italy	Golfo Aranci	52,133	1,637,846	19,300	1,247,003
20	West Wales and The Valleys, UK	Fishguard	49,420	1,936,283	16,100	5,113,000
21	West Wales and The Valleys, UK	Holyhead	49,420	1,936,283	16,100	5,113,000
22	West Wales and The Valleys, UK	Pembroke	49,420	1,936,283	16,100	5,113,000
23	Västsverige, Sweden	Gothenburg	48,955	1,892,328	29,600	4,030,458
24	Västsverige, Sweden	Strömstad	48,955	1,892,328	29,600	4,030,458
25	Västsverige, Sweden	Varberg	48,955	1,892,328	29,600	4,030,458
26	Attiki, Greece	Piraeus	47,332	3,961,122	26,900	1,141,018
27	Attiki, Greece	Lavrio	47,332	3,961,122	26,900	1,141,018
28	Hampshire and Isle of Wight, UK	Portsmouth	44,058	1,908,498	25,600	2,798,000
29	Lietuva, Lithuania	Klaipėda	41,033	3,003,641	16,900	1,090,318
30	Sydsverige, Sweden	Karlskrona	38,021	1,405,912	26,800	2,169,464
31	Sydsverige, Sweden	Trelleborg	38,021	1,405,912	26,800	2,169,464
32	Sydsverige, Sweden	Karlshamn	38,021	1,405,912	26,800	2,169,464
33	Pomorskie, Poland	Gdynia	37,452	2,283,500	15,600	1,511,595
34	Kent, UK	Dover	36,431	1,739,957	21,200	1,486,000
35	Schleswig-Holstein, Germany	Kiel	34,765	2,837,641	25,900	5,262,000
36	Merseyside, UK	Liverpool	32,924	1,508,892	20,200	1,245,000
37	Prov.West-Vlaanderen, Belgium	Zeebrugge	31,974	1,173,818	28,500	1,730,961
38	Toscana, Italy	Livorno	30,770	3,667,780	27,600	5,489,961
39	Toscana, Italy	Piombino	30,770	3,667,780	27,600	5,489,961
40	Pays de la Loire, France	Saint Nazaire	29,219	3,630,780	24,100	5,464,222
41	Syddanmark, Denmark	Esbjerg	24,705	1,201,342	27,800	1,151,795
42	Sor-Ostlandet, Norway	Larvik	24,604	949,963	27,500	2,658,344
43	Sor-Ostlandet, Norway	Sandefjord	24,604	949,963	27,500	2,658,344
44	Northern Ireland, UK	Belfast	23,226	1,818,935	19,700	2,073,000
45	Northern Ireland, UK	Larne	23,226	1,818,935	19,700	2,073,000
46	Mecklenburg-Vorpommern, Germany	Sassnitz	22,529	1,634,734	21,100	6,501,273
47	Mecklenburg-Vorpommern, Germany	Rostock	22,529	1,634,734	21,100	6,501,273
48	Principado de Asturias, Spain	Gijon	21,503	1,074,308	22,700	1,501,806
49	South Western Scotland, UK	Cairnryan	19,845	2,332,454	22,300	2,323,000
50	South Western Scotland, UK	Troon	19,845	2,332,454	22,300	2,323,000
51	Campania, Italy	Napoli	18,258	5,764,424	15,700	2,734,344
52	Campania, Italy	Casamicciola	18,258	5,764,424	15,700	2,734,344
53	Lazio, Italy	Civitavecchia	17,765	5,500,022	29,300	3,634,164
54	Agder og Rogaland, Norway	Kristiansand	17,606	728,934	36,500	1,925,614
55	Jadranska Hrvatska, Croatia	Split	14,839	1,410,551	14,700	1,005,235
56	Hovedstaden, Denmark	Copenhagen	12,770	1,714,589	38,300	1,196,177
57	Midtjylland, Denmark	Grenaa	12,682	1,266,682	28,200	717,686
58	Marche, Italy	Ancona	8,316	1,540,688	25,500	1,854,613
59	Nordjylland, Denmark	Frederikshavn	7,917	579,996	27,500	574,229
60	Nordjylland, Denmark	Hirtshals	7,917	579,996	27,500	574,229
61	Northumberland and Tyne and Wear, UK	Newcastle	6,950	1,422,375	20,800	2,032,000
62	IIles Balears, Spain	Ibiza	6,871	1,100,715	25,300	1,362,008
63	IIles Balears, Spain	Formentera	6,871	1,100,715	25,300	1,362,008
64	Oslo og Akershus, Norway	Oslo	5,641	1,169,539	47,400	2,685,092
65	Languedoc-Roussillon, France	Sete	5,042	2,699,498	20,900	6,540,839
66	Bretagne, France	Roscoff	4,939	3,239,659	22,400	5,298,813
67	Bretagne, France	St Malo	4,939	3,239,659	22,400	5,298,813
68	Cantabria, Spain	Santander	4,803	592,383	23,500	1,268,303
69	Lancashire, UK	Heysham	4,035	1,463,495	19,600	2,107,000
70	Essex, UK	Harwich	3,189	1,735,048	21,500	961,000
71	Basse-Normandie, France	Cherbourg	2,751	1,478,057	21,200	2,928,513
72	Basse-Normandie, France	Caen	2,751	1,478,057	21,200	2,928,513
73	Surrey, East and East Sussex, UK	Newhaven	2,696	2,755,118	26,800	3,066,000
74	Devon, UK	Plymouth	2,374	1,139,062	20,200	3,612,000
75	Ciudad Autonoma de Ceuta(ES), Spain	Ceuta	1,554	83,845	20,900	52,137
76	Corsica, France	Bastia	1,544	318,316	22,800	1,746,324
77	Corsica, France	Calvi	1,544	318,316	22,800	1,746,324
78	Corsica, France	Ajaccio	1,544	318,316	22,800	1,746,324
79	Notio Aigaio, Greece	Andros	1,216	343,283	22,300	538,635
80	Notio Aigaio, Greece	Milos	1,216	343,283	22,300	538,635
81	Notio Aigaio, Greece	Syros	1,216	343,283	22,300	538,635
82	Notio Aigaio, Greece	Naxos	1,216	343,283	22,300	538,635
83	Anatoliki Makedonia, Thraki, Greece	Kavala	856	622,159	14,200	313,581
84	Dorset and Somerset, UK	Weymouth	752	1,281,108	21,100	3,188,000
85	Dorset and Somerset, UK	Poole	752	1,281,108	21,100	3,188,000
86	Ciudad Autonoma de Melilla(ES), Spain	Melilla	604	81,792	19,000	36,718

Source: [1] Marine Traffic (2014), [2] Eurostat (2011–2012)

Table 4: One-to-One Port Networks in Europe

NO.	Region A	Port A	Region B	Port B	NO.	Region A	Port A	Region B	Port B
1	Northumberland and Tyne and Wear, UK	Newcastle	Noord-Holland, Netherlands	Amsterdam	4	Västsverige, Sweden	Strömstad	Sor-Ostlandet, Norway	Sandefjord
2	Surrey, East and East Sussex, UK	Newhaven	Haute-Normandie, France	Dieppe			Varberg	Midtjylland, Denmark	Grenaa
3	Sydsverige, Sweden	Karlskrona	Pomorskie, Poland	Gdynia	5	Campania, Italy	Napoli	Campania, Italy	Casamicciola
		Karlshamn	Lietuva, Lithuania	Klaipėda	6	Andalucia, Spain	Cadiz	Canary Islands	Arrecife
					7	Jadranska Hrvatska, Croatia	Split	Marche, Italy	Ancona

Source: [1] Direct Ferries (2014), [2] Ferrylines.com (2014), [3] Marine Traffic (2014)

Table 5: One-to-More Port Networks in Europe

NO.	Master			Subordinates					
	Region	Port	No. Subordinate Ports	Region	Port	Region	Port	Region	Port
1	Corsica, France	Bastia	5	Toscana, Italy	Piombino	Toscana, Italy	Livorno	Provence-Alpes-Cote d'Azur, France	Nice
				Liguria, Italy	Savona	Provence-Alpes-Cote d'Azur, France	Toulon		
2	Hampshire and Isle of Wight, UK	Portsmouth	4	Cantabria, Spain	Santander	Haute-Normandie, France	Le Havre	Basse-Normandie, France	Caen
				Basse-Normandie, France	Cherbourg				
3	Basse-Normandie, France	Cherbourg	4	Dorset and Somerset, UK	Poole	Southern and Eastern, Ireland	Rosslare	Devon, UK	Plymouth
				Southern and Eastern, Ireland	Dublin				
4	Cataluna, Spain	Barcelona	4	Liguria, Italy	Genoa	Languedoc-Roussillon, France	Sete	IIIes Balears, Spain	Ibiza
				IIIes Balears, Spain	Formentera				
5	Andalucia, Spain	Almeria	4	Oriental	Nador	Ciudad Autonoma de Melilla(ES), Spain	Melilla	Tlemcen Province	Ghazaouet
				Oran Province	Oran				
6	Northern Ireland, UK	Belfast	3	Lancashire, UK	Heysham	South Western Scotland, UK	Cairnryan	Merseyside, UK	Liverpool
7	Dorset and Somerset, UK	Poole	3	Basse-Normandie, France	Cherbourg	Bretagne, France	St Malo	Principado de Asturias, Spain	Gijon
8	Southern and Eastern, Ireland	Dublin	3	Merseyside, UK	Liverpool	West Wales and The Valleys, UK	Holyhead	Basse-Normandie, France	Cherbourg
9		Rosslare	3	West Wales and The Valleys, UK	Fishguard	Basse-Normandie, France	Cherbourg	West Wales and The Valleys, UK	Pembroke
10	Provence-Alpes-Cote d'Azur, France	Nice	3	Corsica, France	Calvi	Corsica, France	Ajaccio	Corsica, France	Bastia
11	Oslo og Akershus, Norway	Oslo	3	Nordjylland, Denmark	Frederikshavn	Schleswig-Holstein, Germany	Kiel	Hovedstaden, Denmark	Copenhagen
12	Notio Aigaio, Greece	Syros	3	Notio Aigaio, Greece	Andros	Notio Aigaio, Greece	Milos	Notio Aigaio, Greece	Naxos
13	Kent, UK	Dover	2	Nord-Pas-de-Calais, France	Calais	Nord-Pas-de-Calais, France	Dunkerque		
14	Devon, UK	Plymouth	2	Bretagne, France	Roscoff	Cantabria, Spain	Santander		
15	Essex, UK	Harwich	2	Zuid-Holland, Netherlands	Hoek of Holland	Syddanmark, Denmark	Esbjerg		
16	Merseyside, UK	Liverpool	2	Southern and Eastern, Ireland	Dublin	Northern Ireland, UK	Belfast		
17	East Yorkshire and Northern Lincolnshire, UK	Hull	2	Prov.West-Vlaanderen, Belgium	Zeebrugge	Zuid-Holland, Netherlands	Rotterdam		
18	Northern Ireland, UK	Larne	2	South Western Scotland, UK	Troon	South Western Scotland, UK	Cairnryan		
19	South Western Scotland, UK	Cairnryan	2	Northern Ireland, UK	Larne	Northern Ireland, UK	Belfast		
20	West Wales and The Valleys, UK	Holyhead	2	Southern and Eastern, Ireland	Dún Laoghaire	Southern and Eastern, Ireland	Dublin		
21	Bretagne, France	St Malo	2	Dorset and Somerset, UK	Poole	Dorset and Somerset, UK	Weymouth		
22	Corsica, France	Ajaccio	2	Provence-Alpes-Cote d'Azur, France	Nice	Provence-Alpes-Cote d'Azur, France	Toulon		
23	Provence-Alpes-Cote d'Azur, France	Toulon	2	Corsica, France	Ajaccio	Corsica, France	Bastia		
24	Sydsverige, Sweden	Trelleborg	2	Mecklenburg-Vorpommern, Germany	Sassnitz	Mecklenburg-Vorpommern, Germany	Rostock		
25	Västsverige, Sweden	Gothenburg	2	Schleswig-Holstein, Germany	Kiel	Nordjylland, Denmark	Fredrikshavn		
26	Nordjylland, Denmark	Hirtshals	2	Agder og Rogaland, Norway	Kristiansand	Sor-Ostlandet, Norway	Larvik		
27	Schleswig-Holstein, Germany	Kiel	2	Västsverige, Sweden	Gothenburg	Oslo og Akershus, Norway	Oslo		
28	Liguria, Italy	Genoa	2	Cataluna, Spain	Barcelona	Sicilia, Italy	Palermo		
29	Sicilia, Italy	Palermo	2	Liguria, Italy	Genoa	Lazio, Italy	Civitavecchia		
30	Toscana, Italy	Livorno	2	Corsica, France	Bastia	Sardegna, Italy	Golfo Aranci		
31	Attiki, Greece	Piraeus	2	Voreio Aigaio, Greece	Vathy	Voreio Aigaio, Greece	Mytilene		
32		Lavrio	2	Anatoliki Makedonia, Thraki, Greece	Kavala	Voreio Aigaio, Greece	Mesta		
33	Cantabria, Spain	Santander	2	Hampshire and Isle of Wight, UK	Portsmouth	Devon, UK	Plymouth		
34	Andalucia, Spain	Algeciras	2	Ciudad Autonoma de Ceuta(ES), Spain	Ceuta	Tangier-Tetouan	Tangier Med		
35	IIIes Balears, Spain	Ibiza	2	Comunidad Valenciana, Spain	Valencia	Cataluna, Spain	Barcelona		
36	Principado de Asturias, Spain	Gijon	2	Dorset and Somerset, UK	Poole	Pays de la Loire, France	Saint Nazaire		

Source: [1] Direct Ferries (2014), [2] Ferrylines.com (2014), [3] Marine Traffic (2014)

3.2 Correlation of Freight Tonnage with Regional Economy

Short Sea Shipping is supported by economical activities in the short term. In the longer term, port networks of the Short Sea Shipping might, however, be affected by political relations, historical background, military power, and other factors. Analyses therefore demand the use of a macro approach by which variables are widely applicable to different economic areas and a micro approach by which variables are specialized to regionally oriented matters. Because these analyses examine the former set of variables, it is better to include universal variables applicable to both Europe and Asia. The authors selected population, GDP, and number of tourists as such universal variables, although other candidate variables can be considered.

Table 6 presents correlation coefficients of the freight tonnage of both the one-to-one and the one-to-more port networks with the population, GDP, and the number of tourists per inhabitant in the regions connected with the port networks, with the calculated R2. The population was significant, but GDP was not significant for any port network. Each had few tourists per inhabitant but were not significant for one-to-more port networks, although no significance was found for the one-to-one port networks.

Table 6: Correlation of Short Sea Shipping with Regional Economy in Europe by R^2

	One-to-More Port Networks	One-to-One Port Networks
Population (Inhabitants)	0.6277	0.4181
GDP (per Inhabitant)	0.0383	0.0022
No. Tourists per Inhabitant	0.1064	0.057

Comparison of R^2 of the population as shown in Figure 2 shows that coefficients of one-to-more port networks were significant, as were those of one-to-one port networks. This result might be explained by Table 3: most networks appearing in the table have greater importance for connecting two countries as a corridor rather than for meeting demand for the regional economies of local ports. This reasoning matches the finding of a lack of significance of one-to-one port networks with both GDP per inhabitant and the number of tourists per inhabitant in regions connected by port networks. Because China and Japan are already connected by container transportation, maintaining such national economic corridors for decades, it is difficult for short sea shipping to be newly introduced between the countries under conditions of one-to-one port networks.

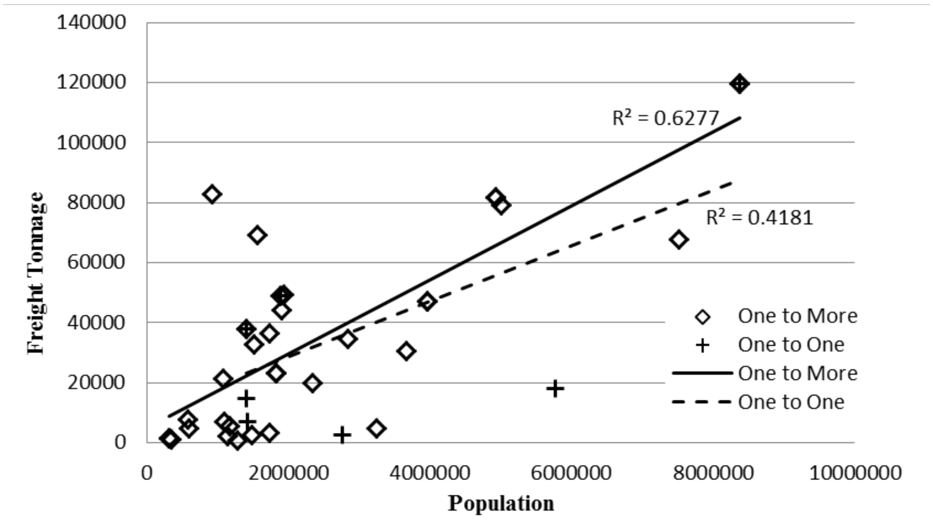

Figure 2: Comparison of Correlation (R^2) with Freight Tonnage to Population between One-to-One and One-to-more Port Networks

3.3 Characteristics of Newly Introduced Short Sea Shipping between China and Japan

Characteristics of short sea shipping in Europe suitable for China and Japan are found in the one-to-more port networks. However, too many networks exist, as shown in Table 5. It is therefore reasonable to infer that limited characteristics might be applicable for introducing new short sea shipping between China and Japan. When reviewed in Table 6, the population should be regarded as a general characteristic needed for all the one-to-more port networks because of the higher value of R^2. The number of tourists per inhabitant might affect a few networks, but apparently not all, because of the lower value of R^2. To verify this assumption, master ports and subordinate ports were compared with the number of tourists per inhabitant as shown in Figure 3.

Two groups are clearly evident in the figure: one has a greater number of networks ranging widely in the figure; the other has only a few networks concentrated at the master ports but lower at the subordinate ports. These are the networks connected to Corsica of the Mediterranean as master ports. This is unexpected: an isolated region with low population such as Corsica has master ports. Therefore, master ports and subordinate ports were compared with the population, as shown in Figure 4, which emphasizes the position of Corsica as highlighted by arrowed lines.

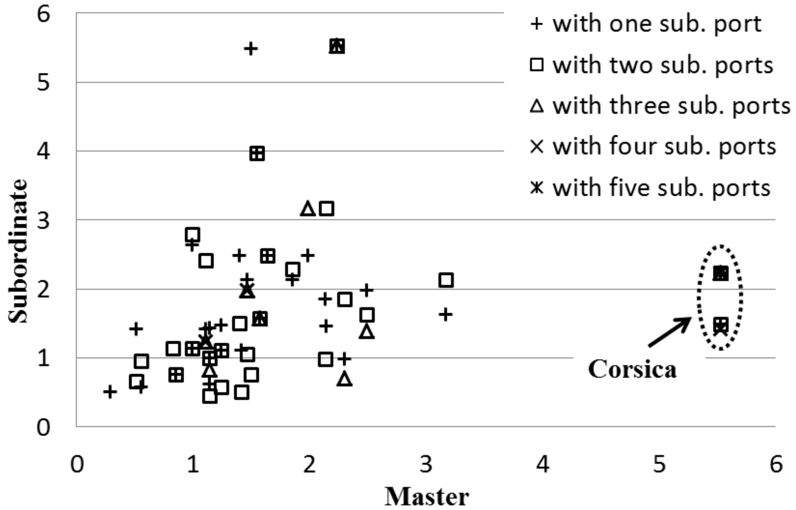

Figure 3: Relation between Master Port and Subordinate Port on Number of Tourists per Inhabitant

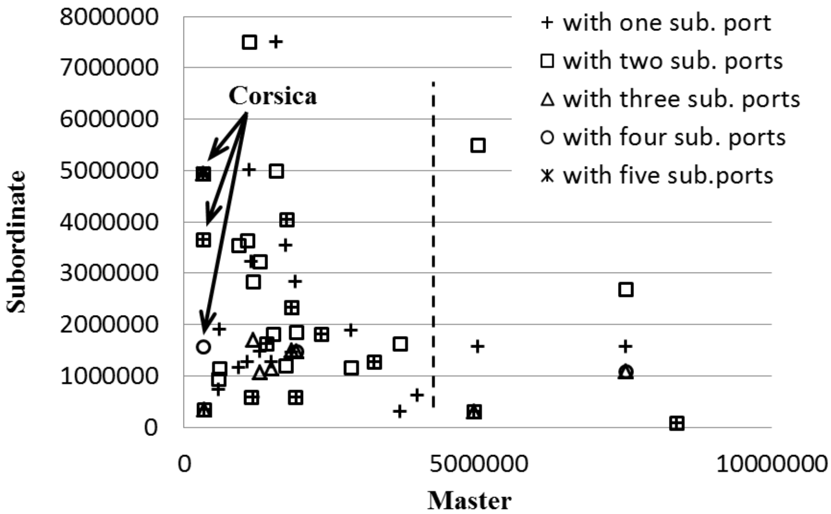

Figure 4: Relation between Master Port and Subordinate Port on Population

Two groups are shown in the figure as one distributed lower for master ports, but wider for subordinate ports and as other positions, mostly higher for the master ports. Corsica belongs to the former, and higher than subordinate ports because Corsica is surrounded by populated and economically developed regions such as France and Italy, as shown at the right in Figure 1.

Corsica is located intermediate between France and Italy. In addition to its position, the island has attractive resources of tourism, although it is less populated. This is an ideal condition for RORO or ferry operators who wish to benefit from both the demand of pure logistics between the two countries and tourists to the island using a route connected countries of destination at both sides calling for a master port at the island on the middle of the route, as illustrated at right in Figure 1. By this configuration, the operators can maintain higher or stable booking orders for ships on the route throughout the year.

4. Possible One-to-more Port Networks of Short Sea Shipping between China and Japan

4.1 Similarity between Okinawa in Japan and Corsica in the Mediterranean

Okinawa in Japan, located near the southwestern border of the country, can satisfy similar conditions to those of Corsica as follows.

- Isolated island in the ocean.
- Surrounded by economically active countries nearby: China, Taiwan, and Japan.
- Valuable tourism resources exist on the island, which has various marine flora and fauna because of coral reefs near the island.

Figure 5 presents the geographical proximities of Okinawa to the three countries.

Figure 5: Geographical Proximities of Okinawa to China, Taiwan and Japan
Source: All China Info (2015)

4.2 Verification on Benefits of Okinawa for Master Ports

As the master port, Corsica is located intermediate between France and Italy (Figure 1) with five subordinate ports as shown in Table 5. To find the relation between Corsica with the capitals of the nearby countries, a comparison of the number of tourists per inhabitant and population between Corsica, Paris, and Rome is shown in Figure 6. Results show that Corsica has numerous tourists per inhabitant but less population than either Paris or Rome.

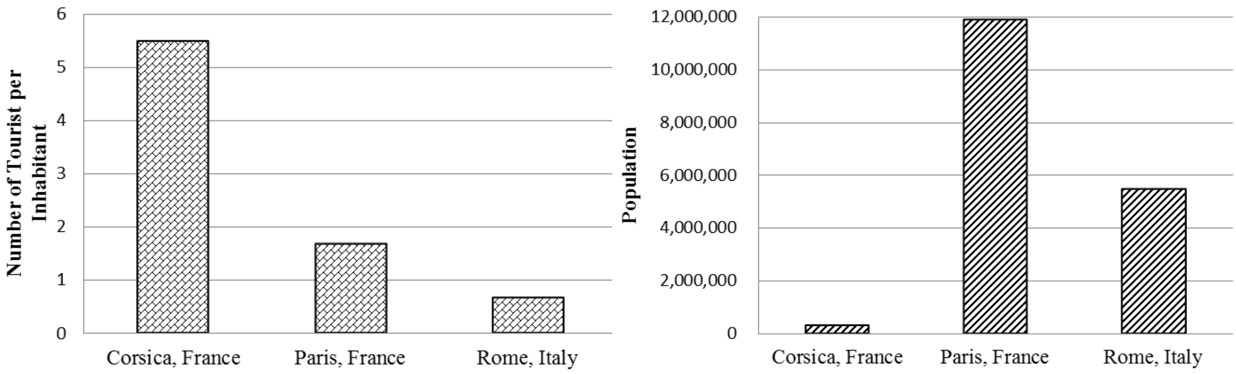

Figure 6: Comparison of the Number of Tourists per Inhabitant and Population between Corsica, Paris and Rome
Source: Eurostat (2011–2012)

To verify the advantage of Okinawa to have master ports on the one-to-more port networks of short sea shipping, the number of tourists per inhabitant and the population were compared between Okinawa, Tokyo and Taipei, as shown in Figure 7.

It is readily apparent that Okinawa has great potential for tourism despite its lower population. For Okinawa, it owns the same tendency with Corsica, at the aspects of number of tourists per inhabitant and the population comparing with the capitals. Therefore, Okinawa might benefit both from pure logistics among the three countries and from tourism from the three countries to the island.

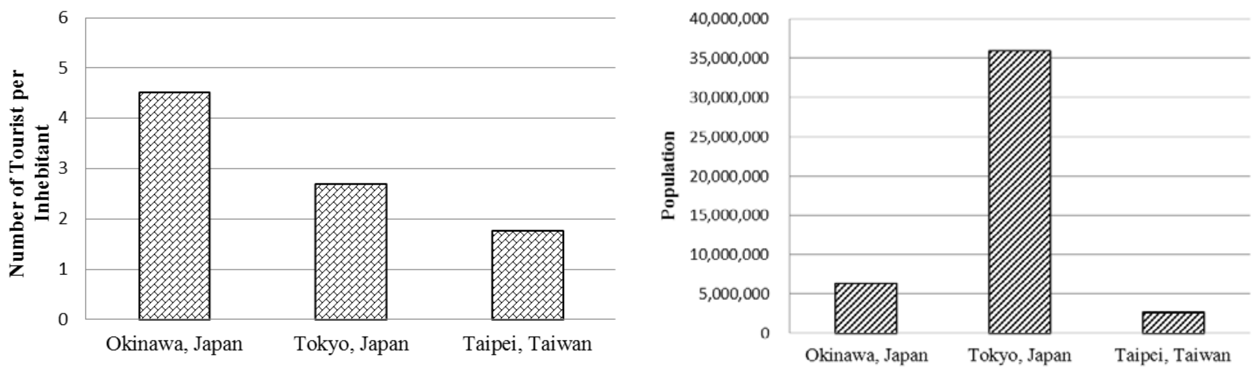

Figure 7: Comparison of the Number of Tourists per Inhabitant and Population between Okinawa, Tokyo and Taipei

Source: [1] The Japanese municipality of Okinawa Prefecture (2013), [2] Tokyo Metropolitan Government (2013)

4.3 Possible Expansion of Short Sea Shipping from Okinawa to China

A domestic short sea shipping network has been operated by a Japanese operator for decades, connecting Okinawa with Tokyo and other economically developed regions throughout Japan. It was fortunate and good timing that the operator opened a new international short sea shipping route between Taiwan and Okinawa in June 2015: RKK Line (2015). This fact supports results presented in the paper described above. Furthermore, the new route of the operator is expected to be expanded southward to east coast regions of China from Taiwan because of the results presented in this paper, as shown in Figure 7.

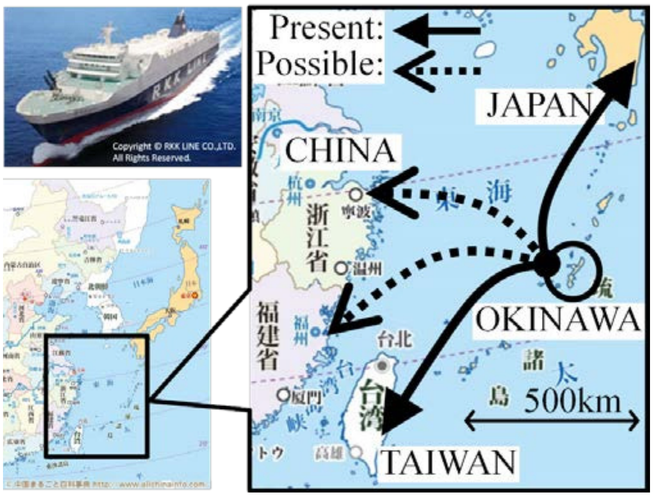

Figure 7: Possible Expansion of Short Sea Shipping from Okinawa to China

Source: [1] All China Info (2015), [2] RKK Line 2015)

5. Conclusions

Results of this study demonstrate that Okinawa can expand short sea shipping networks to China as a master port on the networks because of its similarity to Corsica in the Mediterranean. Corsica has benefited greatly from short sea shipping for many decades. Because of new short sea shipping routes opened between Taiwan and Okinawa this year, the conclusions presented herein are expected to contribute to mutual understanding between China and Japan of the importance and benefits of short sea shipping in the near future.

This paper mainly presents a macro view to explain an exploration of the possibility of short sea shipping networks between China and Japan. For further research, the authors expect to examine micro-scale issues for comparison with macro aspects to specialize in regional matters, environmental factors, trade patterns, historical background, etc.

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Applying Metafrontier Approach to Evaluate the Efficiency of Major Container Ports

Shih-Liang Chao and Yen Chou

Department of Shipping and Transportation Management, National Taiwan Ocean University, Keelung, Taiwan, ROC

Abstract

As global container volume has been increasing year by year, liner shipping has become the dominant way of global transportation. The container ports are playing important roles because they provide an interface to exchange containers between sea and land. Running such a business is very costly and the service of the berth and yard cannot be reserved. Therefore, port operators are concerning their efficiency which influences their competiveness. In addition to evaluating the efficiency of major container ports in the world, all decision making unit (DMU) were further divided into four groups: Europe, America, Middle East/Africa and Asia Pacific to compare the efficiency between the four groups. In the empirical study, two inputs variables (length of container berths and the number of gantry cranes) and one output variable (container handling volume) were taken into account, and the Metafrontier approach was applied to measure Malmquist productivity index (MPI) in this study.

Keywords: container port, efficiency evaluation, Metafrontier Malmquist Productivity Index

1. Introduction

International trade is one of the determinants of national economic development. The maritime transport plays a crucial role to support the international trade. The world's major economies are all committed to improve the strength of their maritime transport to enhance competitiveness. Container port performance relates to its competitiveness. Countries bounded by sea are devoted to enhance the performance of port operations and the container handling ability to promote trade and economic development. In recent years, the global container traffic grows remarkably in the Asian regional. China has become the factory of the world due to its strength of working population and low labor cost. The booming export trade in China not only provides adequate supply of global container shipping, but also led to a substantial growth of local container throughput. This study stands alone the port area of China to compare the port performance with the port located in Asia, Europe and the American.

This study selected Europe, Asia, North America and China as the analytical regions. Each regional has six major container ports as decision making units (DMU). In total, there are 24 ports including port of Rotterdam, port of Hamburg, port of Antwerp, port of Felixstowe, port of Bremen and port of le Havre from Europe, port of Los Angeles, port of Long Beach, port of New York, port of Savannah, port of Oakland and port of Vancouver from North America, port of Singapore, port of Busan, Port Klang, port of Kaohsiung, port of Tanjung Pelepas and port of Laem Chabang from Asia, port of Shanghai, port of Shenzhen, port of Hong Kong, port of Ningbo, port of Qingdao and port of Guangzhou from China. The ports are organized in Table 1.

Table 1: Major container port with throughput (2014)

Region	Port	Country	Throughput (2014)
Europe	Rotterdam	Netherlands	12,300,000
	Hamburg	Germany	9,700,000
	Antwerp	Belgium	9,000,000
	Felixstowe	United Kingdom	4,000,000
	Bremen	Germany	5,780,000
	le Havre	France	2,900,000

North America	Los Angeles	America	8,340,000
	Long Beach	America	6,820,000
	New York	America	5,770,000
	Savannah	America	3,350,000
	Oakland	America	2,390,000
	Vancouver	Canada	2,910,000
Asia	Singapore	Singapore	33,870,000
	Busan	South Korea	18,680,000
	Port Klang	Malaysia	10,900,000
	Kaohsiung	Taiwan	10,590,000
	Tanjung Pelepas	Malaysia	8,600,000
	laem Chabang	Thailand	6,600,000
China	Shanghai	China	35,290,000
	Shenzhen	China	24,030,000
	Hong Kong	China	22,270,000
	Ningbo	China	19,450,000
	Qingdao	China	16,620,000
	Guangzhou	China	16,160,000

Source: CONTAINERISATION INTERNATIONAL and Clarkson Research Service

2. Literature review

2.1 DEA models to evaluate the performance of port operation

After 30 years of development, Data Envelopment Analysis (DEA) has been widely applied in the assessment of operating efficiency of various profit organizations and non-profit organizations. There are lots of studies using DEA to assess the current operating efficiency. The application covers the fields of financial, manufacturing, electronics, transportation, school units, medical institutions and government agencies and other various industries and organizations. In recent years, DEA has occasionally been used to analyze the port productivity. Compared with traditional approaches, DEA has the advantage of taking multiple inputs and outputs into account. This accords with the characteristics of port production, so that there exists, therefore, the capability of providing an overall evaluation of port performance.

With regard to DEA models studying the efficiency of container ports, Roll and Hayuth (1993) used the CCR model based on constant returns to scale to evaluate and determine the efficiency of ports for advanced economies. Their work was treated as a theoretical exploration of applying DEA to the port sector rather than as an actual application since no data were collected or analyzed. Martinez-Budria et al. (1999) used the DEA-BCC model to evaluate 26 Spanish ports by collecting data from 1993 to 1997 to compare the relative efficiencies which was divided into three tiers. Valentine and Gray (2001) used the DEA-CCR model to evaluate 31 container ports out of the world's top 100 container ports for the year of 1998 to compare the efficiency. The result was used to determine whether there is a particular type of ownership and organizational structure that leads to a more efficient port. Cullinane et al. (2004) applied the DEA window analysis to compare the world's top 30 leading container ports (ranked in 2001) to examine the relative efficiency over time.

Furthermore, there are some studies used two or more methods in addition to DEA. For instance, Tongzon (2001) used the DEA-CCR and DEA-additive models to study the efficiency of four Australian and 12 other international container ports to test if the differences in output could affect the performance and efficiency of the ports or not. Itoh (2002) used the CCR, BCC models and the DEA Window analysis to evaluate the relative performance of eight international ports in Japan from 1990 to 1998. So et al. (2007) applied the output-oriented CCR and BCC models to test the efficiency of 19 major container ports in Northeast Asia. Al-Eraqi et al. (2008) determined the relative efficiency of 22 ports in the Middle East and Africa by a DEA cross-sectional data and Window analysis.

From the perspective of international container ports, Lu (2012) applied Super-Efficiency model to examine the growth efficiency of top 20 container ports in the world between 2005 and 2009. Chao et al. (2009) used CCR, BCC and two different system models to measure not only the efficiency of selected sixteen international container ports with a throughput of over 1 million TEUs in the Cross Strait Tri-Region, but also the efficiency of two different port administrations by six inputs and one output. Further, Chao and Chang (2011) chose the DEA-BCC, CCR and the assurance region (AR) models to evaluate the performance of 16 international container ports across the Taiwan Strait and identified the key factors for allocating operation resources of each port.

2.2 Application analysis of metafrontier approach and MPI

Traditional analysis of the operating performance of common assessment methods from the views of frontier includes DEA and Stochastic frontier analysis (SFA). By assuming a constant frontier of production technology, DEA could calculate the efficiency value of each DMU. Conventional DEA can measure the efficiency among the different groups, but cannot measure the efficiency of intertemporal variation. Therefore, this study uses Malmquist Productivity Index (MPI) to consider the intertemporal factors. Hayami (1969) introduced the concept of a metaproduction function to solve the incomparability of performances for different groups of DMUs. The metaproduction function was regarded as the envelope of commonly conceived classical production functions. Ruttan et al. (1978) made the concept of the metaproduction function more specific by defining the metaproduction function as the envelopment of the production points of the most efficient producers. The theory underlying the metaproduction is meaningful and useful because all producers in the analysis have the potential to access the same metaproduction technology.

Afterwards, many studies used the metafrontier approach to evaluate the vendors across different technologies of productivity. For example, Battese and Rao (2002) used the framework for an efficiency analysis of the Indonesian garments firms in five regions where they assumed that there are five different stochastic frontiers along with the metafrontier production function. Battese et al. (2004) introduced a modified model assuming a single data-generation process. Rao (2006) used the concept of distance function to define metafrontier production function and extend the concept of the metafrontier to total factor productivity index to improve losing baseline problem with traditional MPI model. O'Donnell et al. (2008) combined metafrontier DEA model and metafrontier SFA model to analysis 97 countries' agriculture technology efficiency and technology gap ratio. Oh and Lee (2010) applied the concept of metafrontier to analyze the macroeconomic productivity in 58 countries from 1970 to 2000. The findings showed that Asian countries had better catch-up effect, and Europe countries had more advanced technology in the world.

3. Research Methodology

3.1 Distance Function

Distance functions are very useful in describing the technology in a way that makes it possible to measure efficiency, and intended to describe the relationship of technology between multi-output and multiple-input. The concept of distance function is closely related to production frontiers. The basic idea underlying distance function is involving radial contractions and expansions in defining the function. Distance function theory was developed by Shephard (1970). Given the existence of a production possibility frontier, the distance that any producer is away from the frontier is a function of the set of inputs used, **x**, and the level of outputs produced, **y**. For the output-oriented model, this can be expressed as follows:

$$D_0(x,y) = \min \{ \theta : \left(\frac{y}{\theta}\right) \in P(x) \} \tag{1}$$

Figure 1 takes two inputs(x1, x2) and one output(y) for instance. A given input vector x^0 determines the output set, $P(x^0)$. An output vector, y^0, is arbitrary chosen. The value of $D_0(x^0, y^0)$ locates $y^0/D_o(x^0, y^0)$ on the boundary of $P(x^0)$ and on the ray through y^0. In this example, y^0 is the interior of $P(x^0)$ and thus $D_o(x^0, y^0) < 1$. If, y^0 had been outside $P(x^0)$ then the value of D_0 would have been great than unity.

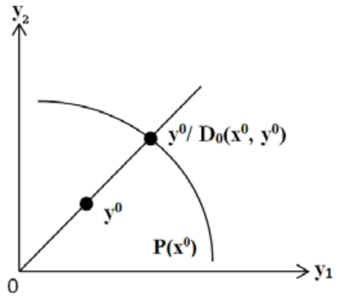

Figure 1: The output set and the output distance function

3.2 Metafrontier Malmquist Productivity Index

The MPI was first theoretically approved by Caves et al.(1982). The research explained that changes in productivity may be a function of the ratio of the distance between the two to measure. This study uses Metafrontier Malmquist Productivity Index (MMPI) proposed by Oh and Lee (2010), and the concept of Metafrontier from Battese and Rao (2002) to evaluate the performance between different groups.

The global benchmark technology constructs a single reference production set from the observations throughout the whole set of observations and the entire time period across all groups. Contrary to the definition above, this single global benchmark technology covers all groups. For measuring efficiency, all DMUs are assumed to be able to access the global technology, although there might be barriers to accessing the other technologies.

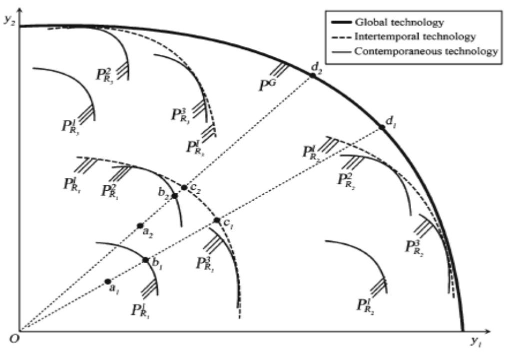

Figure 2: The concept of the Metafrontier in the Malmquist productivity index
Source: Oh and Lee (2010)

To illustrate the definition of MMPI, three contemporaneous technology sets in three periods and three groups are shown in Fig. 2. The superscript on P represents the time period and the subscript on P denoted the indicator of various groups. The interior solid curves are the contemporaneous technology sets. Those broken lines are intertemporal technology sets and the thick solid line is the global technology set. As Fig. 1 depicts, the intertemporal benchmark technology of a specific group envelopes its contemporaneous benchmark technologies and the global benchmark technology envelopes all the intertemporal benchmark technologies.
An MMPI index, proposed by Oh and Lee (2010) is defined on P^G which can be shown as Eq (1).

$$M^G(x^t,y^t,x^{t+1},y^{t+1}) = \frac{D^G(x^{t+1},y^{t+1})}{D^G(x^t,y^t)} \qquad (2)$$

In Eq (1), the output distance function $D^G(x, y) = \inf\{\varphi > 0|(x, y/\varphi) \in P^G\}$ is defined in the global technology set. Just like the contemporaneous and intertemporal MPI, the MMPI can be deconstructed by Eq (2).

$$M^G(x^t,y^t,x^{t+1},y^{t+1})$$

$$= \frac{D^G(x^{t+1},y^{t+1})}{D^G(x^t,y^t)}$$

$$= \frac{D^{t+1}(x^{t+1},y^{t+1})}{D^{t}(x^{t},y^{t})} \times \left\{\frac{D^{t}(x^{t},y^{t})}{D^{t+1}(x^{t+1},y^{t+1})} \times \frac{D^{G}(x^{t+1},y^{t+1})}{D^{G}(x^{t},y^{t})}\right\}$$

$$= \frac{D^{t+1}(x^{t+1},y^{t+1})}{D^{t}(x^{t},y^{t})} \times \left\{\frac{D^{t}(x^{t},y^{t})}{D^{t+1}(x^{t+1},y^{t+1})} \times \frac{D^{I}(x^{t+1},y^{t+1})}{D^{I}(x^{t},y^{t})}\right\} \times \left\{\frac{D^{I}(x^{t},y^{t})}{D^{I}(x^{t+1},y^{t+1})} \times \frac{D^{G}(x^{t+1},y^{t+1})}{D^{G}(x^{t},y^{t})}\right\}$$

$$= \frac{D^{t+1}(x^{t+1},y^{t+1})}{D^{t}(x^{t},y^{t})} \times \left\{\frac{D^{I}\left(x^{t+1},\frac{y^{t+1}}{D^{t+1}(x^{t+1},y^{t+1})}\right)}{D^{I}\left(x^{t},\frac{y^{t}}{D^{t}(x^{t},y^{t})}\right)}\right\} \times \left\{\frac{D^{G}\left(x^{t+1},\frac{y^{t+1}}{D^{I}(x^{t+1},y^{t+1})}\right)}{D^{G}\left(x^{t},\frac{y^{t}}{D^{I}(x^{t},y^{t})}\right)}\right\}$$

$$= \frac{TE^{t+1}}{TE^{t}} \times \frac{BPG^{I,t+1}}{BPG^{I,t}} \times \frac{TGR^{t+1}}{TGR^{t}}$$

$$= EC \times BPC \times TGC \qquad (3)$$

EC is the efficiency change measure proposed by Färe et al. (1994) and BPC is the best practice gap change measure between P_{Rj}^{I} and P_{Rj}^{s} measuring along rays (x^s , y^s), s = t, t + 1. A BPC larger than one indicates that the contemporaneous benchmark technology in period t + 1 in the region[(x^{t+1}, $y^{t+1}/D^{t+1}(x^{t+1}, y^{t+1})$)] is closer to the intertemporal benchmark technology than is the benchmark technology in period t in the region[(x^t , $y^t /D^t(x^t , y^t)$)] and BPC less than one, vice versa. TGR^s (s = t, t +1) is the technology gap ratio of the observations for the producer in group R_j (Battese et al. 2004). It measures the technology gap between the technology levels for the *j* th group relative to the potential technology level that is defined by the global technology set. The smaller the TGR is, the farther it is located from the state of *j* th group's technology from the global frontier technology. DMUs with TGR = 1 are located on the global frontier and appear to take the lead in inventing new technologies. The group having several DMUs with TGR = 1 is the leading group. This is regarded as a measure of technology leadership and TGC is the change in technology leadership.

4. Empirical Analysis

4.1 Input and output variable

This study selects quay length and number of quay cranes as input variables, and the throughput of each port as output variable. Table 2 shows input and output variables.

Table 2: Definition of input and output variable

Variable Category	Variables	Units	Variables Definitions
Input	Quay Length	Meter	The total length of container terminal berth. The longer berth, the more space.
	Quay Crane	Number	Gantry crane as the main container handling large equipment by ship side, is an important project affected the efficiency of container handling.
Output	Throughput	TEU	The total container throughput of the port in that year.

Table 3 shows the input and output variables of the research about evaluating port performance recent years in Taiwan. Most studies used number of berth and quay length as input variable, but these two variables are highly correlated to affect the result. Therefore, this study uses quay length as input variable. The remaining variables are all in accordance with the completeness of the information collected.

Table 3: Common I/O variables for port efficiency evaluate

	Input variable										Output variable	
Author	Berth	Quay length	Quay crane	Yard crane	Terminal area	Yard capacity	Reefer	Number of tug	Manpower	Delay time	Throughput	Ship working rate
Tsao,		☐✓	☐✓		☐✓			☐✓	✓	☐✓	☐✓	☐✓

(2004)												
Lin, (2006)	□✓	□✓	□✓		□✓	□✓		□✓			□✓	
Hsueh, (2007)	□✓	□✓	□✓		□✓	□✓	□✓				□✓	
Lin, (2011)	□✓	□✓	□✓	□✓	□✓						□✓	
Huang, (2011)	□✓	□✓	□✓	□✓	□✓						□✓	
Lu, (2012)	□✓	□✓	□✓		□✓	□✓					□✓	
This study		✓	□✓								□✓	

4.2 DEA-CCR model and technology gap ratio

In the first step, we used DEA-CCR model to determine the efficiency scores of the DMU we chose. Efficiency scores determined by the model can reflect whether the inputs were effectively used. The higher value of efficiency scores can increase the use of the various input items. Second, we divided all DMU into four groups: Europe, North America, Asia and China to analyze the efficiency scores in terms of groups.

Table 4: Global Efficiency, Contemporaneous Efficiency and Technology Gap Ratio

Region	Ports	Global Efficiency	Contemporaneous Efficiency	Technology Gap Ratio
Europe	Rotterdam	0.380888617	0.7805769	0.48795782
	Hamburg	0.43401548	0.8891667	0.48811488
	Antwerp	0.351042719	0.8945783	0.39241139
	Felixstowe	0.503489457	1	0.50348946
	Bremen	0.296495897	0.5960625	0.49742417
	le Havre	0.192494447	0.4691176	0.41033299
North America	Los Angeles	0.436425479	1	0.43642548
	Long Beach	0.402157938	0.9284089	0.43316897
	New York	0.34812436	0.749874	0.4642438
	Savannah	0.350795344	0.7557281	0.46418195
	Oakland	0.232480944	0.4947549	0.4698911
	Vancouver	0.495747225	1	0.49574723
Asia	Singapore	0.775905168	1	0.77590517
	Busan	1	1	1
	Port Klang	0.669028525	0.8205149	0.81537649
	Kaohsiung	0.48179426	0.6253322	0.77046136
	Tanjung Pelepas	0.797379738	0.989809	0.80558948
	laem chabang	0.355219722	0.4042547	0.80558948
China	Shanghai	1	1	1
	Shenzhen	0.60246208	0.6024621	1
	Hong Kong	0.895803405	0.8958034	1
	Ningbo	1	1	1
	Qingdao	0.990698842	0.9906988	1
	Guangzhou	0.808504893	0.8086924	0.99976817

Table 4 shows that regional efficiency scores is higher than metafrontier efficiency value. An efficiency value of 1 represents that the port has the best technology efficiency in its regional. Under the regional efficiency, the ports of Felixstowe in Europe, Los Angeles and Vancouver in North America, Singapore and Busan in Asia and Shanghai and Ningbo in China have efficient operations due to their efficiency scores all equal to one. Under the metafrontier efficiency, the ports of Busan, Shanghai and Ningbo have better technology efficiency scores in all DMU.

Technology gap means the distance between global technology and intertemporal technology. TGR is the main indicators of the judgment when we applied metafrontier approach to evaluate the performance of DMUs. To determine the TGR of each DMU, we had metafrontier efficiency divide by regional efficiency. Table 5 shows the result of TGR. Ports TGR = 1 are located on the global frontier and appear to take the lead in inventing new technologies. The group having several producers with TGR = 1 is the leading group. This is regarded as a measure of technology leadership.

4.3 Mann–Whitney U test

As most sampling-related studies did, the reliability and validity of the returned samples have to be tested to ensure the representativeness of the measurement model. In this study, we used composite reliability (CR), average variance extracted (AVE), factor loadings and critical ration (cr) that are common evaluation indices as the measures to identify reliability and validity of the samples.

As Table 4 shows, the CR value of each construct is greater than 0.8, which exceeds the recommended level of 0.7 and the AVE value of each construct exceeds the recommended level of 0.5. In addition, all factor loadings exceed 0.59 and a value of cr is greater than 1.96, which ensures the desired convergent validity of this empirical study. Hence, we can confirm a sound convergence validity between the collected data and the measurement model in this study.

The Mann–Whitney U test is a nonparametric test of the null hypothesis that assuming two samples come from the same population against an alternative hypothesis, especially that a particular population tends to have larger values than the other. It can be applied on unknown distributions contrary to t-test which has to be applied only based on normal distributions, and it is nearly as efficient as the t-test on normal distributions. This study uses Mann–Whitney U test to test the difference among sets of TGR.

Table 5: The result of Mann–Whitney U test of TGR

	Europe	Asia	North America	China
Europe	1	0.002**	0.589	0.002**
Asia	0.002**	1	0.002**	0.015*
North America	0.589	0.002**	1	0.002**
China	0.002**	0.015*	0.002**	1

Note: ** significant at the $P<0.01$, *significant at the $P<0.05$

Table 5 shows the result of Mann–Whitney U test of TGR. We found that the difference of TGR scores of groups of Europe and Asia, Europe and China, Asia and North America, and China and North America are significant at P=0.01. Moreover, the difference of TGR scores of Asia and China is significant at P=0.05. The result shows that the five region pairs have significant difference in TGR. However, the difference of TGR scores between Europe and North America is insignificant. We can say that technology efficiency of ports in these two regions is similar.

5. Conclusions

In the trend of globalization, the world's major economies all committed to enhance the operational efficiency in order to maintain a competitive strength. With proper management performance evaluation, port operators and regulatory authorities can understand their industry position and efficiency gap to improve operation efficiency and find the industry niche. Most studies used DEA to evaluate ports efficiency with conventional models, few studies used the metafroniter approach. In this study, based on geographic regions, we divided the ports into four different areas: Europe, Asia, North America and China to compare their efficiency. The result shows that port of Busan, Shanghai and Ningbo have the best performance in metafrontier efficiency. In terms of TGR, port of Busan, Shanghai, Shenzhen, Hong Kong, Ningbo and Qingdao got efficiency scores of 1. This study collected the data of 2014, the operating performance of these ports are relatively best. It is found that the ports in Asia and China have better efficiency, in which five ports are in China. According to the result, the port operation technology in China holds technical leadership.

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Towards Sustainable Port Development Model: Challenges and Opportunities for Korean Ports

Saeyeon Roh[1], Vinh V. Thai[1] and Gi-Tae Yeo[2]

[1]Civil and Environmental Engineering, Nanyang Technological University, Singapore
[2]Graduate School of Logistics, University of Incheon, Korea

Abstract

In recent years, it is generally accepted that sustainability is not strictly limited to environmental issues, but rather extended to include economic and social aspects simultaneously. Reviewing recent developments in the real business world, it has become evident that the new business paradigm for economic growth should be a balancing act between meeting economic needs and ensuring social and environmental sustainability at the same time. Increasing environmental awareness posits new challenges to the development of ports. Ports must plan and manage their operations and future expansions (growth) in a sustainable way in order to cope with the limited or decreased environmental space and intensified interactions with their hinterlands. The recognition and accommodation of this concept in harmony with the surrounding cities clearly render green growth an important economic driver. Korean ports have been implementing various sustainable activities seeking to reduce the environmental impact of shipping and related activities and promote clean and green port operations. In this connection, there has been little literature which describes clearly and comprehensively what a sustainable port development actually is. Therefore, there exists the need for an integrated approach to improve the validity of sustainable port's development indicators. Furthermore, most of the existing studies emphasized on the role of port authorities and overlooked the port customers' perspective towards sustainable port development. To address these gaps, this research aim to investigate the main factors that shape sustainable port development. This will be conducted through a comprehensive review of related literature as well as confirmatory in-depth interviews with port authorities and customers. As a result, findings from this research will help identify key elements and the priorities of sustainable port development from both port authorities' and other stakeholders' perspectives. The challenges, opportunities and managerial implications for Korean Ports will also be discussed accordingly.

Keywords: sustainable port development, green port, Korean Ports

1. Introduction

Increasing environmental awareness posits new challenges to the development of ports including climate change which calls for measures that aim at minimizing its impact and pursuing sustainable operations. Several legislations relating to the construction and extension of ports have been timely introduced at both international and domestic levels in an attempt to minimize the environmental impacts and pursue sustainable operations in the long run. Based on stricter standards, these legislations are trying to incorporate the environmental issues into core strategies of port development. Therefore, sustainability is increasing seen as one of the key drivers in port development in the next decades.

Ports must plan and manage their future developments (growth and expansion) and operations in a sustainable way in order to cope with the limited or decreased environmental space and intensified interactions with their hinterlands. The recognition and accommodation of the concept of harmony with the surrounding cities clearly render green growth an important economic driver (Black, 1996). In this respect, several studies have been conducted to measure sustainable port's performance (i.e. Lirn et al. 2012; Tsinker, 2004; Chin and Low, 2010; Wiegmans and Louw, 2011). Despite the presence of previous studies, there has been little knowledge which describes clearly and comprehensively what sustainable port development actually is. Therefore, there exist the needs for an integrated approach to improve the validity of sustainable port's development indicators.

2. Sustainable Development

2.1. Shipping

Shipping operations interact with the environment in many ways, either accidently or intentionally (Talley, 2006), not only generating substantial damages to natural habitats, but also affecting economic activities, especially along coastlines with a concentration of maritime-related economic activities such as ports (Heaver, 2006). Shipping operations and catastrophic accidents are the source of oil and chemical spills which cause health hazards (Gupta et al. 2005). Shipping firms are increasingly expected to embrace green practices so as to make their system and process environmentally friendly as a result of rising environment awareness in business worldwide (Yang et al. 2013). A challenge for shipping firms is how to perform shipping operations profitably while reducing their negative impacts on the environment (Cheng and Tsai, 2009). International regulatory bodies also have shifted their focus on environmental sustainable management. For example, MARPOL now deals with the prevention of pollution from oil chemicals and other hazardous substances, ballast water treatment, a reduction in the use of harmful paints and emission from ships, and ship recycling (Heij et al. 2011).

There are several studies of the environmental impact on water quality caused by ship operations. The impact of ballast water on plankton in the port design and development plan was studied by Frankel (1987). Fernandez (2007) indicated that ships might unintentionally carry alien species of marine plant, animal or microorganisms to vulnerable ports during the discharging of their ballast water in the loading ports. These species could have negative impacts on human health, marine ecosystem and economic production of marine resources. Matishov and Selifnova (2008) addressed that there is an absence of a scientifically based and generally recognized methodology of ballast water control in ports. Maritime operations such as bunkering and anchoring my engender oil spill risk with potentially catastrophic impacts on beaches, food chains, sediment and fishing communities and damage irreplaceable environments (Backhurst and Cole, 2000; Edoho, 2008; Idemudia and Ite, 2006; Ray, 2008). Gupta et al. (2005) identified two major types of environmental impacts caused by harbor and ship operations influencing water and air quality. Ports generate sewage, bilge wastes, sludge, waste, oil discharges and leakages of harmful materials both from shore and ships which are the main causes of polluted water quality. The emission from ships would also affect the air quality in the port area. Zonn (2005) studied the anthropogenic environmental pollution caused by shipping, port terminals, and the shipping and transportation of oil by barges, tankers, and etc. Ng and Song (2010) assessed the environmental impact costs of pollutant generated by routine shipping operations.

Chin and Low (2010) found that shipping generates a range of atmospheric emissions, including not only nitrogen oxide (NOx), carbon dioxide (CO2), and sulfur dioxide (SO2), but also oil spills and damages to soil and wildlife environment around ports. It is reported that containerships are by far the most important source of CO2 emissions in the shipping industry, in both absolute and per tone-km terms (Psarafits and Kontovas, 2009). Bengtsson et al. (2012) evaluated the environmental assessment of the two alternative pathways to bio-fuels, the diesel route and the gas route, in the shipping industry. They illustrated the use of bio-fuels as one possible measure to decrease the global warming impact from shipping and ascertained that the gas route has a better overall environmental performance than that of the diesel route. Walsh and Bows (2012) highlighted that ship type and vessel size are crucial determinants of emissions, particularly for smaller ships where the variance in emission factors are the greatest in the case of UK shipping activity.

2.2. Port

New ports are being constructed and existing ports are being expanded throughout the world to meet the increasing demand of population and requirements from various industries (Gupta et al. 2005). The development of port facilities and their associated operations contribute significantly to the growth of maritime transport, economic development of coastal countries, and provide both direct and indirect employment to the region (Paipai, 1999). Ports, as part of a network or supply chain, are considered responsible for a wider set of impacts and seek to reconcile short-term views, private and public interests, and commercial and social objectives (Dooms et al. 2013). However, port development, operations and activities have adverse consequences on the environment and are responsible for a number of negative external effects

(Acciaro et al. 2014; Dinwoodie et al. 2012; Gupta et al. 2005). Port activities would facilitate commercial and economic growth, but also likely cause deterioration of air and marine water quality in the surrounding areas (Grifoll et al. 2011; Gupta et al. 2005). Port authorities, although being diverse in size, geographical surroundings, activity profile and administration, all have to satisfy economic demands and industrial activities with sustainable development and comply with legislation and cost and risk reduction (Puig et al. 2014). It is well studied from various researchers on how port development could lead to severe pollution problems such as emissions of air pollutants (i.e. Cooper, 2003; Rodhe, 1989; Ray, 2008) and sea-based pollution along heavily congested shipping routes (i.e. Chua 1995; Edoho, 2008).

Accario et al. (2014) reviewed the main functions of a port authority and how environmental sustainability influences or interferes with main port authority function using the case study of major ports. Puig et al (2011) investigated the current status and trends over time in the environmental performance of European ports where air quality, port waste and energy consumption emerged as the three major priorities. Rather than studying the impact of sustainability in port management, most of the literature related to sustainable port development are focused on ecological issues (i.e. Berechman and Tseng, 2012; Dinwoodie et al. 2012; Liao et al. 2010) and monitoring environmental impacts (i.e. Darbra et al. 2004, 2005; Gupta et al. 2005; Wooldridge et al. 1999). Recently, some authors analyzed the strategic issues (i.e. Haezendonck et al. 2006; Denktas-Sakar and Caratas-Cetin, 2012) and operations of green ports (i.e. Acciaro et al. 2014) contributing to the identification of the value added that environmental performance might bring to ports. Among a few studies about the impact of sustainability in port management, only environmental (i.e. Gouliemos, 2000; Peris-Mora et al. 2005; Le et al. 2014; Villalba and Gemechu, 2011), or both economic and environmental aspects of sustainability have been considered (i.e. Asgari et al. 2015). Yap and Lam (2013) studied the impact of port's spatial expansion development to the environmental, economical and social dimension. They emphasized that it is even more important to address ecological issues at the planning stage and before terminal construction for any future port development projects than taking note of green port practices when the port is already in operations.

3. Impact on Sustainable Development

3.1. Environmental Dimension

Environmental management is increasingly practiced as an essential component of any operation that claims to be sustainable, efficient and compliant with legislation particularly in port activities (Puig et al. 2015). The major objective of environmental management is to control the impact of port activities, products and services on air, water, soil and sediment (Gupta et al. 2005; Puig et al. 2014). Implementing environmental action initiatives considering the environmental impact leads to improvement in environmental performance (Gimenez et al. 2012). Adopting environmental programs and green marketing strategies would lead to better environmental performance (Gimenez et al. 2012; Rao, 2002; Zhu and Sarkis, 2004) and firm competiveness (Yang et al. 2013). It is also found that promoting and practicing ISO 14001 series in the industrial port would enhance environmental performance (Saengsupavanich et al. 2009).

Activities of reducing pollutant and decreasing green cost to enhance environmental performance are consistently needed as well (Wagner and Schaltegger, 2004; Yang et al. 2013; Zhu et al. 2007). Costly monitoring programs are conducted to reduce the occasions of having business partners acting unethically or even illegally in terms of environmental and/or social issues (Carter and Rogers, 2008; Simpson and Power, 2005). Audits, evaluation, assessment practices of business partners were found to have positive impact on environmental performance (Klassen and Vachon, 2003; Theyel, 2001).

It is important for port authorities to continuously collaborate with shipping companies to reduce environmental damage they produce. Reducing CO2 emissions is an essential issue for container shipping industry in achieving environmental and economical sustainability (Buhaug et al. 2009; Qi and Song, 2012). Many operational strategies are directly linked to reducing ship speeds (Qi and Song 2012) as such a reduction of 10% would decrease emissions by at least 10 – 15% (Psarfitis and Kontovas). Encouraging the use of low-sulfur was used as one of the environmental performance indicators in several major ports (Gilman, 2003; Lirn et al. 2013). Ports give a certain percentage of concessions in port dues for ships with low sulfur content emissions or with voluntary vessel speed limit (Lirn et al. 2013; Puig et al. 2014). Lai et al. (2011) proposed a conceptual framework with several propositions to promote green shipping practices in shipping operations and identified the dimensions of green practices in shipping operations. Green practices in the shipping industry such as using clean-burning low sulfur fuels, environmental-friendly materials and equipments, and adopting environmental friendly design shipbuilding have positive impact on green performances and firm competitiveness (Yang et al. 2013). Hartman and Clott (2012) studied the impact of truck emissions control on a port's container throughput which indicates that diesel container trucks are a large source of NOx. It is also suggested that regular exercise of Port State Control for ship inspection is needed for sustainable development port (Saengsupavanich et al. (2009). To prevent a serious conflict between port and community, ports need to collaborate with urban authorities to evaluate projects (Daamen and Vries, 2013; Wiegmans and Louw, 2011).

Meanwhile, internal social programs such as employee welfare, education and training play an important part in environmental management (Wu and Goh, 2010). Despite of some studies which found that social sustainability initiative were not related to environmental performance (Pullman et al. 2009), they have been positively related to the reduction of potentially damaging environmental practices and lead to improvement on environmental performance (Florida, 1996; Gimenez et al. 2012; Marshall et al. 2005).

3.2. Economical Dimension

Environmental management can reduce the negative effects of their activities on the natural environment and enhance firm's competitive positions (Shrivastava, 1995). Success in addressing environmental management could improve a firm's image (Hick, 2000) and provide new opportunities for firms to enhance their capabilities (Hansmann and Caludia, 2001). Sharfman and Fernando (2008) indicated that improved environmental risk management reduces the probability of environmental crises that can negatively affect a firm's expected cash flows such as lawsuits, clean-up costs of environmental accidents, fines, reputation damage, etc. Gimenez et al. (2012) studied the positive impact of environmental management initiatives to economic performance adding that the use of more environmentally friendly materials and process can lead to resource reduction and efficiency resulting in reducing cost. Profitable firms can afford to make sustainable investment in green activities to raise the environmental performance (Stefan and Paul, 2008).

Greater collaboration is a key component to improve environmental performance and to foster the development of improved environmental practices and reduce pollution (Gotschol et al. 2014; Vachon and Klassen, 2006). The green collaborative activities can benefit supply chain members from an economic and environmental point of view (De Giovanni and Esposito Vinzi, 2012). Yang et al. (2013) indicated that external green collaboration, corporate image improvements, and internal green practices have positive impact on green performance and firm competiveness.

Some researchers claimed that environmental initiatives are costly undertaking, thus leading to worse economic performance (i.e. Walley and Whitehead, 1994). Alvarez Gil et al. (2001) also indicated that firms which invest to improve environmental performance may experience negative economic and financial performance. However, firms that integrate environmental responsibility in their economic strategies can achieve cost savings from resource reduction and efficiency while increasing revenue generated from improved stakeholder relations and brand image (Hart, 1995; Hoffman and Ventresca, 1999). The recent empirical studies support the positive influence of environmental management on economic performances (i.e. Gimenez et al. 2012; Lamberti and Lettieri, 2009; Rao and Holt, 2005; Zhu et al. 2004). Gotschol et al. (2014) also showed that lower consumption of energy is directly linked to better environmental performance that, consequently, leads to higher economic performance through higher cost savings.

Rao and Holt (2005) and Zhu and Sarkis (2004) also found that environmental programs that included both collaboration and assessment of business partners have a positive impact on economic performance. It is important to note that, without effective follow-up and engagement, an assessment alone is unlikely to be effective (Fabian and Hill, 2005). Reuter et al. (2010) pointed out that relying on supplier selection and evaluation alone in an effort to exclude business partners which do not meet the standards is not considered sustainable.

3.3. *Social Dimension*

It is nowadays believed that socially responsible firms, which contribute both economically and ethically to the society and local communities they serve, are better positioned to grow in terms of reputation and revenues (Drobetz et al. 2014). Environmental programs have positive effect on internal communities and external ones (Gimenez et al. 2012; Pullman et al. 2009). Effective environmental management is essential if stakeholders are to continue their support for port operations and development as environmental awareness is increasing throughout the society (Puig et al. 2014). The adoption of a process that generates less pollution improves the working conditions for employees and the community's quality of life (Gimenez et al. 2012). The implementation of employee safety and enhancement of working conditions as well as supporting community projects may result in improvements to firm's social performance and reputation. Relationship with the local community to promote positive image and building trust through various efforts from port authorities have been implemented (Saengsupavanich et al. 2009; Puig et al. 2015). Port authorities take statutory duties to meet social and environmental obligations whilst embedding Corporate Social Responsibility (CSR) concept in port management systems and undertaking routine operations and development projects commercially (Pettit, 2008). Increased CSR reporting enhances firms' transparency and lowers information costs on the part of investors, potentially leading to positive financial effects (Drobetz et al. 2014).

Meanwhile, there are some studies showing that implementing social initiatives do not always influence sustainable development positively. For example, Gimenez et al. (2012) indicated that, while social programs may lead to better corporate social reputation and indirectly to increased sales, they also increase operations costs. The negative impact of social programs on operational costs may be because this performance measure is based on short term but not necessarily in the long-term (Cruz and Walkolbinger, 2008). In the short run, the cost of CSR may be seen high, however, this cost would be less in the long run compared to the cost of liability for pollution, compliance with regulation, dangerous operations, health and safety issues, etc. (Gimenez et al. 2012).

3.4. *The Case of Korean Ports*

Korea was ranked fourth in Asia with a GDP of 1,410 billion US dollars in 2014 after China (US$10,360 billion), Japan (US$4,601 billion) and India (US$2,066 billion) (World Bank, 2015). The country's Cumulative Average Growth Rate (CAGR) has increased at the rate of 6.31% since 2004 (US$680 billion). Similar growth pattern can also be found in the Korean container port throughputs as reflected in Table 1. Specifically, from 2004 to 2014, the overall CAGR of Korean container port throughputs shows 5.61%. It can also be seen that the CAGR of three major ports have also increased with a similar growth rate as well (Busan – 4.98%, Gwangyang – 5.66%, Incheon – 9.58%). According to Ministry of Oceans and Fisheries (MOF), the trading volumes in 2020 are forecasted to increase to 1.27 billion tons, with a CAGR of 5.1% compared to that in 2009 (MOF, 2010). Among these, Busan is forecasted to increase its throughputs to 22,101 thousand TEUs (CAGR 5.2%), Gwangyang to 6,520 thousand TEUs (CAGR 12.2%), and Incheon to 4,160 thousand TEUs (CAGR 9.2%). This strong promising forecasted growth allows Korean ports to develop internally and externally to handle the increased projected throughputs.

Table 1: Summary of Korean Ports Throughputs (thousand TEUs)

Port \ Year		2004	2005	2006	…	2011	2012	2013	2014	CAGR (%)
Busan	North Port	11,492	11,843	11,801	…	8,434	7,603	6,723	6,717	-5.23
	New Port	n/a	n/a	237		7,750	9,443	10,963	11,966	4.56
Gwangyang		1,349	1,461	1,770	…	2,085	2,154	2,284	2,338	5.66
Incheon		935	1,149	1,377	…	1,998	1,982	2,161	2,335	9.58
Pyongtaek		303	228	260	…	530	517	519	546	11.13
Ulsan		225	219	183	…	487	478	386	392	2.61

Mokpo	76	63	69		99	105	94	106	3.38
Others	179	156	114	…	388	373	339	398	8.32
Total	14,523	15,216	15,964	…	21,610	22,550	23,469	24,798	5.50

Source: Ministry of Oceans and Fisheries (MOF), (2015)

4. Methodology

The principal goal and rationale of this research is to conduct the preliminary validation of sustainable development of Korean ports. To achieve this goal, the current study utilizes triangulation methods, which combines semi-structured interviews with secondary data. Base on the existing literature, semi-structured interviews were employed to port managers to validate the sustainable development port criteria of Korean ports. After the semi-structured interviews were analyzed, secondary data were also obtained to find out whether sustainable development criteria are actually practiced or implemented in Korean ports.

4.1. Sample and Measures

Semi-structured interviews were constructed based on the literature with internal and external management aspect of sustainable development following the previous studies of Gimenez et al. (2012), Gotschol et al. (2014), and Yang et al. (2013). The interview questionnaire was distributed via email due to limited time frame of the research. Out of 17 ports in Korea, a total of 67 port managers replied back from the three major ports in Korea (Busan, Incheon, Gwangyang). The criteria of internal and external management aspect are presented in Table 2 and Table 3. For the second phase of the research, container ports were evaluated based on data availability. As mentioned before, literature gaps exist in the previous studies where only one or two sustainable dimensions and impact of port development were considered. In the current study, both internal and external management consider all aspects of sustainable dimensions (economic, environmental and social) for port to be developed sustainably.

4.2. Research Method

The current paper conducts a preliminary study to validate the sustainable development criteria for Korean ports. The port managers were asked to indicate whether a port should include the given port sustainable development criteria. Their answers were categorized into O – Yes, X – No, and ∆ – Not sure. Open-ended questions were also given at the end of the semi-structured interview to obtain further insights of the sustainable development of Korean ports. Secondary data were also collected to compare how Korean ports are practicing or implementing the selected criteria.

Table 2: Sustainable Development Port Internal Management Criteria

Internal Management	**Author(s)**
A. Internal Environmental Management	
A1. Clear environmental policy statement	
A2. Establishment or upgrade of the “Green Policies” annually	
A3. Regular updates of environmental conservation information in the port’s website	
A4. Environmental Management System, such as ISO 14001 series	
A5. Management support environmental supply chain	
A6. Environmental risk management practices	References[i]
A7. Activities to reduce environmental damages	
A8. Environmental education and training support	
A9. Clear environmental performance indicators	
A10. Budget on green performance, including promotion campaign	
A11. Punishment mechanism to penalize operators that disobey environmental rules	

A12. Regular exercise of Port State Control for ship inspection	
A13. Green initiatives and eco-services to attract customers	
B. Optimized Operation Planning	
B1. Continuously implementing berth planning improvement strategy	References[ii]
B2. Continuously implementing quay crane scheduling improvement strategy	
B3. Continuously implementing loading/unloading sequence improvement strategy	
B4. Continuously implementing space planning improvement strategy	
B5. Continuously reducing truck queuing time at the port's gates	
B6. Integrated various port operations activities	
B7. Collaboration with business partners in information sharing, improving data accuracy, and integrated scheduling	
B8. Continuously improving customer satisfaction monitoring programs	
C. Cost Savings	
C1. Use of cleaner technology port equipment, such as hybrid/alternative (e.g bio-energy, electric powered) quay cranes, RTGs, etc.	References[iii]
C2. Use of automated port equipment	
C3. Collaboration with business partners in sharing the cost of environmental-friendly equipment	
D. Internal Social Programs	
D1. Constantly giving support for corporate social activities	References[iv]
D2. Constantly improving employees' working conditions and safety	
D3. Constantly improving employee welfare	
D4. Constantly giving support for employees' training and education	
D5. Constantly improving transparent employee evaluation system	
D6. Constantly improving transparent recruiting system	

Table 3: Sustainable Development Port External Management Criteria

External Management	Author(s)
E. External Environmental Management	
E1. Having common environmental goals collectively with business partners	References[v]
E2. Developing a mutual understanding of environmental risk and responsibilities with business partners	
E3. Working together with business partners to address environmental risks and establish a green supply chain	
E4. Requiring and guiding business partners to comply with ISO 140001 environmental management standards	
E5. Including environmental criteria in selecting business partners	
E6. Conducting environmental audits for partners	
F. Environmental Collaboration with Shipping Companies	
F1. Providing incentives to shipping companies which use clean-burning low sulfur fuels for their ships' main and auxiliary engines while at port	References[vi]
F2. Providing incentives to shipping companies which use environmental-friendly materials and equipments (e.g. non-toxic paint, electric deck machine, ballast water system)	
F3. Providing incentives to shipping companies which adopt environmental-friendly design of shipbuilding (e.g. improved engine design, waste heat recovery systems, double skin and internal oil tank)	

F4. Providing incentives to shipping companies whose ships reduce speed while at port	
G. External Social Program	
G1. Providing expansion plan project information to the public	References[vii]
G2. Giving support to community social activities	
G3. Providing scholarships to students	
G4. Providing internships to students for work experience	
G5. Giving support to community economical activities	
G6. Giving support to community projects in general	
H. External Evaluation Collaboration	
H1. Working with external partners such as academics/research institutions to evaluate port projects c	References[viii]
H2. Collaborate with academics/research institute for project evaluation	
H3. Providing transparent trade information to establish fair transaction culture	

5. Results of Findings

5.1 Internal Management Aspects

Table 4 shows the results of internal management criteria for port sustainable development. It can be seen that only five criteria were indicated with a low percentage of agreeing whether they should be included in the sustainable port development model. It is noteworthy that they are all about the Internal Environmental Management and Cost Savings. The criteria of internal environmental management that have low percentage are: Environmental Management System, such as ISO 14001 series (A4, 70%), punishment mechanism to penalize operators that disobey environmental rules (A11, 75%), and regular exercise of Port State Control for ship inspections (A12, 79%). It is also interesting that, for the case of Gwangyang port, there was not a high positive response (75%) whether sustainable port development should include clear environmental policy statement (A1), clear environmental performance indicators (A9, 75%), and regular exercise of Port State Control for ship inspections (A12, 65%). Also, about 74% port managers in Busan New Port and Gwangyang indicated that management support of the environmental supply chain (A5) should be included in the sustainable port development model; 65% port managers in Incheon and 75% in Gwangyang replied to include punishment mechanism to penalize operators that disobey environmental rules (A11), and 88% of Busan New Port managers indicated that sustainable port development model should include Environmental Management System, such as ISO 14001 series (A4), while the overall average responses of 70% agreed on this.

For cost savings, most managers (94%) were confident that the use of cleaner technology port equipment (C1) should be included as one of sustainable port development criteria. Meanwhile, the use of automated port equipment (C2) had a low percentage of 71%. Meanwhile, 51% of the interviewees agreed that collaboration with business partners in sharing the cost of environmental-friendly equipment (C3) should be considered for a sustainable development port.

Most of the port managers agreed that all proposed criteria for internal management should be included in the sustainable port development model. Especially, for Optimized Operation Planning and Internal Social Programs, all respondents agreed that all proposed criteria should be considered for a port to be developed sustainably.

Table 4: Internal Management Criteria Results (unit: %)

Criteria	Busan (32)						Gwangyang (20)			Incheon (15)			Total (67)		
	North Port (24)			New Port (8)			O	X	∆	O	X	∆	O	X	∆
	O	X	∆	O	X	∆									
A1	88	4	8	88	0	12	75	15	10	100	0	0	87	6	7
A2	92	0	8	88	0	12	90	0	10	100	0	0	93	0	7
A3	96	4	0	88	0	12	70	10	20	93	0	7	87	4	9
A4	79	4	17	88	13	0	50	15	35	73	13	14	70	10	20
A5	88	4	8	75	0	25	75	10	15	87	0	13	82	4	14
A6	100	0	0	100	0	0	85	10	5	80	0	20	91	3	6
A7	100	0	0	88	13	0	95	5	0	100	0	0	97	3	0
A8	100	0	0	88	13	0	95	0	5	100	0	0	97	1	2
A9	88	8	4	75	13	12	75	5	20	80	7	13	81	7	12
A10	92	0	8	100	0	0	85	10	5	87	7	6	90	4	6
A11	80	13	8	88	12	0	75	15	10	60	20	20	75	15	10
A12	88	0	12	88	0	12	65	0	35	80	0	0	79	0	21
A13	80	13	7	88	12	0	85	5	10	87	6	6	84	9	7
B1	96	0	4	100	0	0	90	0	10	93	0	7	94	0	6
B2	96	0	4	100	0	0	85	10	5	80	13	7	90	6	4
B3	92	4	4	100	0	0	90	0	10	87	6	7	91	3	6
B4	88	8	4	100	0	0	95	0	5	87	6	7	91	4	5
B5	96	4	0	100	0	0	95	5	0	100	0	0	97	3	0
B6	100	0	0	100	0	0	95	5	0	87	0	13	96	1	3
B7	100	0	0	88	12	0	95	0	5	93	7	0	96	3	1
B8	92	4	4	100	0	0	100	0	0	93	0	7	96	1	3
C1	96	0	4	100	0	0	95	5	0	87	13	0	94	4	15
C2	88	8	4	63	37	0	80	20	0	67	20	13	77	18	4
C3	63	17	20	25	75	0	55	20	25	40	33	27	51	30	20
D1	100	0	0	100	0	0	100	0	0	93	0	7	99	0	1
D2	100	0	0	100	0	0	100	0	0	93	0	7	99	0	1
D3	96	4	0	100	0	0	100	0	0	93	0	7	97	1	2
D4	100	0	0	100	0	0	100	0	0	93	0	7	99	0	1
D6	88	8	4	100	0	0	95	0	5	93	0	7	93	3	4
D7	100	0	0	100	0	0	100	0	0	80	0	20	96	0	4

O – Agree to include the criteria , X – Do not agree to include the criteria, ∆ – Not sure

5.2 External Management Aspects

The validation results of the sustainable development port's external management criteria are shown in Table 5. For external environmental management, in general port managers indicated with low percentage that most of the criteria should be included in the sustainable port development model. However, the following criteria received a high level of agreement from interviewees, including, having common environmental goals collectively with business partners (E1, 91%), developing a mutual understanding of environmental risk and responsibilities with business partners (E2, 94%), working together with business partners to address environmental risk and establish a green supply chain (E3, 94%), giving support to community social activities (G2, 85%), and providing transparent information to establish fair transaction culture (H3, 91%).

Meanwhile, criteria related to guiding business partners to comply with environmental management standards (E4), selecting environmental criteria in selecting business partners (E5), and conducting environmental audits for partners (E6) had the low level of agreement (64%, 67%, 58% respectively) to include them into the sustainable port development model.

The interviewees also concurred that all Environmental Collaboration with Shipping Companies criteria which contain providing incentives to shipping companies who practice green shipping should be included in the sustainable port development model. Among them, providing incentives to shipping companies which use environmental-friendly materials and equipments (F2) had the highest level of agreement (76%). Meanwhile, about 63% of port managers indicated the lowest level of agreement that providing incentives to shipping companies whose ships reduce speed while at the port (F4) should be included in the model.

For the criteria included in External Social Programs, port managers also indicated that all of these criteria should be included in the sustainable port development model. Among those, 85% of interviewees concurred about giving support to community social activities (G2), while 57% also agreed that providing scholarships to students (G3) should be included in the sustainable port development model.

Meanwhile, all port managers expressed that all the criteria proposed in External Evaluation Collaboration should be included in the sustainable port development model. Especially, 91% of interviewees agreed that providing transparent trade information to establish fair transaction culture (H3) should be part of the sustainable port development model.

Table 5: External Management Criteria Results (Unit: %)

Criteria	Busan (32)						Gwangyang (20)			Incheon (15)			Total (67)		
	North Port (24)			New Port (8)											
	O	X	∆	O	X	∆	O	X	∆	O	X	∆	O	X	∆
E1	94	3	3	92	4	4	85	5	10	93	7	0	91	4	5
E2	94	3	3	92	4	4	90	0	10	100	0	0	94	1	5
E3	97	0	3	96	0	4	85	5	10	100	0	0	94	1	5
E4	75	6	19	67	8	25	50	5	45	60	13	27	64	7	29
E5	72	13	15	63	17	20	60	15	25	67	0	33	67	10	23
E6	63	22	15	50	29	21	60	15	25	40	20	40	58	19	23
F1	72	19	9	79	8	13	75	20	5	67	13	20	72	18	10
F2	78	16	6	83	4	13	75	15	10	73	13	14	76	15	9
F3	66	22	12	75	8	17	75	5	20	73	13	14	71	15	14
F4	63	28	9	71	17	12	75	15	10	47	27	26	63	24	13
G1	75	13	12	75	13	12	70	5	25	67	13	20	72	10	18
G2	84	9	7	83	8	9	90	5	5	80	7	87	85	7	8
G3	44	38	18	46	29	25	75	5	20	60	20	20	57	24	19
G4	78	19	3	83	13	4	85	0	15	73	20	8	79	13	8
G5	69	22	9	67	21	12	85	5	10	73	13	14	75	15	10
G6	66	25	9	71	17	12	65	20	15	73	0	27	67	18	15
H1	78	19	3	83	13	4	65	15	20	73	7	20	73	15	12
H2	75	19	6	79	13	8	65	15	20	73	7	20	72	15	13
H3	97	0	3	96	0	4	80	5	15	93	0	7	91	1	8

O – Need to include the criteria , X – Do not need to include the criteria, ∆ – Not sure

5.3. General perception of port sustainable development

Korean port managers appreciated the importance of sustainable port development as a critical aspect of port strategy, planning and investment contributing to stable long term revenue and beneficial to employees, local community and regional development. Especially, sustainable port development would contribute to national economy as it will improve port efficiency and competitiveness in the competition with global ports. The collaboration with business partners is often done through regular meetings. Through these meetings, they share idea and information of how to benefit all, provide feedback to improve in the future, tackle important issues, and establish systematic operations.

Building mutual understanding with business partners to share common goals and address environmental risk is important. There is a need for an environmental-friendly port as it will have positive influence on management. Port authorities and business partners need to plan for mutual benefits in short and long terms. It is also important to analyze risks, share the common lessons and preventive solutions together in order to cooperate in the external environmental management. Port authorities believe that it is important to build mutual understanding through professional education and training to understand environmental protection issues in the quest to be a profitable port.

Port authorities are trying to encourage shipping to take part in the environmental efforts that the port is committed. They encourage shipping companies to apply CO2 emission reduction by reducing their speed while berthing. Also, shipping companies should implement safety speed control while entering and leaving ports. Some port managers indicated that port authorities should cooperate with shipping companies such as in making CSR report. Applying Environment Shipping Index (ESI) was suggested to provide incentives to shipping companies. It is also mentioned that most of the shipping companies establish their own environmental practice so it is not really necessary to encourage them. However, all of them indicated that government support is strongly needed to implement strict environmental policy regarding to reduction of speed, air pollution, waste disposal etc.

Korean port authorities are aware of the fact that good public reputation is a value added to port service quality for sustainable development. They believe public participation is important in contributing to sustainable development. Some of the activities they participate for external social programs are charity/volunteer programs around the city, cleaning public area, providing work experience and scholarships, and supporting local community activities.

It is found that Korean ports should further collaborate with external partners to synergise professional contribution and different suitable evaluation methods. They also suggested that public participation is critical in the collaboration process to achieve common goal of sustainable development.

5.4. Current Implementation of Sustainable Port Development Criteria

This section illustrates whether Korean ports are practicing the proposed sustainable port development criteria (Table 6).

Table 6: Implementation of Sustainable Port Development Criteria

Criteria \ Ports	Busan	Gwanyang	Incheon	Pyongtaek	Ulsan	Mokpo
Internal environmental management	O	O	O	O	O	O
Optimization operation planning	O	O	O	O	O	O
Cost savings	O	O	O	△	O	O
Internal social programs	O	O	O	O	O	O
External environmental management	O	O	O	O	O	O
Environmental collaboration with shipping companies	O	X	X	X	X	X
External social programs	O	O	O	O	O	O
External evaluation collaboration	O	O	O	O	O	O

O – Practicing, X – Not practicing, △ – limited data available

5.4.1. *Internal Environmental Management*

The implementation of environmental management in Korean ports is somewhat late compared to other developed countries. Recently, MOFA has established and initiated the project entitled 'Comprehensive Plan to Establish Green Port' in 2010 (MOFA, 2015). The ports of Busan and Incheon have implemented this project since 2011 and 2013 respectively with the goal to reduce GHG emission of Business As Usual (BAU) to 30% by 2020. Pyeontaek Port has also initiated a project to reduce GHG by using solar-powered energy and expanding waterfront areas. Owing to the environmental projects led by the government, Korean ports provide well organized information regarding to environmental management. Most of the information related to the internal environmental management criteria is available in Korean ports. Publications and reports of sustainable development also exist in every port.

5.4.2. *Optimization Operation Planning*

Korean ports collaborate with business partners for facility improvements, system development through regular meetings. They share feedbacks from each other on how to improve the operation planning. Incentives are negotiated by securing a certain number of throughputs. In some ports, IT is applied throughout by the computer-aided operations and management at the terminal to achieve rapid and accurate information sharing and processing which result in reducing harbor fees, minimizing human errors, and reducing loading and unloading times. Optimization planning to reduce truck waiting time is planned as well.

5.4.3. *Cost Savings*

The use of cleaner technology port equipments such as E-RTG, electronic powered equipments are not only to save fuel cost but also limit CO_2 emissions. Busan Port Authority (BPA) is preferentially promoting the improvement of energy efficiency for RTGC and Y/T at Busan Port which accounts for 85% of the total fuel used at container piers. BPA has carried out the E-RTGC project from 2007 and 92 cranes were converted by 2012. Through these efforts, operating expenses were saved, energy expenses were reduced by 90%, and GHG emissions were cut down by over 74% (BPA, 2015). The total cost of converting from fuel oil to electricity per unit is about US$ 400 thousand and the terminal operators and BPA have agreed to share the total cost on an equal basis. Gwangyang Port is expected to reduce 92% of the energy cost when the project of converting 48 RTGCs to E-RTGCs is completed (YGPA, 2015). Incheon Port has installed 14 Automated Rail Mount Gantry Crane (ARMG) to not only reduce cost but also optimize the operations during bad weather condition in all circumstances (IPA, 2015). In general, Korean ports have been reducing energy consumption by installing high-efficiency equipment and new and renewable energy facilities. BPA has replaced the lighting system in Busan Port with LED lighting in 2014, saving KRW 258 million annually. All indoor lighting devices at Busan Port will also be replaced with LED by 2020 (BPA, 2015).

5.4.4. *Internal Social Programs*

Most of Korean ports consistently improve reasonable human resource system through transparent recruiting and evaluating systems. They focus on developing training and education programs to strengthen their work skills, capabilities and personal responsibility in the port. Korean port authorities also constantly communicate with the employees on ways to improve their welfare. Continuous improvement of employees' working conditions and safety is implemented to meet global standards. Due to constant efforts to improve internal social programs, along with other index evaluated by employees, Ulsan Port Authority (UPA) has improved employee welfare satisfaction index to 77.6 in 2013 from 61.6 in 2011 (UPA, 2014).

5.4.5. *External Environmental Management*

Korean port authorities take environmental issues seriously and have tried their best to change the mindset of business partners on how important these issues are. They try to share the definition of environmental friendly activities and experience on how to achieve those. They also emphasize on how environmental protection leads to improved profit and sustainability. It is important to develop the mutual understanding about environmental issues in an attempt to implement environmental friendly practices. Mutual understanding to meet global environmental policy standards using environmental friendly equipment and energy is also regarded as important factor.

5.4.6. External Collaboration with Shipping Companies

Korean port authorities are well aware of the pollution caused by vessels. However, only BPA provides incentives to shipping companies. Since January 2014, BPA has implemented the Environmental Ship Index (ESI) by assigning the scores for four items emitted by vessels including NOx, SOx, CO2, and Onshore Power Supply (OPS) on the scale of 1 – 100. Busan Port is the first in Asia to adopt this system by providing ESI incentives, reducing entry and departure charges by 15% for vessels with over 31 ESI points. In 2014, the number of eco-friendly vessel callings was 423, and a total of KRW 603 million was reduced for entry and departure fees (BPA, 2015).

5.4.7. External Social Program

External social programs are practiced by Korean ports such as disclosing port's expansion project information, providing field trips, community support, local social activities and various volunteer activities. For example, Gyeongji Pyeongtaek Port Corporation (GPPC) publicized the detailed activities in external social programs that have been supported by them. They have also provided free medical service to 2,192 people who have access difficulties, volunteered service to various local communities, invited children to participate in port field trips, supported community social activities and enhanced community economic activities by supporting small-scale traders (GPPC, 2014).

5.4.8. External Evaluation Collaboration

Most of Korean ports provide transparent trade information to establish fair transaction culture. Incheon Port Authority (IPA) has achieved zero incidents where unfair transactions were reported due to the establishment of systematic procedures to settle transparent trade information for the organization (IPA, 2014). They have not only strengthened fair transaction culture but also established the monitoring system for payment of purchase to subcontractors. As the Korea port authorities are aware of the importance of collaborating with external partners to evaluate projects, they encourage external partners to participate through notice of tender on their website.

6. Conclusion

The current study aims to present a conceptual model of sustainable port development through a preliminary research with Korean ports. Further research has also been conducted to explore whether they are practicing or implementing various proposed sustainable port development criteria in their port. Unlike previous studies in which only one or two sustainable dimension was considered, the current research applies a holistic approach in which port sustainable development involves all three dimensions of sustainable development (economical, social, and environmental).

It was found that a sustainable development port should have most of the criteria in the proposed conceptual model. Especially, it was indicated that all the criteria of optimization operation planning, internal social program, and external evaluation collaboration should be considered for a port's sustainable development. For some criteria, the level of agreement was low but still acceptable as it is higher than the level of disagreement. For instance, the criteria relating to the evaluation or selection and punishment of business partners for environmental performance had low level of agreement between interviewees. However, they also insisted that this should be approached by the government with strong regulations. Port authorities also gave low level of agreement regarding whether the use of automated port equipment and sharing the cost of environment-friendly equipment should be considered in the model. As mentioned earlier, Incheon Port has just installed the ARMG and Busan Port also converted to E-RTGCs by sharing the cost with business partners. As the green port project has just initiated by the government, Korean ports are just starting to covert to be sustainable. Even though criteria relating to environmental collaboration with shipping companies had a low level of agreement, Korean ports are aware of giving incentives to those shipping companies who practice green operations. BPA just started to collaborate with shipping companies by introducing ESI to their port and provide incentives to those who satisfy the required score. It is interesting that external social program had low level of consensus but this is the area where the Korea port authorities actively make reports and provide the most information to the public.

Korean port authorities insisted that strong government regulations should be implemented regarding environmental issues. For instance, the Ministry of Oceans and Fisheries has regulated pollutants from vessels to preserve and manage the deteriorating marine environment as part of the implementation of the international conventions to prevent marine pollution. They all gave similar opinion that the government should support ports by reinforcing a stronger regulation for shipping companies and business partners to comply with environmental issues.

There are several challenges that Korean ports are facing so as to develop sustainably. Transforming the port into a sustainable one is a long-term process and the time taken for the realisation of performance is not guaranteed. Sustainably developing a port is an important agenda but there always is a risk as it is a long-term project while the global market is changing so rapidly. Korean ports need to adapt and should always be ready to be competitive in order to survive in a competitive market especially with neighboring countries. Transforming the port to be sustainable is a high cost project and time-consuming. There are also opportunities as the sustainable port project in Korea is within the national plan of development. Therefore, ports will receive further support from the government in terms of finance and regulations. Sustainable port development is a global trend in developed countries. As the green port project has been initiated in 2010, Korean ports will be competitive in the future so as to compete well with other global sustainable ports.

There exist various limitations in the current research such as responses were only from port managers in three ports among 17 ports in Korea due to the limited time frame. However, the current research could be a stepping stone for further research in validating a conceptual framework to measure port sustainable development in the future. Further studies such as applying quantitative empirical analysis, AHP and SEM, could be conducted to provide further insight to the research.

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Supply Chain Resilience and Firm Performance in Liner Shipping Industry

CL Liu[1], KC Shang[2], TC Lirn[1], Kee-hung Lai[3] and Venus Y.H. Lun[3]*

[1]Department of Shipping & Transportation Management, National Taiwan Ocean University
[2]Department of Transportation Science, National Taiwan Ocean University
[3]Department of Logistics and Maritime Studies, The Hong Kong Polytechnic University, Hong Kong

[*]*Corresponding author: tedlirn@email.ntou.edu.tw*

Abstract

This study explores the relationship between supply chain resilience and firm performance in the Taiwanese liner shipping industry. The constructs of supply chain resilience consist of risk management culture, agility, integration, and supply chain (re-)engineering. The results show that the direct effects of risk management culture on agility, integration, and supply chain (re-)engineering are significant, and risk management performance has a significant direct effect on firm performance. The findings also suggest that the risk management performance plays an intermediary role between the three aspects of resilience (i.e., agility, integration, and supply chain (re-)engineering) and firm performance.

Keywords: Supply chain resilience, Firm performance, Liner shipping industry

1. Introduction

Businesses no longer compete individually but as a member of a supply chain (Christopher, 1998). A well-managed supply chain (SC) becomes one of the long lasting resources to enhance a corporate's competitiveness, and how to reduce inventory level and lead time to increase the SC efficiency and profit becomes an formidable challenge confronting many managers. Specialization in manufacturing technology and globalization forced manufacturers outsource their production activities to the nations with lower wage for cost reduction. On the other hand, manufacturers have to sell their final products to the emerging markets with strong purchasing power for better revenue. SC members firstly transform themselves from local manufacturers to regional manufacturers and finally global manufacturers. SC becomes complicated and fragile after the enlarging number of its members from different cultures, location, and time zones to join a SC.

Liner shipping industry is the cornerstone of the SC pursuing for great profit. Thus shipping lines have to constantly increase the numbers of their container ships which can provide a broadly geographical service coverage. Liner shipping companies firstly served a single nation, then a cluster of nations in a region, and finally many nations globally. The expansion of service coverage and service routes made liner companies' operation complicated and fragile. Wide spreading political instability, climate change, communicable diseases, and terrorist attacks frequently result in the high likelihood of SC disruption. The outbreak of 911 terrorist attack, the damage from Hurricane Katrina, Tohoku earthquake in Japan in 2011, Debt Crisis in the EU, and the 2011 flooding in Thailand all have significant impacts on the SC management (Pettit et al., 2013).

Liner shipping industry has encountered problems resulting from unstable economic cycle, empty container repositioning, seafarer shortage, escalating bunker price, cargo space oversupply, fluctuating ship price, and port closure (e.g. ports closure due to an explosion in the Tianjin Port, industrial strike in the port of Long Beach and Los Angels, the earthquake and tsunami in Japan). Damages to the ship due to collision, fire, explosion, warfare, terrorist attack, piracy, etc. also weaken the SC resilience. Thus, port authorities and liner operators have to change their business mindset. They don't have to consider whether the disruption will occur or not, but to consider when the disruption will occur and how long the impacts will be lasting before they can operate as usual. In addition to SC cost and efficiency, they have to improve the resilience of their

SC (i.e. SCR) to ensure the continued operations of the whole SC and eventually create a long lasting competitiveness for their SC (Zsidisin and Wagner, 2010; Christopher and Peck, 2004).

SCR represents an enterprise's ability to adapt to environmental changes or confront with external threats in order to mitigate the negative impacts of supply chain vulnerability (Ponomarov and Holcomb, 2009). It is useful for an enterprise to quickly assess the impacts of risks on the supply chain as well as the possible levels of recovery during disconnections, which is beneficial to the collaboration between supply chain partners (Soni et al., 2014). SCR can be defined as an enterprise's ability to identify bottlenecks and potential risks in a supply chain, which allows it to adopt effective measures before a supply chain is disconnected (Brandon-Jones et al., 2014).

SCR is one of the most important aspects of supply chain management (SCM), and its enablers have also been extensively studied (e.g. Ivanov et al., 2014; Pettit et al., 2013; Ratick et al., 2008; Soni et al., 2014; Spiegler et al., 2012; Vugrin et al., 2011). According to a study conducted by Alcantara (2014), 81% of respondents report that they have encountered at least one instance of supply chain disruption in 2013, and almost a quarter of respondents (23.6%) report annual cumulative losses of at least €1 million due to supply chain disruptions. Many corporates' profitability and economic sustainability are greatly threatened as a result of their inability to deal with uncertainty and risks they encountered. Hendricks & Singhal (2005) surveyed 800 American companies which have at least once experienced SC disruption, and found SC disruption results in the company's revenue and sales value decreased by 107% and 7% respectively. Unfortunately, their total cost has increased by 11%. When the risk events are occurred, these two negative impacts are continued for at least another two years and the companies' stock prices are also quickly fallen. Thus, the SC resilience capability cannot be overemphasized.

There are three motivations for this research. Firstly, although SCR has been identified as one of the most important issues in contemporary supply chain management (Brandon-Jones et al., 2014; Ivanov et al., 2014; Spiegler et al., 2012; Urciuoli et al., 2014), the theoretical basis for understanding SCR is fragmented, blurred, and undiscussed. Extant researches on SCR are mostly qualitative oriented (e.g. Azevedo et al., 2013; Jüttner and Maklan, 2011; Johnson et al., 2013; Leat and Revoredo−Giha, 2013; Scholten et al., 2014; Urciuoli et al., 2014; Wedawatta et al., 2010). Quantitative researches by large scale survey on SCR are very limited (e.g. Ambulkar et al., 2015; Brandon-Jones et al., 2014). To narrow the gap between practice and theory, a prudent and quantitative research technique is used to discuss the relationship between the firms' SCR capability and their performance. Secondly, most SCR researches focused on surveying the manufacturing industry (e.g. Azevedo et al., 2013; Carvalho et al., 2012; Colicchia et al., 2010; Jüttner and Maklan, 2011; Pettit et al., 2010; Wieland and Wallenburg, 2013). To the authors' knowledge, there exists no SCR research in the liner shipping industry context which is frequently operated under a competitive and unstable environment. Thirdly, there are no commonly accepted sub-constructs for SCR (Hohenstein et al., 2015). In addition, few empirical evidences existed to reveal how different constructs/measurements of SCR can simultaneously influence the firms' performance. Some of previous researches simply treated SCR as a dependent variable in examining the factors that influence it, and how it is moderated by other variables (e.g. Brandon-Jones et al., 2014; Jüttner and Maklan, 2011). In contrast, the other researches merely focused on the influences of various SCR's constructs on supply chains' customer values (Wieland and Wallenburg, 2013). In short, very few of the above-mentioned researches have discussed the relationships between the different SCR sub-constructs/measurements or the mediating effect between various SCR sub-constructs/measurements and firms' performance, and this study aims to examine these relationships.

This research uses data collected from one of the most important service industry, the liner shipping industry, to empirically examine the impact of supply chain resilience on supply chain performances from the resource base view. The key questions posed by this study include:

- What are the constructs/measurements of SCR and their interrelationships in the liner shipping industry?
- How do different types of SCR affect firm performance in the liner shipping industry?

This study has made several contributions to the literature and practice of SCR. First, it examined the concepts of different types of SCR as well as their interrelationships. Second, it revealed the impacts of different types of SCR on firm performance from the RBV perspective. Finally the present study also provided several principles for the management personnel to understand how to commit efforts and resources in response to different types of SCR. These principles also provided a detailed illustration of how to manage different measurements of SCR to increase firm performance.

2. Literature Review and Hypothesis Development

2.1 SCR

SCR represents "the system's adaptive capability to deal with temporary disruptive events" (Soni et al., 2014). An organization may adopt a series of precautions to mitigate damages brought by known and detectable disruptions (Ivanov et al., 2014; Pettit et al., 2013). For example, the organization may investigate in advance risk factors that may weaken its supply chain and evaluate its supply chain's level of sensitivity against said risk factor. This can strengthen the supply chain's ability to resist temporary disruptive events and maintain supply chain robustness (Pettit et al., 2010). For non-preventable risks, the organization should prepare a suitable amount of resources to increase its supply chain's adaptive capability in handling unavoidable events (Ratick et al., 2008; Vugrin et al., 2011).

Various measurements of SCR have been proposed in literature, such as agility, collaboration, information sharing, sustainability, risk and revenue sharing, trust, visibility, risk management culture, adaptive capability, and structure (Soni et al., 2014). In order to understand the interaction between each measurement and their relationships to performance, studies must first consider the variables of each measurement. However, the variables of SCR are presented with significant disparity in the literature (Hohenstein et al., 2015; Jüttner and Maklan, 2011). While some studies propose SCR as a unidimensional construct (e.g. Ambulkar et al., 2015; Brandon-Jones et al., 2014; Gölgeci and Ponomarov, 2015), others perceive SCR come from agility and robustness (e.g. Wieland and Wallenburg, 2012; Wieland and Wallenburg, 2013). And some adopt even more constructs (e.g. Azadeh et al., 2014; Hohenstein et al., 2015; Johnson et al., 2013; Pereira et al., 2014; Pettit et al., 2013; Scholten et al., 2014). While each of these measurements represents an important aspect of SCR, there are also quite a few overlapping areas between them. The framework of this study follows the report by Christopher and Peck (2004) who indicated the SCR of a company can be measured by its risk management culture, agility, collaboration, and supply chain (re-)engineering ability.

Risk management culture, or risk awareness, is the overall organizational philosophy that puts risk management as a priority, which is an important element of SCR (Sheffi and Rice, 2005). Improved risk awareness in a supply chain helps managers decrease the risks in both the organization and its partners (Jüttner, 2005). As researchers have pointed out, "to be resilient, organisations need to develop appropriate management policies and actions that assess risk continuously and coordinate the efforts of their supply network" (Scholten et al., 2014).

Agility, or flexibility, focuses on "rapid system reconfiguration in the face of unforeseeable changes" (Bakshi and Kleindorfer, 2009). When there are changes in customers' demands or disruptions in the supply chain, organizations with less agility will expose partners in their supply chain to operational risk (Azevedo et al., 2013). The main elements of agility are visibility and velocity (Christopher and Peck, 2004). The first represents a clear understanding of upstream and downstream partners' available stocks, supply and demand conditions, as well as production and purchase timelines. The latter refers to the supply chain's speed of recovery after a disruption occurs (Azevedo et al., 2013). An organization's agility is also affected by its supply chain partners' ability to react (Braunscheidel and Suresh, 2009). For example, through cooperation with a highly responsive supplier, an manufacturer can effectively lower its inventory risks (Chopra and Sodhi, 2004). For a container ship operator, agility reflects its ability to respond to external environmental change, thereby countering the volatile market. These abilities may include sensitivity to external environment, service routes, flexibility in cargo hold slots exchange, and partners' ability to react.

Integration, or collaboration, represents the cooperation (Huo, 2012) and the coordination (Glenn Richey, 2009; Swaminathan et al., 1998) between departments or functions within an organization. Within a supply chain system, integration may refer to internal and external integration. Internal integration refers to the coordination between various functions within an organization. External integration is the collaboration with partners in the supply chain to meet customers' demands (Cao et al., 2015). Since integrations are often accompanied by high risks, organizations need to establish effective information exchange between them to decrease uncertainty (Christopher and Peck, 2004). An enterprise may use a potential partner's level of supply chain integration to determine whether to start a strategic alliance or cooperatively manage intra- and inter-organizational processes (Huo, 2012), thereby decreasing supply chain uncertainty and more effectively manage risks (Sinha et al., 2004). Integration is reflected in information sharing and operational integration between organizations, helping supply chain to send information and react quickly in the face of disruptions. Moreover, it is sharing experiences among supply chain partners after the disruptions are overcome (Sheffi, 2001).

Reengineering refers specifically to the design of the new business process (Davenport, 2013). It is to integrate processes and activities for product and service flow optimization. Reengineering are programs of business improvement which can make corporations on journeys of radical business redesign (Hammer, 1996). There are two types of reengineering. The internal reengineering is used to modify the habits, routines and mental models that have led to activities and processes being performed with low results, and the strong challenges of implementing reengineering measures lie in the cultural and mental change in the individuals working in the firm (Rodriguez-Diaz & Espino-Rodriguez, 2006). Establishing a resilient supply chain also requires knowledge and understanding of supply chain structures (Soni et al., 2014). "Resilience must be built into a supply chain in advance of a disturbance and incorporate readiness to enable an efficient and effective response" (Scholten et al., 2014). In existing supply chain designs, Jüttner (2005) believes that risk assessment tools can be utilized to find the weakest link in supply chain network, thereby making effective precaution before a disruption occurs. Moreover, due to possible sudden disruptions in the supply chain, its designs must also consider process redundancies, excess capacities (Mason-Jones and Towill, 1998), and supply chain partners' risk awareness (Christopher and Peck, 2004).

2.2 Performance

2.2.1 Risk management performance

Risk management performance evaluates a company's ability to confront opportunities and threats in an environment (Andersen, 2009). Different kinds of constructs are used to measure the risk management performance of a firm. For example, Carreno et al. (2007) measured risk management performance using four constructs: identification of risk, risk reduction, disaster management, as well as governance and financial protection. Kloss-Grote and Moss (2008), on the other hand, constructed a risk management performance assessment based on two basic concepts—risk management ability and resource input level for risk management.

2.2.2 Firm performance

A review of available literatures shows that there is a wide range of opinions regarding firm performance. Most of the researches focus on financial performances of the firm, such as using ROA, profitability ratios, and market value ratios as evaluation criteria (Andersen, 2009; Fairbank, 2006; Yang, 2012). However, other researchers (e.g. Jun and Rowley, 2014) have already pointed out that supply chain evaluations that are based on financial performance may have some limitations, making it difficult to describe the performance of certain enterprise structures. This study adopted a general performance concept as the criteria for evaluating firm performance. Thus, the evaluation criteria used in this study integrates operational performance and financial performance (Ou et al., 2010), such as customer loyalty, customer satisfaction, service level, market share, and net profit before tax.

2.3 The impact of risk management culture on agility, integration and SC (re-)engineering

The formation of organizational culture helps to create common core values and behavioral standards for members of the organization, which is beneficial for the organization in reaching its goals (Kuhn and Youngberg, 2002; Mello and Stank, 2005; Summerill et al., 2010). The establishment of risk management culture, however, can effectively incorporate risk management procedures into the entire operating structure, thereby ensuring normal operation of the supply chain (Sheffi and Rice, 2005). For example, one of the obstacles in supply chain visibility is the lack of information exchange between organizations (Christopher and Peck, 2004), resulting in higher operational risks for the enterprise due to belated awareness of disruptions. Through sharing of risk management knowledge and establishing risk awareness, supply chains may overcome the wall between organizations and gain more awareness of its external environmental changes (Faisal et al., 2006). Similarly, this also helps enterprises to establish appropriate management policies and actions to react to uncertainty (Kuhn and Youngberg, 2002). Risk management culture can help companies to understand the opportunities and threats in the business environment and to respond rapidly to the changing market. Without the philosophy of risk management, it is difficult for companies to maintain flexibility in operation (Kuhn and Youngberg, 2002). Based on the above, it is logical to hypothesize that:

H1-1 Risk management culture has a positive impact on agility.

Organizations' different perspectives and attitudes towards risks often influence the sharing of risk event-related information (Soni et al., 2014). The establishment of risk management culture is beneficial to the sharing of risk information between organizations (Christopher and Peck, 2004), helping consolidate external and internal information of an enterprise. Moreover, the emphasis of risk management culture is that organizations should focus on normal operation of the supply chain and not on operational performances of individual departments. Such culture increases awareness to disruptions and improves the reaction ability during a disruption, helping the enterprise to cooperate with other members upstream and downstream of the supply chain. Risk management culture enhances the effectiveness of inter-departmental information sharing and improves cooperation and collaboration with supply chain partners. Thus, this study proposes the following hypothesis:

H1-2 Risk management culture has a positive impact on integration.

Risk management culture enhances the awareness of supply chain risks, improves risk management ability of supply chain partners and increases an organization's capability to recognize important changes in the supply chain. Without the awareness of risk management, it is difficult for companies to allocate more resources to deal with incidents related to supply chain risks. Thus, this study proposes the following hypothesis:

H1-3 Risk management culture has a positive impact on supply chain (re-)engineering.

2.4 The impact of agility, integration and supply chain (re-)engineering on performance: A RBV perspective

RBV evaluates competitive advantages based on internal distinctive competence (i.e. resources) of an organization (Barney, 1991). Daft (2004) defines resources as tangible properties and intangible abilities that an enterprise can control and use to increase effectiveness and performance through strategic thinking. Barney (1991) divides resources into tangible and intangible resources and lists the following four characteristics: value, rareness, imperfect imitability, and non-substitution. SCR can be viewed as a type of organizational resource which helps organizations to adapt to the environment for sustainable development (Ponomarov and Holcomb, 2009). The following uses RBV perspective to discuss the impact of agility, integration and supply chain (re-)engineering on firm performance separately.

A company's agility falls into the RBV's definition of resources (Chiang et al., 2012; Christopher and Peck, 2004; Sharifi and Zhang, 2001). For example, organizations will develop specific agility based on the level of agility they require (Sharifi and Zhang, 2001). This is a characteristic of imperfect imitability. More than helping organizations to mitigate risk in the supply chain (Christopher and Peck, 2004), agility also provides resources during supply chain disruptions to maintain supply chain stability, thus it also has a "valuable" characteristic. Agility helps firms to quickly adapt to environmental influences, respond appropriately to changes, responds even quicker to supply chain partners, and increases supply chain stability as well as profitability. Based on the RBV, this study proposes:

H2-1 Agility has a positive impact on risk management performance.
H2-2 Agility has a positive impact on firm performance.

The exchange of information among SCM partners is the foundation for integration (Scholten et al., 2014). However, organizations require long-term investment of resources, accumulation of experiences, and establishment of trust in order to share information (Rodríguez-Díaz and Espino-Rodríguez, 2006). This is also a characteristic of imperfect imitability. Collaborative partnerships not only play a key role before and during a disruption but also decrease the likelihood of the bullwhip effect (Lee et al., 1997), presenting the "valuable" characteristic. Effective integration among SCM parties increase visibility (Christopher and Peck, 2004), decrease uncertainty (Soni et al., 2014), and, with operational efficiency, increase firm performance (Huo, 2012). Based on the RBV, this study proposes:

H3-1 Integration has a positive impact on risk management performance.
H3-2 Integration has a positive impact on firm performance.

Craighead et al. (2007) believes that by nature, all supply chains have risks. The impact severity from a supply chain disruption depends on the supply chain's risks detection/warning and recovery abilities and the resources the supply chain owns. Not only the supply chain (re-)engineering detects the weakest link in the supply chain, it also effectively reduces the threat caused by the disruption and increases subsequent recovery ability (Craighead et al., 2007). Thus, it can increase enterprise competitiveness and earning power (Rodríguez -Díaz and Espino-Rodríguez, 2006). Based on the RBV, this study proposes:

H4-1 Supply chain (re-)engineering has a positive impact on risk management performance.
H4-2 Supply chain (re-)engineering has a positive impact on firm performance.

2.5 The impact of risk management performance on firm performance

Theories and business cases both generally agree that risk management performance is positively related to firm performance (Andersen, 2009; Jun and Rowley, 2014; Teoh and Rajendran, 2015). For instance, the ability to confront opportunities and threats in the environment helps firms satisfy customers' requirements under market uncertainty, and in turn increases firms' market shares and growth. Moreover, better risk management ability can help firms mitigate the negative impacts of supply chain vulnerability, which reduces costs and leads to better financial performance. An efficient risk management in shipping companies includes identifying malfunctions, periodical updating of the risk evaluation and by taking corrective measures. ISM code is a risk management tool employed by shipowners to ensure the safety operation of ships. Both ship-owner and cargo insurer can also use insurance as a risk control measure to improve firm performance (Georgescu, 2011). This leads to the following hypothesis:

H5 Risk management performance has a positive impact on firm performance.

In summary, a conceptual model for SCR and performance is proposed in Figure 1.

3. Method

3.1 Sampling

The 253 companies used within the survey were obtained from the membership directory of Taiwan Shipping Agents Association and National Association of Chinese Shipowners (Taiwan). Companies not involved in liner shipping agency operation are excluded from our mailing list.

3.2. Questionnaire design

Questionnaire scales in this research were based on previous studies in the relevant academic literature. A preliminary survey was pre-tested in Taiwan by interviewing three practitioners with relevant work experiences in order to identify and correct problems such as sequence or wording of questions. After the pilot test, the revised questionnaires using multiple-item scales were formulated, as shown in Appendix A. The questionnaire consists of four parts: supply chain risks, SCR, risk management performance and firm performance. Twenty-nine items selected as measures of supply chain risks were based upon previous literature (Wagner and Bode, 2008). Respondents were asked to indicate the levels of negative influence on their company or their container ship operator that were caused by the listed supply chain risks using a five-point Likert scale, where 1 represented "completely no influence" and 5 represented "huge influence".

In turn, twenty-nine indicators were employed to assess SCR that had been employed in previous literature (Christopher and Peck, 2004; Jüttner and Maklan, 2011; Johnson et al., 2013). Respondents were asked to provide a rating of an agreement level with the company's SCR using a five-point Likert scale anchored by "1= strongly disagree" and "5= strongly agree". Moreover, this study adopted existing validated items to assess risk management performance (Wagner and Bode, 2008) and firm performance (Fawcett et al., 1997; Shang and Marlow, 2005; Wagner and Bode, 2008; Wieland and Wallenburg, 2013). Respondents were asked to provide a rating of a company's satisfaction level with the risk management performance and firm performance using a five-point Likert scale anchored by "1= strongly dissatisfied" and "5= strongly satisfied".

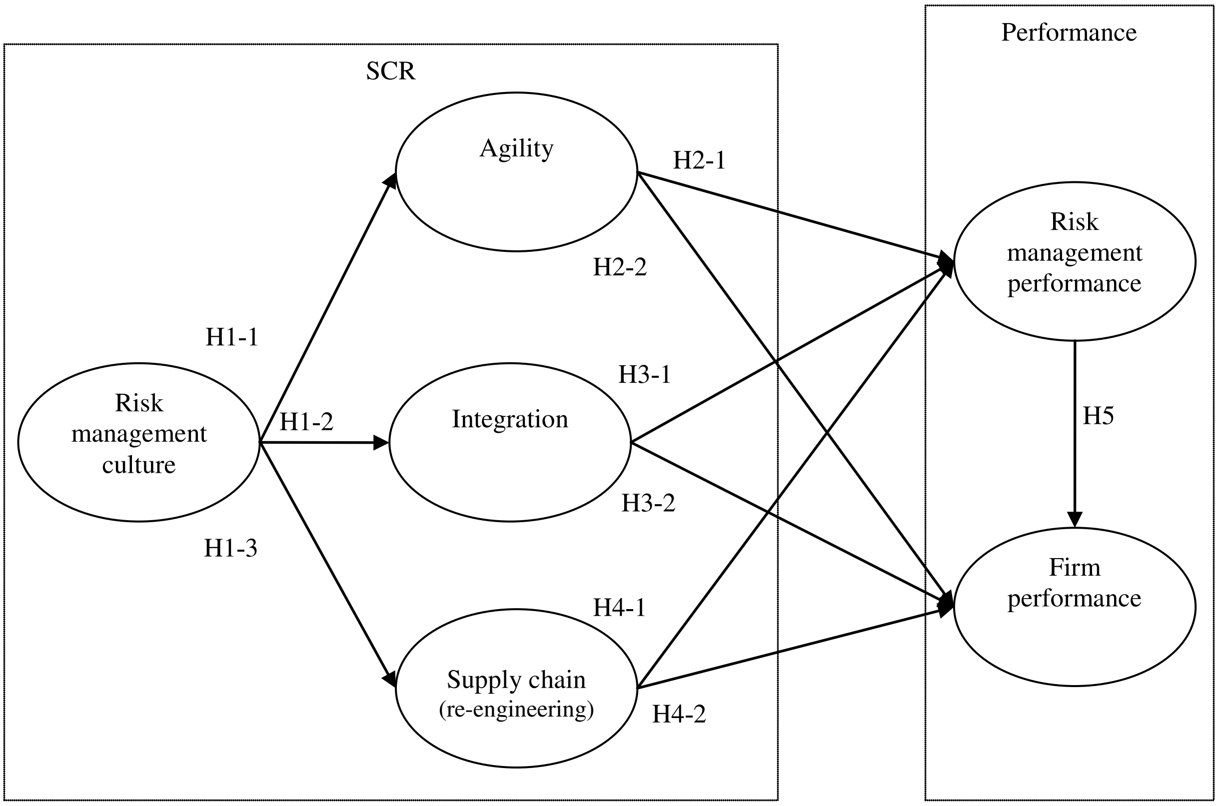

Figure 1: Proposed model

3.3 Choices of statistical techniques

A partial least squares structural equation modeling (PLS-SEM/PLS) approach was used to test the research hypotheses. All analyses were carried out using the SPSS version 12.0 and the SmartPLS version 2.0.M3 statistical packages.

4. Analysis Results

4.1 Response rate

The data collection phase of the study began on the beginning of May 2014 and concluded on the middle of October 2014. The total usable number of responses was 112. Therefore, the overall response rate was 44.3% (112/253).

4.2 Representativeness

The non-response bias was tested using an independent-sample t test by comparing the responses that were received during the first 3/4 and final 1/4 of the questionnaire response period (Armstrong and Overton, 1977). The returned surveys were compared based on their total sales volume, full-time employees and the levels of all the Likert ratings. Most items were not statistically significant at the 0.05 level, except one item of risk management culture (c4) and one item of integration (i2), which suggests nonresponse bias may not be a problem in this study.

4.3 Profile of respondents

75% of the respondents had managerial responsibilities, reinforcing the reliability of survey findings. 78% of firms had been in operation for more than 21 years, 17% between 11 and 20 years, and nearly 5% less than 10 years. Nearly 34% of respondents reported their firms' 2013 total sales volume as less than 16.7 million USD, 30% as 66.7 million USD or more, and 36.4% as between 16.7 and 66.7 million USD. In terms of the numbers of staffs they employed, 26% had more than 250 employees, 34%had fewer than 51 employees, and 40% had between 51 and 250 employees. Most sampled firms were local companies (57.3%) in Taiwan. Only 27.3% were foreign companies. 54% of firms were shipping agent sand 46% were of them were containership operators.

4.4 Perceptions of supply chain risk

In order to understand the effects of different types of supply chain risk to the firms' operation from the liner shipping companies' perspective, respondents of liner shipping companies were asked to rate each item for supply chain risk using a five point Likert scale ranging from "1 = absolutely no influence" to "5 = strongly influenced." As displayed in Table 4.1, when examining the 29 types of supply chain risk, the top five ones that strongly influenced firm's operations (their mean scores were over 3.40) were:
r8. Rapid increases or drastic changes in gasoline prices.
r9. Excessive or drastic changes in market's shipping space.
r1. Problems with a sluggish demand as a result of the global recession.
r26. Natural disasters (such as an earthquake, flood, extreme weather, and tsunami).
r24. Unstable political environments, wars, riots, or other social-political crises.

4.5 Assessment of common method bias (CMB)

This study involving cross-sectional correlational variables is vulnerable to CMB (Siemsen et al., 2010). A Harman's one-factor test (Podsakoff and Organ, 1986) for CMB was performed on the six scales (i.e., risk management culture, agility, integration, supply chain (re-)engineering, risk management performance, and firm performance) with 42 items by using principal components analysis where the unrotated factor solution was examined. The results indicated the existence of nine factors with eigenvalues greater than one, with the first factor explaining only 39.94 per cent of the variance and not explaining the majority of the variance. To further assess CMB, a confirmatory factor analysis (CFA) was applied on the one factor and measurement model (Korsgaard and Roberson, 1995). The model fit indices for one factor model is χ^2 (819) = 2829.29, GFI = 0.39, AGFI = 0.33, RMSEA = 0.15 were significantly worse than those of the measurement model. These findings, therefore, suggested that the common method bias is not an issue in this study.

4.6 Measurement model

Results of the PLS analysis are presented in Tables 2 and 3. Convergent and discriminant validity of the measurement model is evaluated by examining the loadings and cross-loadings of the indicators, which are hence presented in Table 2. All of the indicators load higher on the construct of interest than on any other variables, thereby providing evidence for these constructs' discriminant validity (Hair et al., 2014). Moreover, most of the individual factor loadings were greater than 0.707 (Hair et al., 2014), ranging from 0.682 to 0.921, thereby assuring convergent validity.

Table 1: Respondents' perceptions on supply chain risk

Types of supply chain risk (Constructs/Measurements)	Mean	Standard deviation
Demand Side Risk		
r1. Problems with a sluggish demand as a result of the global recession.	3.90	0.900
r2. Unexpected or drastic changes in client demands.	3.21	0.963
r3. Clients providing insufficient or exaggerated purchase orders or quantity demanded.	2.77	0.969
r4. Key accounts or freight forwarders transfer orders without notice.	3.04	1.040
Supply Side Risk		
r5. Schedule conflicts in dispatching empty cargo containers.	3.23	1.048
r6. Unstable quality of delivery.	2.96	0.986
r7. Overseas agents go out of business without notice.	2.73	1.272
r8. Rapid increases or drastic changes in gasoline prices.	4.01	0.939
r9. Excessive or drastic changes in market's shipping space.	3.95	1.012
r10. Insufficient or overcrowded docks.	3.27	1.107
r11. Shortage of sailors.	2.47	1.102
r12. Increases or drastic changes in the cost of shipbuilding.	3.13	1.078
Regulatory, Legal, and Bureaucratic Risk		
r13. Changes in political environment caused by new laws or regulations.	3.15	1.033
r14. Obstacles from government regulations for supply chain setup and operation.	3.16	1.049
r15. Delays in custom clearance for cargo containers.	2.92	1.058
r16. Delays in the ship's schedule to enter or leave the harbor.	3.04	1.150
Infrastructure Risk		
r17. Ship shutdown or loss in shipping space due to regional destructions (such as a strike, fire, explosion, and industrial accident).	3.30	1.199
r18. Ship shutdown or loss in shipping space due to physical damages to the ship (such as a collision, fire, and explosion).	3.13	1.253
r19. Interruptions caused by failed or damaged internal information or communication systems at the company (such as computer viruses or software problems).	2.66	1.070
r20. Ship shutdown due to its own technical problems (such as the ship is too old or the equipment is impaired).	2.71	1.077
r21. Ship shutdown due to its supply chain partner's technical problems (such as old or damaged cargo-handling gear at the harbor).	2.96	1.116
r22. Failed or damaged external information or communication systems.	2.77	1.022
r23. Regional destruction or interruption of road infrastructure.	2.73	1.170
Disaster Risk		
r24. Unstable political environments, wars, riots, or other social-political crises.	3.44	1.176
r25. Illness or infectious diseases (such as SARS and H1N1).	2.95	1.139
r26. Natural disasters (such as an earthquake, flood, extreme weather, and tsunami).	3.49	1.215
r27. International terrorist attacks.	3.06	1.240
r28. Pirates.	2.93	1.235
r29. Illegal trades and organized crimes.	2.79	1.158

Note: Mean scores are on a five-point Likert-type scale

Table 2: Factor loadings (bolded) and cross loadings

Construct / Indicator	Risk management culture	Agility	Integration	Supply chain (re-) engineering	Risk management performance	Firm performance
c1	**0.858**	0.462	0.591	0.702	0.548	0.402
c2	**0.906**	0.519	0.592	0.657	0.485	0.366
c3	**0.907**	0.431	0.612	0.686	0.502	0.331
c4	**0.741**	0.438	0.521	0.482	0.391	0.362
c5	**0.821**	0.411	0.477	0.586	0.389	0.239
c6	**0.844**	0.456	0.607	0.650	0.491	0.472

a1	0.520	**0.869**	0.554	0.334	0.503	0.360
a2	0.477	**0.899**	0.578	0.357	0.534	0.531
a3	0.369	**0.788**	0.507	0.331	0.386	0.402
a6	0.398	**0.765**	0.374	0.186	0.329	0.315
i1	0.462	0.590	**0.806**	0.359	0.462	0.405
i2	0.533	0.480	**0.765**	0.477	0.517	0.364
i3	0.485	0.430	**0.770**	0.417	0.326	0.381
i4	0.544	0.548	**0.857**	0.484	0.498	0.464
i5	0.605	0.516	**0.823**	0.539	0.483	0.419
i7	0.622	0.431	**0.820**	0.559	0.509	0.516
i8	0.510	0.473	**0.799**	0.424	0.489	0.562
s1	0.595	0.448	0.503	**0.741**	0.515	0.476
s4	0.695	0.257	0.562	**0.871**	0.498	0.362
s5	0.634	0.280	0.475	**0.921**	0.528	0.391
s6	0.602	0.300	0.404	**0.840**	0.421	0.393
s7	0.637	0.286	0.524	**0.879**	0.478	0.416
rp1	0.423	0.447	0.438	0.460	**0.866**	0.591
rp2	0.402	0.430	0.475	0.395	**0.874**	0.574
rp3	0.594	0.435	0.507	0.656	**0.807**	0.463
rp4	0.447	0.435	0.484	0.423	**0.840**	0.492
rp5	0.483	0.518	0.572	0.495	**0.851**	0.650
p6	0.268	0.373	0.414	0.354	0.565	**0.811**
p7	0.406	0.427	0.448	0.391	0.594	**0.863**
p8	0.326	0.452	0.437	0.406	0.592	**0.798**
p9	0.400	0.383	0.514	0.418	0.581	**0.908**
p10	0.434	0.456	0.537	0.422	0.601	**0.842**
p11	0.344	0.419	0.486	0.413	0.480	**0.824**
p12	0.382	0.391	0.477	0.399	0.430	**0.781**
p13	0.201	0.269	0.283	0.318	0.404	**0.682**

c = Risk management culture, a = Agility, i = Integration, s = Supply chain (re-)engineering, rp = Risk management performance, p = Firm performance

Reliability results are shown in Table 3. The composite reliabilities of the different measures ranged from 0.900 to 0.941, which exceeded the 0.700 cut-off value proposed by Fornell and Larcker (1981). Table 3 also present validity results. The average variance extracted (AVE) of each measure fulfilled Fornell and Larcker's (1981) accepted value of 0.5, supporting the convergent validity of our measures. Moreover, the square root of AVE values were all greater than the inter-correlation values, thereby assuring discriminant validity (Hair et al., 2014). In sum, the results of Table 3 provides evidence of sufficient reliability and validity for the measures.

Table 3: Inter-construct correlations: consistency and reliability tests

	AVE	Composite Reliability	Risk management culture	Agility	Integration	Supply chain (re-)engineering	Risk management performance	Firm performance
Risk management culture	0.720	0.939	**0.848**					
Agility	0.693	0.900	0.535	**0.832**				
Integration	0.650	0.929	0.671	0.613	**0.806**			
Supply chain (re-)engineering	0.727	0.930	0.745	0.370	0.582	**0.853**		
Risk management performance	0.666	0.941	0.429	0.490	0.556	0.479	**0.816**	
Firm performance	0.719	0.927	0.556	0.537	0.587	0.575	0.658	**0.848**

*Square root of the AVE on the diagonal.

4.7 Structural Model

The results of the PLS analysis for the research model are presented in Figure 2 and Table 4.

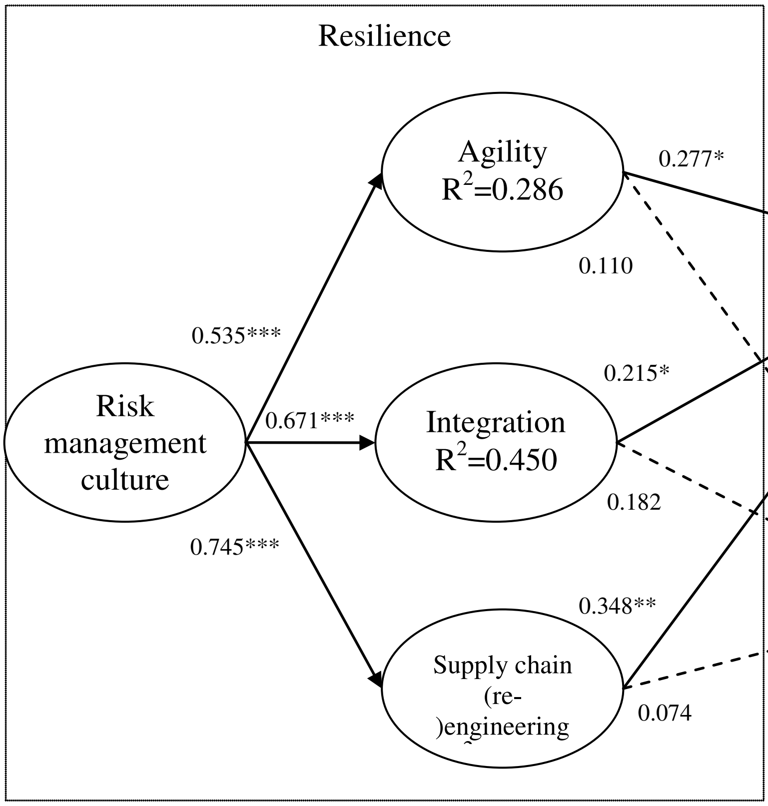

Figure 2: Structural model results
*Represents significant level p < 0.05; ** p < 0.01; *** p < 0.001
The R^2 indicates the amount of variance explained by the model

Table 4: Structural model results

	Paths	Path coefficient	Standard Error	t-value	Supported/ Not-supported
H1-1	Risk management culture → Agility	0.535	0.087	6.123	Supported
H1-2	Risk management culture → Integration	0.671	0.060	11.214	Supported
H1-3	Risk management culture → Supply chain (re-)engineering	0.745	0.043	17.251	Supported
H2-1	Agility → Risk management performance	0.277	0.117	2.372	Supported
H2-2	Agility → Firm performance	0.110	0.137	0.805	Not-supported
H3-1	Integration → Risk management performance	0.215	0.103	2.086	Supported
H3-2	Integration → Firm performance	0.182	0.111	1.642	Not-supported
H4-1	Supply chain (re-)engineering → Risk management performance	0.348	0.123	2.823	Supported
H4-2	Supply chain (re-)engineering → Firm performance	0.074	0.117	0.632	Not-supported
H5	Risk management performance → Firm performance	0.449	0.107	4.179	Supported

Bootstrapping with 5000 samples was used to evaluate the standard errors and t-values of path coefficients (Hair et al., 2014). The results in Figure 2 and Table 4 indicated that risk management culture demonstrates a direct, statistically significant relationship with container carriers' agility (path coefficient = 0.535, P < 0.001), integration (path coefficient =0.671, P < 0.001) and supply chain (re-)engineering (path coefficient =0.745, P

< 0.001), thus results support H1-1, H1-2 and H1-3. Moreover, the hypothesized positive relationship between agility and risk management performance (H2-1, path coefficient =0.277, $P < 0.05$), between integration and risk management performance (H3-1, path coefficient =0.215, $P < 0.05$), and between supply chain (re-)engineering and risk management performance (H4-1, path coefficient =0.348, $P < 0.01$) was supported. However, no paths were statistically significant between the three aspects of resilience and firm performance, including H2-2 (agility → firm performance, path coefficient =0.110, $P > 0.05$), H3-2 (integration → firm performance, path coefficient =0.182, $P > 0.05$), and H4-2 (supply chain (re-)engineering → firm performance, path coefficient =0.074, $P > 0.05$). The hypothesized positive relationship between risk management performance and firm performance was supported (H5, path coefficient =0.449, $P < 0.001$). It was confirmed that the risk management performance plays an intermediary role between the three aspects of resilience (i.e., agility, integration and supply chain (re-)engineering) and firm performance. The standardized structural parameter estimates (total effects) are shown in Table 5 and we discuss their implications in the next section.

Table 5: Total effects of structural model results

	Agility	Integration	Supply chain (re-)engineering	Risk management performance	Firm performance
Risk management culture	0.535	0.671	0.745	0.551	0.484
Agility				0.277	0.235
Integration				0.215	0.279
Supply chain (re)engineering				0.348	0.231
Risk management performance					0.449

5. Discussion

Of all four SCR constructs, risk management culture has the greatest indirect influence on firm performance via the supply chain (re-)engineering. As well as having a positive influence on agility, integration and supply chain (re-)engineering, its impact is very significant. Therefore, companies with a higher degree of risk management culture are more likely to have higher degrees of agility, integration and supply chain (re-)engineering. This finding is similar to that of Cao et al. (2015), which showed the impact of organizational culture on supply chain integration. This finding is also similar to that of Williams et al. (2009), which found supply chain security culture can enhance the resilience of an organization. Moreover, the finding indicates the importance of risk management culture in improving firm performance. The largest total influence on firm performance leads us to confidently state that risk management culture is one of the most critical variables for achieving higher firm performance.

The three aspects of SCR, agility, integration and supply chain (re-)engineering, all have a positive significant impact on risk management performance. This implies that market adaptability, internal and external coordination, and sensitive to the market, contribute to performance in risk management. The three aspects of SCR has no significant direct influence on firm performance, but it indirectly influences firm performance through risk management performance. This means that agility, integration and supply chain (re-)engineering have to be transformed into risk management performance before they can create superior performance. This finding is similar to that of Huo (2012), which showed that customer integration can enhance firm performance through customer-oriented performance. As SCR requires extra resources and investments (e.g. extra labour and equipments) to overcome unexpected incidents, it can lead to poor firm performance. Thus, the direct effects of SCR to firm performance may be reduced by the required preparations and investments and result in a negligible direct impact on firm performance.

Risk management performance has a positive significant impact on firm performance. This implies that risk management ability and resource input level for risk management contribute to firm performance. The ability to rapidly respond to the changing market helps companies meet customer needs and mitigate the negative impacts of supply chain vulnerability, which increases firms' revenue and profit.

Many agile practices are frequently used by the shipping liners. For example, the top 20 leading liner companies have time chartered in large percentages of their fleets in the last decade, so that they can avoid owns large amount of tonnages during a market downturn and keep their service capacity in the meantime.

Shipowners also constantly change their routings from round-the-world routing to pendulum routing. Seafarers are trained to work firstly as an ordinary seaman, then able body seaman, and finally general purpose seaman. Deck officers are now trained to handle both the ship navigation and radio operation.

Liner companies' services are also increasingly integrated. Alliance members have shared most of their data on the logistics solution systems such as Cargo Smart. Ocean container carriers are integrating their sea transportation services with their own quayside container terminal operation. APMT, a member of AP Moller Group, has signed an agreement of $1bn value to purchase the remaining 39% of rival terminal operator Grup Maritim TCB in 2015.

Supply chain design and reengineering becomes a must for large liner companies to survive in an unpredictable environment. Maersk Lines, COSCON, Evergreen etc. have setup risk management department and risk management committee. The enforcement of ISM in 1998 also made many ocean carriers reorganize their operation department to include an ISM internal audit team in the liner companies.

Containers liners serve between the Asian and the Europe have to buy many types of insurances, including hull and machinery insurance, protection and indemnity insurance(P&I), piracy attack insurance, etc. Containers liners with a good risk management practice could reduce the chance of the risks occurred. Thus all the insurance premiums and the initial call by P&I clubs will be reduced accordingly. Thus overall financial performance of the container carriers could be largely improved.

6. Conclusion and Implications

This study evaluated the relationship between risk management culture, agility, integration, supply chain (re-)engineering, risk management performance, and firm performance in liner shipping firms in Taiwan. The efforts put into this study are a great addition to existing literature. In the past, there have been relatively few empirical studies on the different types of SCR and their performance using a single model. Thus, this study supplements previous research by linking risk management culture, agility, integration, and supply chain (re-)engineering to risk management and firm performance. The analysis found the perfect mediating effects in the relationships among different types of SCR and performance, providing a greater level of richness to the SCR-performance model. This study identifies four types of SCR and finds that risk management culture directly influences the other factors. In fact, risk management culture is the major driver of firm performance. Most importantly, this study also contributes to SCR implementation by helping managers understand how to direct their efforts to achieve superior performance.

The first managerial implication of this research is that liner shipping firms must develop different SCR abilities to improve overall performance. In order for liner shipping firms to improve their SCR, they must first focus on the establishment of risk management culture. If firms have a weak risk management culture—such as insufficient training against disruptions, low risk awareness, and poor sharing of risk management knowledge—it will be difficult for them to respond appropriately to changes, to increase their ability to share information between organizations at the time of disruption, and to allocate in advance more resources to deal with incidents related to supply chain risks. Second, companies must pay attention to agility (including sensitivity to business environment, resilience to market changes, and even partners' ability to react), integration (including intra- and inter-organizational sharing of information and operation integration), and supply chain (re-)engineering (including knowledge and understanding of supply chain structures) because these factors directly influence risk management performance, which leads to firm performance. Firms should develop these four types of SCR simultaneously because the ultimate firm performance can only be reached when all four of these abilities are fully developed. For example, if a firm is lacking in agility, its risk management culture could not utilize the advantages of the agility mediator to improve firm performance. In the era of labor specialization and globalization, supply chains often appear as weak and complicated. Similarly, service routings of liner shipping firms are also globalized. In terms of demands, liner shipping firms must face problems that arise from the global economic cycles. In regards to supply, there are also severely unstable factors such as personnel shortage on international ships, changes in fuel pricing, and fluctuation in cost of ship construction. Difficulty in controlling operational cost and efficiency make liner shipping firms difficult to use cost and efficiency as their competitive advantages. Instead, the ability to predict changes in supply chain, timely reaction in face of disruptions, and the ability to mitigate negative impacts of supply chain vulnerability are important. Liner shipping firms must prudently develop SCR to ensure smooth operation of their supply chain.

This study has some limitations, as well as some opportunities for future study. First, the research sample was drawn from liner shipping firms in Taiwan. Future research could involve an international comparison to enhance the generalization of the research findings. Second, the results of this research provided only a starting point for more rigorous studies of SCR. Some new coming factors (such as resources sharing and alliance can have potential moderate and mediate effects on SCR) in the relationship between SCR and liner companies' performance should be updated and used in our model for the future study. Moreover, further studies are needed to generate more in-depth knowledge about how to enhance SCR in the liner shipping industry. Finally, the cross-sectional data was collected in this research to minimize causal inference. Future empirical efforts in the area might consider the use of panel data to reveal how perceptions of SCR and performance change over time.

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Dynamics and Interactions between Spot and Forward Freights in the Dry Bulk Shipping Market

Jingbo Yin[1], Meifeng Luo[2] and Lixian Fan[3]*

[1] School of Naval Architecture, Ocean and Civil Engineering, Shanghai Jiaotong University, 800 Dongchuan Rd., Shanghai 200240, China
[2] Department of Logistics and Maritime Studies, The Hong Kong Polytechnic University, Hong Kong
[3]School of Management, Shanghai University, 599 Shangda Rd., Shanghai 200444, China

[*]*Corresponding Author*

Abstract

Analyzing the interactions between spot and FFA (Forward Freight Agreement FFA) prices in the dry bulk shipping is important as they play a significant role for shipping companies to secure their profits and avoid potential risks in the volatile market. By applying the VAR (Vector AutoRegression) and the VECM (Vector Error Correction Model), this paper identifies the long-run and mutual causal relationship between the spot and FFA prices on the BPI T/C and BCI C7 routes. Along with these cointegrating rates, exogenous factors such as the market demand and supply and some economic indices are also recognized as contributing variables for the dynamic movement of the spot and FFA prices. Importantly, the mean-reverting process is justified on both routes with different mechanisms. When the spot and FFA prices deviate from their equilibrium level in the short-run, they will be adjusted to their long-run equilibrium more directly and clearly on the BPI T/C route than those on the BCI C7 route. It also indicates that this adjusting power has direction and size asymmetries on both routes. In addition, the impulse analysis indicates that the spot rate is more volatile than its corresponding FFA prices confronting innovations.

The results of this study provide a reference to the participants in the dry bulk shipping market on the causes of fluctuation in spot and FFA prices and their interactions, which can be used to promote the risk management in the market.

Keywords: Dry Bulk, FFA, VAR, VECM model, Impulse analysis

1. Introduction

Dry bulk shipping is the most important form of seaborne trade in terms of volume of cargoes traded. According to Clarkson's database, the volume of dry bulk in 2013 exceeds 5.2 billion tons (excludes container cargos), accounting for 53% world seaborne trade volume (Clarkson PLC, 2014). However, the dry bulk shipping market is relatively volatile.

Figure 1 illustrates the evolution of the Baltic Dry Index (BDI) from November 1999 to July 2013. The troughs and peaks in the figure demonstrate the violent fluctuation of the BDI index with the lowest value 703 and highest 10844. One main reason for the cyclicity of the dry bulk market is the fluctuation of the world economy. In addition, the intrinsic nature of shipping industry, such as shipbuilding cycles and speculative investments in ships (Haralambides et al., 2005) also contributes to the fluctuation of the freight rate. Consequently, dry bulk shipping has always been considered as one of the most volatile industries (Alizadeh, 2013; Kavussanos & Visvikis, 2006).

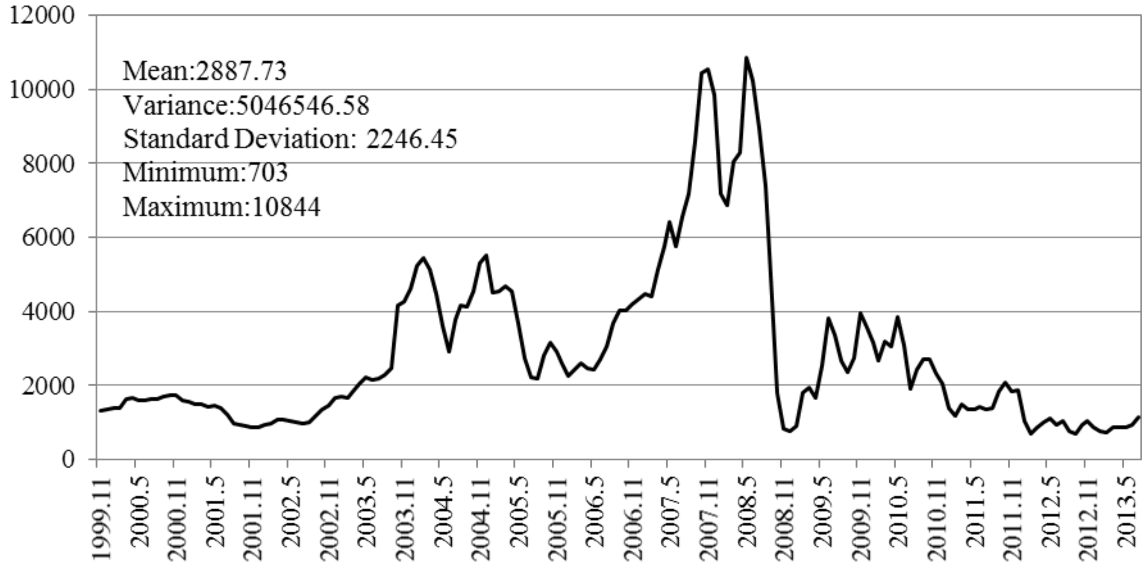


Figure 1: The evolution of BDI index from 1999 to 2013

To reduce the risks brought about by the freight fluctuation of dry bulk cargos, the Baltic International Freight Futures Exchange (BIFFEX) started the BIFFEX shipping futures contract in 1985. By reverse operation of BIFFEX contract, shipowners or charters can buy or sell BIFFEX contracts so as to protect the revenue or reduce the cost of their freights. However, due to the ambiguity in route discrimination and low transaction volumes, the BIFFEX was replaced by the Forward Freight Agreement (FFA) in 1992. The FFA is more effective in risk mitigation than the BIFFEX because the FFA, based on the Baltic dry indices, matches with physical market accurately (Alizadeh, 2013). Currently, the Baltic Exchange provides 4 dry bulk indices for different ship types, which are Baltic Capesize Index (BCI), Baltic Panamax Index (BPI), Baltic Supramax Index (BSI), and Baltic Handysize Index (BHSI). BDI is a weighted average of these indices. In the FFA forward contract, the route or routes, quantity of cargo, size of ship and future time are fixed, and the settlement is the difference between Baltic dry index and contract price.

As a major type of FFA, dry bulk FFA has generally become the barometer of dry bulk market. After 20 years of development, it has become a hedging and speculating instrument and plays a significant role for shipping companies to secure their profits and reduce potential risks in the volatile spot market. Since its advent in 1992, the forward freight market grew rapidly. In February 2008 the trade value has amounted to $150bn (Alizadeh, 2013). After the decline due to the world financial crisis, it seems to recover from the recession in September 2013. The shipping practitioners are preparing to get into the bullish forward market to gain profits, as well as hedge risk in the spot market.

Currently, the main decision instrument in the spot and FFA markets is the BDI indices. Although these indices provide some valuable information on the market trend, they cannot help in identifying all possible factors for the market fluctuation, which are vital for the participants. Without such information, participants have to speculate on the fluctuation and this has helped as well as destroyed many shipping companies, for example, by purchasing large number of FFA contracts, TMT, Inc. gained big prosperity in 2006, while COSCO suffered huge losses in 2008 (Lum, 2009). Consequently, the relationship and interactions between spot rate and FFA prices are of interest to academics and practitioners, since the lead-lag relationship between them reflects market efficiency and possibility of arbitrage. If a lead-lag relationship is identified on a certain route, the leading rate will move fast reflecting new information relative to the other. This could help in forecasting the lagged rate where real trades are absent. In addition to the spot and FFA prices themselves, some other factors such as fleet supply, bunker price, and economy indices may also have potential impacts for the fluctuation of the rates. So in this study, in analyzing the interactions between spot and FFA prices, it also considers some exogenous factor in the VAR (Vector AutoRegrssion) and VECM (Vector Error Correction Model) models. Moreover, if the spot and FFA prices are cointegrated (a long-run correlation), the VECM model can help investigate the adjusting power on a route if there is a short-run deviation from their equilibrium level. Finally, similar to the financial market, the impacts of good news and bad news on the market index may have different magnitude. This asymmetry effects will be analyzed in this study by separating positive and negative deviations and large changes and small changes in fleet size.

Searching in the literature, we find that there have been a number of studies on the forecasting (Batchelor et al., 2003; Cullinane, 1992), risk management and hedging (Kavussanos & Visvikis, 2005; Prokopczuk, 2011), pricing and dynamic relationships for spot and FFA prices (Kavussanos & Nomikos, 2003; Kavussanos & Visvikis, 2004), and other pricing options for the shipping derivative contracts. Despite this plethora of studies on different aspects of spot and forward freight markets, there have been few studies to investigate the effecting factors for the volatility of spot and FFAs. Hence, this paper attempts to fill this gap in the literature by investigating the interactions between spot and FFA markets and the underlying factors that lead to their fluctuation, which are important both in practice and academic area.

The remainder of this paper is structured as follows. Section 2 reviews the related studies on spot and derivative freight markets. Section 3 analyzes the factors impact the dry bulk spot and FFA contract prices. Section 4 presents the data source and methodology used in this study. Section 5 reports the empirical results. Section 6 presents a summary and discussion of the results. Section 6 concludes the paper.

2. Literature Review

Due to the significance in risk management and hedging, many researchers have studied the behavior of the spot and FFA markets. One research area is the long-run relation between future and spot markets. To evaluate the performance of using Baltic Freight Index (BFI) to predict future market index BIFEX, Kavussano and Nomikos (2003) examined the causal relationship between them by applying causality tests and generalized impulse response analysis on daily data. They found that future prices are more responsive to market changes than the spot rate. Similarly, Kavussanos and Visvikis (2004) studied the lead-lag relationship between spot price and FFA in terms of returns and volatilities. Both studies explored the relationship between the real market and future market over the whole sample period. However, some important exogenous factors, such as fleet supply, bunker price and some economy indices are ignored in their model, which may have significant contribution to their interactions.

As one of the main functions of FFA is hedging against the risks from the volatility in the shipping market, Kavussanos and Visvikis (2005) investigated the efficiency of hedging using various models including OLS (Ordinary Least Squares), VECM, and other time series models. They found that FFA's hedging performances vary significantly on the selected trading routes. Haigh (2000) found that BIFFEX does not perform the hedging function as well as FFA because BFI is not focused on the specific route like BDI. Prokopczuk (2011) compared the pricing and hedging accuracy of various FFA models and showed that accuracy can be significantly improved by inclusion of a stochastic factor. Similar to these studies, we also employ time series models such as VAR and VECM, but we focus on the impacts of various independent variables instead of the FFA's hedging role.

In analyzing the predicting power of the spot and FFA, Cullinane (1992) developed a forecasting model for BIFFEX speculation using the Box-Jenkins method and evaluated its predict power. Batchelor et al. (2003) used ARIMA and VAR models to check the performance of the time series models in predicting spot and forward rates on major seaborne freight routes. They found that forward rates contain information about future spot rates and can help to forecast spot rates, while spot prices do not help to forecast forward price. Kavussanos et al. (2004b) studied the prediction power from the perspective of the unbiasedness of FFA prices. Using cointegration techniques, they found that the unbiasedness of FFA as a predictor of spot price changes with different routes and the time to maturity of the contract. Batchelor et al. (2007) verified the good predicting power of FFA on spot rates using VECM, and indicated the speculative efficiency. Based on these time series models, in this study, we analyze the short-run and long-run relationship simultaneously between spot and FFA prices. In addition, we also investigate the asymmetry adjusting powers of the market.

The results from above studies indicate the causal relationship between spot rate and its FFA prices, the forecasting and hedging functions, and other role of FFAs. However, the underlying factors that affecting the dynamics of spot and FFAs are ignored by the former studies and which are important for the trading and risk management in the market.

3. Major Factors of Dry Bulk Spot and FFA

Based on the summarization and analysis above, the spot and FFA prices are inherently correlated by the mechanism. So their fluctuations are inevitably subjects to the shipping demand-supply relationship. As a derivative market from the shipping industry, the FFA prices along with their spot rate are also influenced by economic cycle, government policy, and psychological factors of market players. Therefore, the selected potential factors of dry bulk spot and FFA prices are listed as follows: demand of market namely the dry bulk trade volume, supply of market refers to dry bulk fleet, and economic index like bunker price and the Steel Index.

Although there are many FFA trades by specific routes, in this study, only the BPI T/C (time-charter) Average (mean of the four time-charter routes) and the BCI C7 routes are chosen as they have the largest trade volume in dry bulk time-charter and voyage charter markets. So, the following analysis of the major factors will consider the characteristics of these routes.

3.1 Demand and supply of shipping market

The demand for shipping is derived from the world trade (Stopford, 2009). Hence, the fluctuation of the freight rate is determined by the relative strength of demand and supply for shipping services. When the global economy is in prosperity, due to the heavy investment in infrastructure construction, the demand for energy and raw material like iron ore and coal would be enormous. If the growth in supply cannot catch up with demand increases, the freight rate will increase, which may in turn push up the FFA prices. On the other hand, if shipping supply increases faster than demand, the limited recovery in economic growth may not be effective to bring up shipping freight rate and FFA prices.

The four time-charter routes of BPI geographically connect the Atlantic, the Pacific, the Continent and Far East. Major cargoes delivered are coal and iron. Thus the trade volume of these cargos can be a good indicator for demand changes. The BCI C7 route, run by Capesize ships (150,000) between Bolivar and Rotterdam, is a specific route carrying coal. So, the trade volume of coal can be used as an index of demand.

The market supply in shipping is mainly subject to changes in active shipping fleet, which increases with delivery and decreases with demolition. Before the 2008 financial crisis, shipowners placed huge amount of new-building orders. This resulted in the vast increases in supply, and which leads to the precipitous fall of the BDI at 2008 (Figure 1). Actually, even though market demand has recovered to pre-crisis level in 2011, the shipping market is still in its tough time due to the overcapacity in the shipping supply as a result of irrational booking of vessels.

Thus the fleet number of dry bulk carrier, i.e. Capesize and Panamax, and the trade volume of coal and iron would be selected as potential factors for the dynamics of spot and FFA prices.

3.2 Other economic indicators

In addition to the above, other factors, such as bunker prices, raw material prices will also affect the spot and FFA markets through affecting sea transportation costs. These factors have to be considered in analyzing the factors for spot and FFA fluctuations.

Bunker cost takes a large proportion of running cost during a voyage. Thus the bunker price index is a crucial variable measuring profitability of shipping companies. It is believed that freight rates (current and future) and shipowner's profitability are vulnerable to the impact of changing bunker price.

The Steel Index (TSI) is composited by the spot market transactions for steel, scrap and iron ore products in the world, which is a popular price index for industry participants in future contract and risk management.

Besides, TSI and FFA both perform as risk management tools, thus TSI is listed as a potential positive influencing factor.

In conclusion of this section, trade volume, fleet number, bunker price and TSI are chosen, in terms of demand, supply and economic environment, for potential influencing factors of fluctuation for spot and FFA prices.

4. Data and Methodology

4.1 Data Sources and Description

The spot rate of BPI T/C Average (*TCSPOT*) is the arithmetic mean of the time-charter rates in four routes P1A_03, P2A_03, P3A_03 and P4_03, with ship size of 74,000 dwt, for a duration of 35-65 days. These four routes are Trans-Atlantic round voyage (including east coast of South America), Continent trip Far East, Transpacific round voyage, and Via US West Coast-British Columbia range to Japan/South Korea respectively. Since FFA prices could be contracted for any period in the future, Baltic Exchange provides the FFA prices of BPI T/C Average for different contract maturities in the three nearest quarters, i.e., BPI T/C average 1 quarter (*TCQ1*), 2 quarter (*TCQ2*), and 3 quarter (*TCQ3*). The BCI C7 route is described as delivery 150,000 dwt coal from Bolivar to Rotterdam, we get the sport rate of *C7SPOT*, and its FFA prices for maturities in three different future periods, which are C7 1 month (*C7M1*), 2 months (*C7M2*) and 3 months (*C7M3*). In this paper, all these data consist of daily settlement prices from January, 2007 to November, 2013, thus adequately incorporating both the bullish period in freight rates before 2008, as well as the subsequent crash from the second half of 2008 to recent years. To keep accordance with all other time series, we use the monthly arithmetic mean of these variables in the following analysis.

All other data, the trade volume of coal (*VCOAL*) and iron (*VIRON*), bunker price (*BUNKER*), the steel index (*TSI*), and fleet size of Panamax (*FPANAMAX*) and Capesize fleet (*FCAPE*) are selected on a monthly basis from World Bank and Clarkson Shipping Intelligence Network (CSIN) data base.

Table 1 summarizes the descriptive statistics for the logarithm of the variables. The skewness and kurtosis are two parameters used to show the distribution of the variable, while the Jarque-Bera statistic is used to test if the variable is a normal distribution. The last column is the probability that the data sample follows a normal distribution. It shows that most of the variables are not normally distributed. This, to some extent, indicates the high volatility of the market.

Table 1: Description of the variables

Variables	Mean	Median	Max.	Min.	Std. Dev.	Skewness	Kurtosis	Jarque-Bera	Prob.
LTCQ1	9.87	9.76	11.32	8.69	0.77	0.40	2.05	5.16	0.08
LTCQ2	9.83	9.69	11.22	8.79	0.73	0.50	2.15	5.80	0.06
LTCQ3	9.80	9.66	11.10	8.71	0.70	0.51	2.22	5.48	0.06
LTCSPOT	9.85	9.79	11.36	8.33	0.83	0.17	1.98	3.82	0.15
LC7M1	2.74	2.58	3.94	1.99	0.54	0.85	2.51	10.54	0.01
LC7M2	2.73	2.56	3.90	2.06	0.52	0.96	2.65	12.77	0.00
LC7M3	2.73	2.54	3.87	2.13	0.50	1.04	2.76	14.61	0.00
LC7SPOT	2.74	2.61	4.05	1.67	0.58	0.58	2.37	5.80	0.05
LVIRON	18.10	18.12	18.43	17.69	0.17	-0.28	2.20	3.22	0.20
LVCOAL	17.31	17.32	17.77	17.01	0.21	0.12	1.80	4.96	0.08
LBUNKER	6.59	6.62	7.03	5.90	0.30	-0.47	2.10	5.39	0.07
LTSI	5.52	5.47	6.19	4.95	0.26	0.54	3.45	4.60	0.10
LFPANAMAX	4.87	4.82	5.19	4.62	0.18	0.41	1.82	6.88	0.03
LFCAPE	5.22	5.20	5.67	4.80	0.30	0.12	1.51	7.64	0.02

4.2 *Unit Root Test*

In order to analyze the interactions among the spot and FFA prices, it is necessary to investigate the stationarity of the variables first. There are 3 types of situations for the fluctuation of a time series, i.e., unit root, unit root with drift, and unit root with drift and deterministic time trend separately:

$$\Delta y_t = (\rho - 1)y_{t-1} + \varepsilon_t = \delta y_{t-1} + \varepsilon_t \tag{1}$$

$$\Delta y_t = a_0 + (\rho - 1)y_{t-1} + \varepsilon_t = a_0 + \delta y_{t-1} + \varepsilon_t \tag{2}$$

$$\Delta y_t = a_0 + a_1 t + (\rho - 1)y_{t-1} + \varepsilon_t = a_0 + a_1 t + \delta y_{t-1} + \varepsilon_t \tag{3}$$

where Δ is the first difference operator, ρ and δ are the coefficients, and ε_t is the residual. If a time series is stable or there is no unit root (ρ=1), δ equals 0, then the test for no unit root in the above 3 situations will not be rejected. However, the general *t*-test for testing this null hypothesis has the problem of "near observation equivalence. It cannot distinguish δ equals 0 and δ close to 0. To overcome this problem, the modified ADF (Augmented Dickey-Fuller) (Dickey & Fuller, 1981) and PP (Phillips & Perron, 1988) tests are employed in this study.

Since there is no obvious time trend in the fluctuation of the time series, the second type of integration, i.e., unit root with drift is tested for all the time series using ADF and PP tests. The test results are reported in Table 2. It suggests that all the logarithms of the variables are non-stationary, while their first differences are stationary, indicating that all the variables are integrated of order one, *I*(1).

Generally speaking, if the variables are not stationary, i.e. they are *I*(1) or a mix of *I*(0) and *I*(1), the usual test statistics cannot be used to make inferences. To overcome this issue, the VAR and VECM models are employed to eliminate the impact of unit root.

Table 2: Unit root tests for stationarity

Time Series	Levels		First differences	
	ADF	PP	ADF	PP
LTCQ1	-1.648	-1.143	-5.585***	-5.238***
LTCQ2	-1.284	-0.962	-5.565***	-5.48***
LTCQ3	-1.309	-1.050	-5.753***	-5.738***
LC7SPOT	-1.986	-2.080	-6.922***	-5.775***
LC7M1	-2.318	-1.689	-6.123***	-5.045***
LC7M2	-2.207	-1.346	-5.935***	-5.031***
LC7M3	-2.113	-1.542	-5.472***	-5.056***
LTCSPOT	-1.860	-1.611	-6.596***	-6.532***
LVIRON	-0.766	-1.692	-11.001***	-22.24***
LVCOAL	-2.003	-1.850	-8.199***	-37.658***
LBUNKER	-2.844	-2.167	-3.300**	-5.662***
LTSI	-2.325	-2.246	-6.682***	-6.706***
LFPANAMAX	4.109	3.151	-3.321**	-7.217***
LFCAPE	-0.368	0.165	-2.822*	-5.317***

Note: * Rejection of hypotheses at 10% significance level.
** Rejection of hypotheses at 5% significance level.
*** Rejection of hypotheses at 1% significance level.

4.3 *Vector Error Correction Model*

4.3.1 *Cointegration in the Markets*

After identifying all variables as $I(1)$, the cointegration test is employed to examine whether a long-run relationship exists between FFA prices and the spot rate. In this study, the cointegration test of Johansen's VAR approach (1988; 1991) is adopted because it is based on a multi-variant framework, which allows us to choose the number of lags and take into account both endogeneity and simultaneity problems (Glen, 1997). According to Johansen (1988; 1991), the VAR model can be written in the following equation,

$$\Delta Y_t = \Pi Y_{t-1} + \sum_{i=1}^{p-1} \Gamma \Delta Y_{t-i} + B\Delta X_t + \varepsilon_t = \alpha(\beta Y_{t-1}) + \sum_{i=1}^{p-1} \Gamma \Delta Y_{t-i} + B\Delta X_t + \varepsilon_t = \alpha ECT_{t-1} + \sum_{i=1}^{p-1} \Gamma \Delta Y_{t-i} + B\Delta X_t + \varepsilon_t \qquad (4)$$

where Y_t is the vector of the spot rate and 3 FFA prices on each route. β is the cointegrating vector for the endogenous variables and then the $ECT=\beta Y_{t-1}$ is $I(0)$ (Engle & Granger, 1987; Greene, 2008). X_t is the vector of all the exogenous variables. α is the adjustment parameter (Engle & Granger, 1987; Greene, 2008). In the short-run, if the cointegrating variables drift apart from the equilibrium level, they will eventually be pulled back to their equilibrium relationship in the long-run.

The lag length (p) is set based on the LR (Lagrange), SC (Schwarz information Criterion) and HQ (Hannan-Quinn information criterion). Since all the difference variables are stationary, the stationarity of the model is determined by the rank of Π. If cointegration exists, the rank (R) of coefficients matrix Π must be between zero and 4 (number of variables in Y_t). The commonly used methods to assess the rank are the trace test (λ_{trace}) and maximum eigenvalue test (λ_{max}) (Johansen, 1991). In this model, the short-run impact of the cointegrating variables is estimated in vector Γ. B reflects the impact of the exogenous variables.

For the BPI T/C Average route, vector ΔY_t =($\Delta LTCSPOT$, $\Delta LTCQ1$, $\Delta LTCQ2$, $\Delta LTCQ3$), vector ΔX_t is ($\Delta LFPANAMAX$, $\Delta LBUNKER$, $\Delta LVCOAL$, $\Delta LTSI$, $\Delta LVIRON$). For the *BCI C7* route, they are (*LTC7SPOT*, *LC7M1*, *LC7M2*, *LC7M3*) and (*LFCAPE*, *LBUNKER*, *LVCOAL*, *LTSI*) separately.

The LR, SC and HQ suggest that the lags of the VAR models are 3 for the BPI T/C route and 2 for the BCI C7 route. Table 3 lists the test results for the hypothesized numbers of cointegration equations for each route. The λ_{trace} and λ_{max} tests suggest 3 cointegration equations for both routes. This indicates the existence of cointegration or long-run relationship among the spot rate and FFA prices. The last column of Table 3 lists the normalized cointegrating vectors on each route.

Table 3: Results of Johansen's reduced rank cointegration tests between spot and FFA prices

Route	Lags	Hypothesized No. of CE(s)	Eigen value	Trace Statistic	0.05 Critical Value[a]	Prob.	Max-Eigen Statistic	0.05 Critical Value[a]	Prob.	Cointegrating vector β'=(1,β1,β2,β3)
BPI T/C	3	None *	0.47	78.21	40.17	0.00	45.12	24.16	0.00	Y_t=(*LTCSPOT* , *LTCQ1*, *LTCQ2*, *LTCQ3*)
		At most 1*	0.24	33.09	24.28	0.00	19.84	17.80	0.02	
		At most 2 *	0.17	13.25	12.32	0.03	13.23	11.22	0.02	(1, -5.954, 8.999, -4.0383)
		At most 3	0.00	0.02	4.13	0.92	0.02	4.13	0.92	
BCI C7	2	None *	0.41	86.05	40.17	0.00	38.52	24.16	0.00	Y_t=(*LC7SPOT*, *LC7M1*, *LC7M2*, *LC7M3*)
		At most 1 *	0.32	47.52	24.28	0.00	28.13	17.80	0.00	
		At most 2 *	0.23	19.40	12.32	0.00	19.40	11.22	0.00	(1, -2.907, 2.797, -0.880)
		At most 3	0.00	0.00	4.13	1.00	0.00	4.13	1.00	

Notes:

- [a] represent the critical values from Mackinnon-Haug-Michelis (1999).
- Lag length is determined by the VAR model based on the LR, SC and HQ.
- Estimates of the coefficients in the cointegrating vector are normalized with respect to the coefficient of the spot rate.

Table 4: Estimate results of the VECM models for the BPI T/C route.

$$\Delta LTCSPOT_t = \alpha^S ECT_{t-1} + \sum_{i=1}^{2} \gamma_{1,i}^{S} \Delta LTCSPOT_{t-i} + \sum_{i=1}^{2} \gamma_{2,i}^{S} \Delta LTCQ1_{t-i} + \sum_{i=1}^{2} \gamma_{3,i}^{S} \Delta LTCQ2_{t-i} + \sum_{i=1}^{2} \gamma_{4,i}^{S} \Delta LTCQ3_{t-i} + \Phi^S \Delta X_t + \varepsilon_t^S$$

$$\Delta LTCQ1_t = \alpha^{F1} ECT_{t-1} + \sum_{i=1}^{2} \gamma_{1,i}^{F1} \Delta LTCSPOT_{t-i} + \sum_{i=1}^{2} \gamma_{2,i}^{F1} \Delta LTCQ1_{t-i} + \sum_{i=1}^{2} \gamma_{3,i}^{F1} \Delta LTCQ2_{t-i} + \sum_{i=1}^{2} \gamma_{4,i}^{F1} \Delta LTCQ3_{t-i} + \Phi^{F1} \Delta X_t + \varepsilon_t^{F1}$$

$$\Delta LTCQ2_t = \alpha^{F2} ECT_{t-1} + \sum_{i=1}^{2} \gamma_{1,i}^{F2} \Delta LTCSPOT_{t-i} + \sum_{i=1}^{2} \gamma_{2,i}^{F2} \Delta LTCQ1_{t-i} + \sum_{i=1}^{2} \gamma_{3,i}^{F2} \Delta LTCQ2_{t-i} + \sum_{i=1}^{2} \gamma_{4,i}^{F2} \Delta LTCQ3_{t-i} + \Phi^{F2} \Delta X_t + \varepsilon_t^{F2}$$

$$\Delta LTCQ3_t = \alpha^{F3} ECT_{t-1} + \sum_{i=1}^{2} \gamma_{1,i}^{F3} \Delta LTCSPOT_{t-i} + \sum_{i=1}^{2} \gamma_{2,i}^{F3} \Delta LTCQ1_{t-i} + \sum_{i=1}^{2} \gamma_{3,i}^{F3} \Delta LTCQ2_{t-i} + \sum_{i=1}^{2} \gamma_{4,i}^{F3} \Delta LTCQ3_{t-i} + \Phi^{F3} \Delta X_t + \varepsilon_t^{F3}$$

Dependent	**Model 1**				**Model 2**				**Model 3**			
No.	***ΔLTCSPOT 1***	***ΔLTCQ1ª 2***	***ΔLTCQ2ª 3***	***ΔLTCQ3ª 4***	***ΔLTCSPOT 1***	***ΔLTCQ1ª 2***	***ΔLTCQ2ª 3***	***ΔLTCQ3ª 4***	***ΔLTCSPOT 1***	***ΔLTCQ1ª 2***	***ΔLTCQ2ª3***	***ΔLTCQ3ª 4***
Panel A: VECM model estimates and causality tests												
	Coef.	Coef.	Coef.	Coef.	Coef.	Coef.	Coef.	Coef.	Coef.	Coef.	Coef.	Coef.
ΔLTCSPOT$_{t-1}$	-0.409**	-0.288**	-0.180**	-0.187**	-0.413**	-0.290***	-0.181**	-0.187**	-0.404**	-0.302***	-0.170*	-0.198**
$\gamma_{1,1}$	(0.040)	(0.013)	(0.029)	(0.033)	(0.039)	(0.007)	(0.026)	(0.035)	(0.043)	(0.005)	(0.083)	(0.012)
ΔLTCSPOT$_{t-2}$	-0.112	0.024	0.078	0.038	-0.083	0.033	0.092	0.033	-0.088	0.040	0.093	0.032
$\gamma_{1,2}$	(0.575)	(0.837)	(0.316)	(0.662)	(0.681)	(0.732)	(0.247)	(0.713)	(0.671)	(0.693)	(0.363)	(0.667)
ΔLTCQ1$_{t-1}$	0.499	0.536*	-0.106	0.436*	0.392	0.501	-0.158	0.457*	0.506	0.501	-0.080	0.409*
$\gamma_{2,1}$	(0.335)	(0.075)	(0.659)	(0.059)	(0.462)	0.123*	(0.505)	(0.057)	(0.330)	(0.124)	(0.756)	(0.073)
ΔLTCQ1$_{t-2}$	0.366	-0.052	-0.396*	0.066	0.249	-0.091	-0.453**	0.088	0.322	-0.113	-0.412	0.062
$\gamma_{2,2}$	(0.487)	(0.863)	(0.073)	(0.774)	(0.647)	(0.752)	(0.045)	(0.714)	(0.548)	(0.704)	(0.123)	(0.732)
ΔLTCQ2$_{t-1}$	1.517***	-0.174	0.678***	-0.203	1.548***	-0.164	0.693***	-0.209	1.704***	-0.218	0.729**	-0.264
$\gamma_{3,1}$	(0.006)	(0.568)	(0.004)	(0.387)	(0.005)	(0.475)	(0.002)	(0.378)	(0.007)	(0.491)	(0.018)	(0.209)
ΔLTCQ2$_{t-2}$	0.208	-0.525*	0.357	-0.429**	0.324	-0.486*	0.413*	-0.45**	0.251	-0.429	0.324	-0.383
$\gamma_{3,2}$	(0.668)	(0.064)	(0.138)	(0.049)	(0.522)	(0.051)	(0.053)	(0.048)	(0.608)	(0.205)	(0.183)	(0.100)
ΔLTCQ3$_{t-1}$	-0.881	0.368	-0.067	0.167	-0.793	0.397	-0.024	0.151	-1.067*	0.456	-0.144	0.258
$\gamma_{4,1}$	(0.126)	(0.264)	(0.786)	(0.506)	(0.175)	(0.196)	(0.925)	(0.558)	(0.093)	(0.199)	(0.642)	(0.300)
ΔLTCQ3$_{t-2}$	-0.870	0.429	-0.104	0.282	-0.846	0.437	-0.093	0.277	-0.934	0.397	-0.094	0.272
$\gamma_{4,2}$	(0.147)	(0.214)	(0.677)	(0.285)	(0.160)	(0.189)	(0.720)	(0.296)	(0.130)	(0.311)	(0.755)	(0.329)
ΔLFPANAMAX	-4.274	-4.503**	-2.984*	-3.21**	-8.000	-5.733**	-4.799*	-2.508	-3.411	-5.429***	-2.382	-3.936**
β_1	(0.225)	(0.029)	(0.075)	(0.041)	(0.156)	(0.039)	(0.052)	(0.313)	(0.343)	(0.007)	(0.181)	(0.013)
ΔLBUNKER	0.958**	0.781***	0.622***	0.515**	0.937**	0.774***	0.612***	0.519**	0.951**	0.814***	0.619***	0.528***
β_2	(0.032)	(0.003)	(0.005)	(0.010)	(0.037)	(0.004)	(0.005)	(0.010)	(0.035)	(0.003)	(0.006)	(0.004)
ΔLVCOAL	0.248	0.233	0.112	0.040	0.242	0.231	0.109	0.041	0.225	0.267	0.076	0.075
β_3	(0.494)	(0.268)	(0.423)	(0.801)	(0.506)	(0.147)	(0.435)	(0.797)	(0.539)	(0.104)	(0.675)	(0.532)
ΔLTSI	0.156	0.264	0.381	0.446***	0.118	0.251	0.363	0.453***	0.137	0.262	0.363**	0.458*
β_4	(0.628)	(0.158)	(0.133)	(0.003)	(0.717)	(0.374)	(0.149)	(0.003)	(0.675)	0.367**	(0.027)	(0.062)
ΔLVIRON	0.530*	0.091	0.028	-0.055	0.55*	0.097	0.038	-0.058	0.563*	0.025	0.063	-0.099
β_5	(0.091)	(0.611)	(0.862)	(0.689)	(0.082)	(0.618)	(0.820)	(0.672)	(0.071)	(0.900)	(0.676)	(0.504)
ETC	-0.079	0.109***	-0.076***	0.087***								
α	(0.195)	(0.003)	(0.004)	(0.002)								
ECT(+)					-0.046	0.120***	-0.060**	0.081**				
α_+					(0.518)	(0.000)	(0.030)	(0.014)				
ECT(-)					-0.142	0.086**	-0.107**	0.099**				
α_-					(0.140)	(0.042)	(0.015)	(0.023)				
DLFPANAMAX (big)									-7.695	7.196**	-6.725**	6.997***
α_{Fleet+}									(0.179)	(0.034)	(0.019)	(0.002)
DLFPANAMAX (small)									-22.596	23.205**	-15.495*	18.549***
α_{Fleet-}									(0.224)	(0.032)	(0.093)	(0.006)
R-Square	0.444	0.560	0.528	0.564	0.451	0.562	0.534	0.565	0.448	0.533	0.525	0.550
Durbin-Watson stat	1.967	2.025	1.915	1.875	1.998	2.036	1.950	1.871	1.949	2.070	1.904	1.907
Panel B: Residual diagnostics												
Wald tests	2.524**	4.293***	2.091*	2.581**	2.475**	4.183***	2.730**	2.497**	2.542**	2.879**	2.808**	1.933*
p-value	(0.031)	(0.001)	(0.068)	(0.028)	(0.034)	(0.002)	(0.021)	(0.032)	(0.030)	(0.016)	(0.018)	(0.091)
Jarque-Bera Normality tests	0.545	2.631	4.447	11.927***	0.573	2.570	4.774*	12.337***	1.205	1.701	4.681*	9.882***

p-value	(0.762)	(0.268)	(0.108)	(0.003)	(0.751)	(0.277)	(0.092)	(0.002)	(0.547)	(0.427)	(0.096)	(0.007)
Breusch-Godfrey Test	0.932	0.833	1.412	1.602	0.996	0.810	1.420	1.588	1.108	0.845	1.641	1.142
p-value	(0.524)	(0.617)	(0.194)	(0.124)	(0.467)	(0.639)	(0.192)	(0.129)	(0.377)	(0.606)	(0.113)	(0.352)
Heteroskedasticity Test	1.559	2.288**	2.974***	2.828***	1.397	2.048**	2.66***	2.662***	1.512	2.462***	2.565***	3.018***
p-value	(0.120)	(0.014)	(0.002)	(0.003)	(0.181)	(0.027)	(0.004)	(0.004)	(0.132)	(0.008)	(0.005)	(0.001)

Note:

- *** denotes significance at the 1% level, ** denotes 5%, and * denotes 10%.
- Figures in parentheses (·) indicate p-values.
- *p*-values and Wald tests are adjusted using the White heteroskedasticity correction for the dependent *ΔLTCQ1*, *ΔLTCQ2* and *ΔLTCQ3* in Model (1) to (3).
- The Null hypothesis of the Wald test is H_0: $\gamma_{i,t}$=0, $i \neq$ the No. of the dependent variable.
- The Breusch-Godfrey Serial Correlation LM is the test for 12th order serial correlation.
- The Breusch-Pagan-Godfrey is used for the heteroskedasticity tests.
- [a] the models are corrected using the White heteroskedasticity correction.

Table 5: Estimate results of the VECM models for the C7 route

$$\Delta C7SPOT_t = \alpha^{S} ECT_{t-1} + \gamma_1^{S}\Delta C7SPOT_{t-1} + \gamma_2^{S}\Delta C7M1_{t-1} + \gamma_3^{S}\Delta C7M2_{t-1} + \gamma_4^{S}\Delta C7M3_{t-1} + \Phi^{S}\Delta X_t + \varepsilon_t^{S}$$

$$\Delta C7M1_t = \alpha^{F1} ECT_{t-1} + \gamma_1^{F1}\Delta C7SPOT_{t-1} + \gamma_2^{F1}\Delta C7M1_{t-1} + \gamma_3^{F1}\Delta C7M2_{t-1} + \gamma_4^{F1}\Delta C7M3_{t-1} + \Phi^{F1}\Delta X_t + \varepsilon_t^{F1}$$

$$\Delta C7M2_t = \alpha^{F2} ECT_{t-1} + \gamma_1^{F2}\Delta C7SPOT_{t-1} + \gamma_2^{F2}\Delta C7M1_{t-1} + \gamma_3^{F2}\Delta C7M2_{t-1} + \gamma_4^{F2}\Delta C7M3_{t-1} + \Phi^{F2}\Delta X_t + \varepsilon_t^{F2}$$

$$\Delta C7M3_t = \alpha^{F3} ECT_{t-1} + \gamma_1^{F3}\Delta C7SPOT_{t-1} + \gamma_2^{F3}\Delta C7M1_{t-1} + \gamma_3^{F3}\Delta C7M2_{t-1} + \gamma_4^{F3}\Delta C7M3_{t-1} + \Phi^{F3}\Delta X_t + \varepsilon_t^{F3}$$

Dependent	**Model 1**				**Model 2**				**Model 3**			
No.	***ΔLC7SPOT 1***	***ΔLC7M1 2***	***ΔLC7M2 3***	***ΔLC7M3[a] 4***	***ΔLC7SPOT 1***	***ΔLC7M1 2***	***ΔLC7M2 3***	***ΔLC7M34***	***ΔLC7SPOT 1***	***ΔLC7M1[a] 2***	***ΔLC7M2 3***	***ΔLC7M3[a] 4***
Panel A: VECM model estimates and causality tests												
	Coef.	Coef.	Coef.	Coef.	Coef.	Coef.	Coef.	Coef.	Coef.	Coef.	Coef.	Coef.
ΔLC7SPOT	0.915***	0.686***	0.621***	0.488**	0.911***	0.681***	0.607***	0.472**	0.971***	0.701***	0.635***	0.491**
γ_1	(0.005)	(0.004)	(0.004)	(0.012)	(0.008)	(0.005)	(0.006)	(0.020)	(0.005)	(0.004)	(0.004)	(0.016)
$\Delta LC7M1_{t-1}$	-3.039***	-2.422***	-2.016***	-1.708***	-3.035***	-2.417***	-2.002***	-1.693***	-2.58***	-2.221***	-1.869***	-1.566***
γ_2	(0.002)	(0.001)	(0.001)	(0.003)	(0.002)	(0.001)	(0.002)	(0.004)	(0.007)	(0.001)	(0.002)	(0.006)
$\Delta LC7M2_{t-1}$	4.289***	2.633***	1.250	1.337*	4.287***	2.631***	1.245	1.33*	3.089**	2.111**	0.858	1.005
γ_3	(0.001)	(0.004)	(0.122)	(0.073)	(0.001)	(0.004)	(0.127)	(0.077)	(0.010)	(0.012)	(0.250)	(0.145)
$\Delta LC7M3_{t-1}$	-1.529	-0.499	0.506	0.165	-1.525	-0.495	0.518	0.179	-1.008	-0.266	0.683	0.307
γ_4	(0.104)	(0.451)	(0.402)	(0.766)	(0.108)	(0.460)	(0.396)	(0.749)	(0.286)	(0.688)	(0.258)	(0.580)
ΔLFCAPE	1.896	-0.261	-0.572	-0.758	1.812	-0.358	-0.874	-1.095	1.513	-0.490	-0.732	-0.932
φ_1	(0.358)	(0.859)	(0.668)	(0.538)	(0.507)	(0.853)	(0.620)	(0.501)	(0.478)	(0.743)	(0.591)	(0.458)
ΔLBUNKER	1.293***	0.94***	0.855***	0.851***	1.297***	0.944***	0.867***	0.865***	1.189***	0.903***	0.828***	0.824***
φ_2	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.001)	(0.000)	(0.000)	(0.000)
ΔLVCOAL	0.507**	0.295	0.226	0.230	0.506*	0.294	0.223	0.226	0.531**	0.305	0.234	0.232
φ_3	(0.049)	(0.104)	(0.171)	(0.131)	(0.051)	(0.109)	(0.182)	(0.140)	(0.046)	(0.101)	(0.165)	(0.136)
ΔLTSI	0.067	0.163	0.204	0.208	0.066	0.162	0.199	0.202	0.135	0.186	0.222	0.222
φ_4	(0.777)	(0.337)	(0.190)	(0.147)	(0.784)	(0.348)	(0.206)	(0.163)	(0.588)	(0.289)	(0.166)	(0.133)
ETC	-1.980***	-0.791**	-0.605**	-0.490*								
α	(0.000)	(0.013)	(0.035)	(0.062)								
ECT(+)					-1.964***	-0.773*	-0.547	-0.425				
α_+					(0.001)	(0.053)	(0.131)	(0.201)				
ECT(-)					-2.000***	-0.814*	-0.676*	-0.569				
α_-					(0.001)	(0.061)	(0.087)	(0.117)				
DLFPANAMAX (big)									-127.549***	-50.284**	-39.278*	-28.727
α_{Fleet+}									(0.000)	(0.032)	(0.064)	(0.139)
DLFPANAMAX (small)									-175.646***	-64.867	-49.451	-41.781
α_{Fleet-}									(0.005)	(0.133)	(0.206)	(0.246)
R-Square	0.484	0.516	0.518	0.520	0.484	0.516	0.518	0.521	0.463	0.507	0.512	0.513

Durbin-Watson stat	2.070	2.109	2.134	2.168	2.073	2.115	2.153	2.191	1.829	1.963	2.001	2.063
Panel B: Residual diagnostics												
Wald tests	4.663***	5.552***	4.295***	2.723*	4.584***	5.39***	4.091**	3.074**	3.132**	4.923***	4.065**	2.696*
p-value	(0.005)	(0.002)	(0.008)	(0.051)	(0.006)	(0.002)	(0.010)	(0.034)	(0.032)	(0.004)	(0.011)	(0.053)
Jarque-Bera Normality tests	0.003	0.162	0.250	0.076	0.002	0.148	0.180	0.051	0.320	0.243	0.350	0.143
p-value	(0.998)	(0.922)	(0.883)	(0.963)	(0.999)	(0.929)	(0.914)	(0.975)	(0.852)	(0.886)	(0.839)	(0.931)
Breusch-Godfrey Test	1.206	1.345	1.417	1.281	1.208	1.325	1.382	1.255	1.607	1.573	1.530	1.357
p-value	(0.304)	(0.222)	(0.188)	(0.257)	(0.303)	(0.233)	(0.204)	(0.273)	(0.119)	(0.129)	(0.143)	(0.217)
Heteroskedasticity Test: Harvey	1.123	1.612	1.605	2.038**	0.993	1.430	1.446	1.88*	1.305	2.038**	1.892*	2.279**
p-value	(0.360)	(0.131)	(0.133)	(0.049)	(0.459)	(0.188)	(0.182)	(0.065)	(0.247)	(0.044)	(0.063)	(0.024)

Note:

- *** denotes significance at the 1% level, ** denotes 5%, and * denotes 10%.
- Figures in parentheses (·) indicate p-values.
- *p*-values and Wald tests are adjusted using the White heteroskedasticity correction for the dependent *ΔLC7M1* in Model (3) and *ΔLC7M3* in Model (1) and (3).
- The Null hypothesis of the Wald test is H_0: $\gamma_{i,t}$,=0, $i\neq$ the No. of the dependent variable.
- The Breusch-Godfrey Serial Correlation LM is the test for 12^{th} order serial correlation.
- The Breusch-Pagan-Godfrey is used for the heteroskedasticity tests.
- [a] the models are corrected using the White heteroskedasticity correction.

5. Empirical Results

5.1 Model fitness and residual diagnostic

The results from estimating the long-run and short-run parameters of the VECM models are reported in Table 4-5, panel A. The *R*-squares reflect high explanatory power of the models and the Durbin-Watson statistics suggests that there is no 1st order serial correlation for the error terms.

Panel B presents the residual diagnostic tests. The Jarque-Bera Normality test suggests that almost all the residuals are normally distributed except for the models with dependent *LTCQ*3. The Breusch-Godfrey Serial Correlation LM Test with the first 12 lags is also employed to test for higher order autocorrelations and the results suggest no serial correlation in all the residuals. Further, the heteroskedasticity Harvey tests suggests the existence of heteroskedasticity for *ΔLTCQ1*, *ΔLTCQ2*, and *ΔLTCQ3* in all 3 models on the BPI T/C route, *ΔLC7M1* in Model (3) and *ΔLC7M3* in Model (1) and (3). Thus, we adjust the *t*-statistics and their *p*-values, as well as the Wald test statistics by White (1980) heteroskedasticity correction (see detail in Table 4 and 5).

5.2 The effects on spot and FFA prices and the lead-lag relationships

On the BPI T/C route, the estimated coefficients of the lagged cointegrating difference variables (γ_1 to γ_4) in all 4 models indicate that the changes in spot rate and FFA prices have significant impacts in the spot and FFA equations. The negative significant coefficients of the lagged change in spot rate ($\Delta LTCSPOT_{t-1}$) indicate that if the spot rate is increased in last period, all the prices in this period will be decrease. This reflects the highly volatile of the market. Contradictorily, the change of the lagged *LTCQ*2 has a significant positive impact for all the rates. Further, the adjusted Wald tests on the joint significance of the lags suggest the existence of a mutual feedback causal relationship among the spot rate and the FFA prices. i.e., the changes of any three of the rates can jointly cause the dynamic movement of the other one.

The exogenous variables also have significant impact on the changes of the spot and FFA prices. From the supply side, the fleet size of the market has a significant negative effect on the spot and FFA prices, which confirms to our expectation in section 3. As an important factor in shipping transportation, the coefficient of bunker price is found positively significant for all prices, which suggests the importance of the bunker price on the shipping market. The higher the bunker price, the higher the spot and FFA prices. The steel index also exhibits positive impact on spot and FFA prices in part of the models. Finally, the trade volume of coal is not significant in all the models and the volume of iron is weakly significant only in Model (1). This estimation result may be caused by the inelasticity of freights on shipping demand (Stopford, 2009).

On the BCI C7 route, most of the coefficients for the lagged cointegrating difference variables are significant except the independent variable *ΔLC7M3* and the signs are the same as those in the long-run cointegrating vector (Table 3). The Wald tests on the joint significance of the lagged cointegrating variables suggest the existence of a mutual feedback causal relationship among the spot rate and the 3 FFA prices.

Different with the results on the BPI T/C route, most of the exogenous variables are not significant except the bunker price and the volume of coal. The positive coefficients for bunker price and coal volume indicate the positive impact of these variables on the increase of spot and FFA prices.

5.3 Asymmetry tests of the adjusting power

According to Equation (4), to further investigate the adjusting power α, we run some additional asymmetry tests since it may be different for different deviations:

1) Direction asymmetry tests of the adjusting speed to the long-run equilibrium level through comparing the coefficients when the *ECT* is positive *ECT*(+) and negative *ECT*(-) (Model 2).

2) Size asymmetry tests of adjusting speed to the long-run equilibrium rates by separating large and small changes in an independent variable (Model 3).

It is possible that different changes in supply of ships (big and small) will have different impacts on the prices although the fleet time series are always increasing. Denote Δx_1 as big increases in the fleet size (Panamax or Capesize), i.e. it is the actual increase of fleet if it is larger than the average increase and 0 otherwise. Then by multiplying the lagged *ECT* term we get *DLFPANAMAX*(*big*) and *DLFCAPE*(*big*). Δx_2 denotes for small increases in fleet variables. By multiplying the error term, we get *DLFPANAMAX*(*small*) and *DLFCAPE*(*small*).

5.3.1 BPI T/C route

On the BPI T/C route, Table 4 manifests that the *ECT* terms are all significant in model (1) except for the spot equation. The coefficients for the spot and *LTCQ*2 are negative, while those for *LTCQ*1 and *LTCQ*3 are positive. It implies that when the cointegrating variables drift apart in the short-run, the variables will eventually be adjusted back to the equilibrium level. As Table 3 illustrates, the *ETC* term is calculated by (*LTCSPOT* -5.954×*LTCQ1* + 8.999 × *LTCQ2* - 4.0383 × *LTCQ3*). When there is a positive deviation from their equilibrium relationship at period *t*-1, the *LTCQ*2 (FFA price 2 quarter before maturity) in the next period decreases in value (-0.076), and the *LTCQ*1 (FFA price 1 quarter before maturity) and *LTCQ*3 (FFA price 3 quarter before maturity) increase in value (0.109 and 0.087), thus, eliminating any disequilibrium. This indicates the mean-reverting process of the *ETC* term.

The coefficients for the positive and negative *ECM* are reported in Model (2). All of them suggest that the impacts of positive and negative deviation are different. For the *LTCQ*1, for a positive deviation (i.e. the *ETC* term is higher than the equilibrium level) at time *t-1*, there is a larger power pulling it back at time *t* than when there is negative deviation. For *LTCQ*2 and *LTCQ*3, the pulling power for a negative deviation is larger than a positive deviation.

To further test the size asymmetry for fleet size, Model (3) includes *DLFPANAMAX*(*big*) and *DLFPANAMAX*(*small*). The sign of the estimated coefficients are similar to those in Model (1) and (2). The absolute value suggest that it is faster to adjust to its equilibrium level when there is a small increase in the fleet size than a big increase. This is reasonable as it needs much more time to digest the larger overcapacities in the market.

5.3.2 BCI C7 route

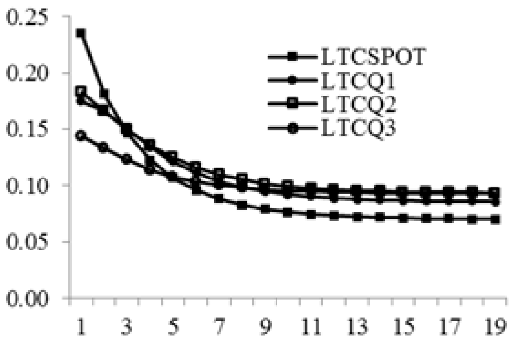
According to the cointegrating vector in Table 3, the *ETC* term is calculated as (*LC7SPOT*-2.907×*LC7M1*+2.297×*LC7M2*-0.880×*LC7M3*). Different with the estimates on the BPI T/C route, all the coefficients for the *ETC* terms are significantly negative on the BCI C7 route. However, as the absolute value represents the adjusting speed, this result can also ensure the mean-everting process of the rates. For example, when there is positive deviation from its equilibrium level at *t*-1 time period, all the rates decrease at next period with different magnitude, the spot rate and *LC7M2* decrease at 198.0% and 60.5% of the deviation separately in next period, while *LC7M1* and *LC7M3* decrease at 79.1% and 49.0% of the deviation separately. This bigger decrease for the positive cointegrating rates (*LC7SPOT* and *LC7M1*) and smaller decrease for the negative cointegrating rates (*LC7M2* and *LC7M3*) can ensure the reverting to the equilibrium of the system.

Although not all of the coefficients for the positive and negative *ECT* terms are significant, the significant ones suggests that the adjusting power for negative deviations is larger than positive ones. Similar to this result, part of the coefficients in Model (3) indicate the faster adjusting speed of the fleet for a small deviation and the lower speed for a big deviation.

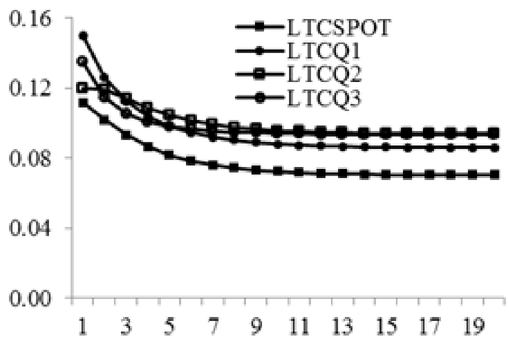
5.4 Impulse Response Analysis

The impulse response function analysis can provide a more detailed and direct insight on the causal relationship between any pair of the cointegrating variables. Since the variance orthogonalized Cholesky methods dependent on the ordering of the cointegrating endogenous variables, the GIR (Generalised Impulse Responses) (1998) method is used in this study.

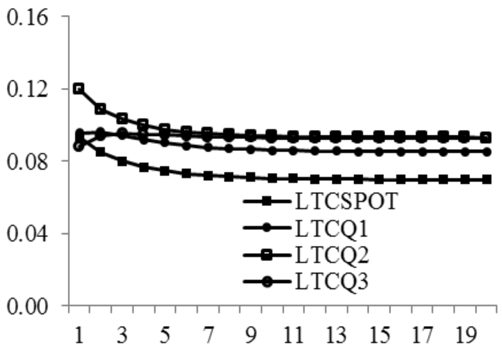
Figure 2 and 3 illustrats the time profiles of the GIR responses of the 4 endogenous variables to innovations in each equation on the BPI T/C and C7 route separately. On the BPI T/C route, an overshooting is observed in its dependent variable (for each equation) and then it is adjusted to equilibrium. The adjustment period is more or less the same for the innovations of *LTCSPOT*, *LTCQ1* and *LTCQ2*. They take approximately 8-11 months to their equibriums. It is slightly different for the innovations of the *LTCQ3*. It only takes 3 months for all 4 rates jumping to the new equilibrium.



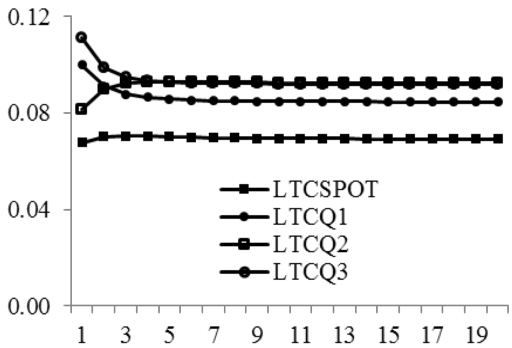
In the *LTCSPOT* equation



In the *LTCQ2* equation



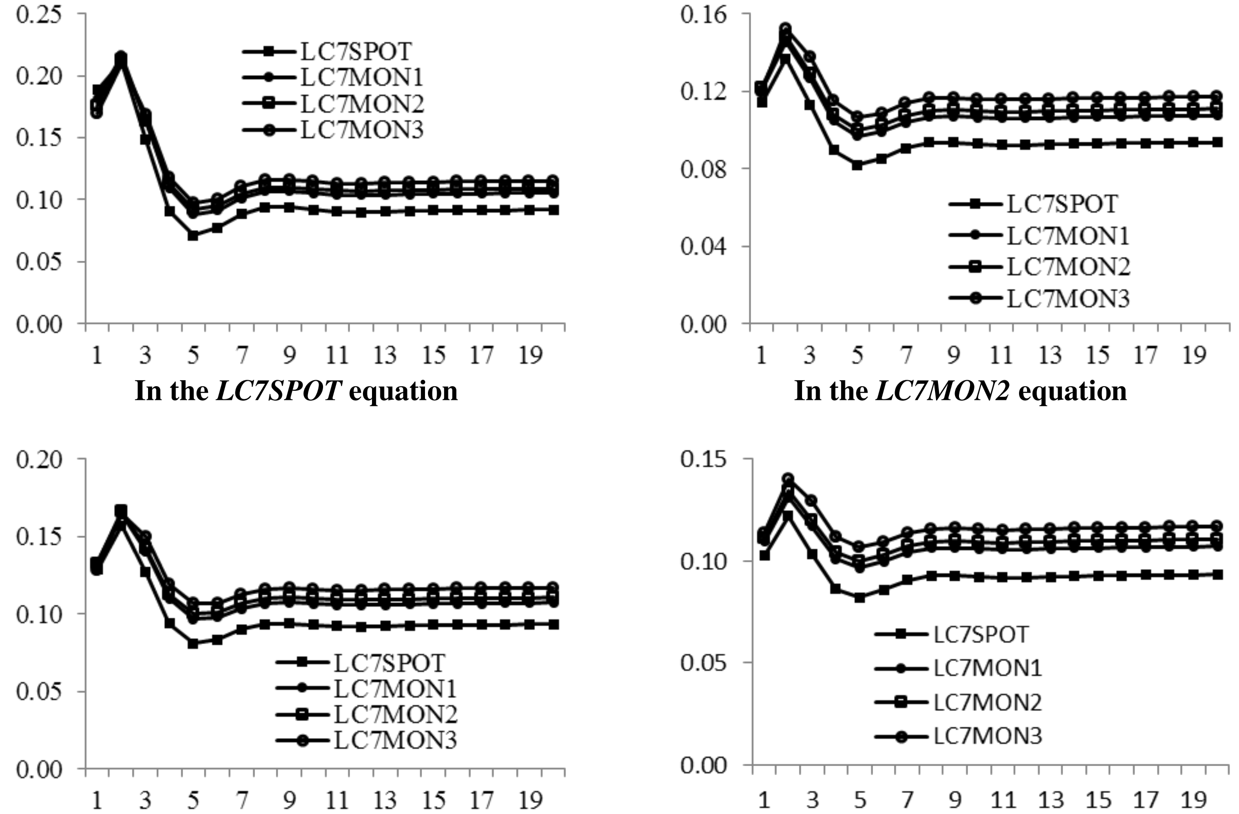
In the *LTCQ1* equation



In the *LTCQ3* equation

Figure 2: GIR to one SE shock on the PBI T/C route

The responses of all 4 endogenous variables are different on the C7 route. The overshooting reaches its peak at the second period. It then jumps to its equilibrium levels quickly. The adjustment periods they take are 7 months for each innovation.



In the *LC7SPOT* equation

In the *LC7MON2* equation

In the *LC7MON1* equation

In the *LC7MON3* equation

Figure 3: GIR to one SE shock on the C7 route

It is worth to note that the equilibrium level of the spot rate is the lowest among all the variables for each equation. This may to some extend indicates the insensitivity of the spot rate to other rate changes. It is reasonable since the spot rate is mainly determined by the current situations in the market, which includes various factors. However, the FFA prices are mainly determined by the expectations of the practitioners.

6. Discussion

The major findings of this study can be summarized as follows: First, spot and FFA prices are cointegrated in the long-run. Although the fluctuations are different in the short-run, they are commoving in the long-run. Figure 4 and 5 illustrate the daily movement of the spot rate and its FFA prices. This long-run relationship could help in forecasting the FFA prices where real trades are absent.

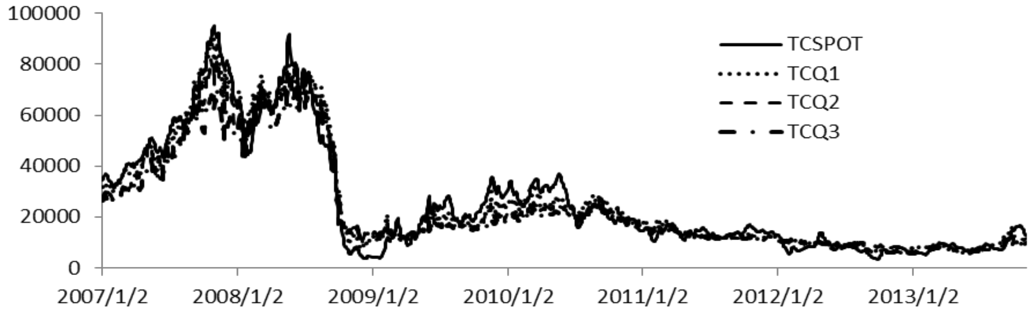


Figure 4: Daily development of spot and FFA prices on route BPI T/C

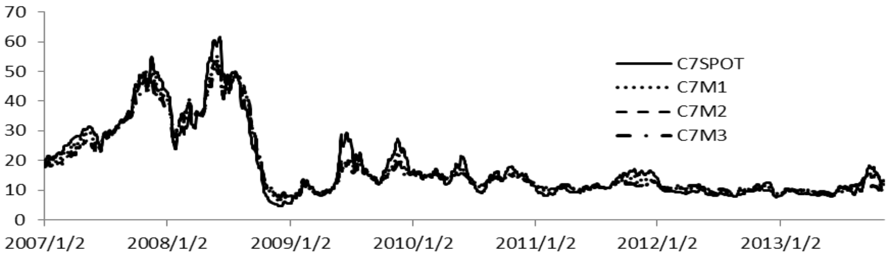


Figure 5: Daily development of spot and FFA prices on route BCI C7

Second, the causality tests suggest the mutual causality relationships among the 4 rates. Any three of them will jointly determine the other one, implying the equally importance of spot rate and FFA prices in assistance of decision making. Third, for the exogenous variables considered, the bunker price has a significant positive impact for the 4 rates on both routes. The fleet supply has a significant negative impact on the BPI T/C route. However, because of the inelasticity of freights on shipping demand, weak significance is identified for trade volumes on the movement of the spot and FFA prices. Fourth, there is a clear and direct mean-reverting process of the *ECT* term on the BPI T/C route, while, on the BCI C7 route, all the rates move in the same direction with different magnitudes to ensure the reverting to the equilibrium of the system. In addition, the asymmetry test suggests the different adjusting speed for positive and negative short-run deviations.

Furthermore, it also indicates the spot rate and FFA prices have a faster adjusting speed to equilibrium level for a smaller fleet increase and a lower speed for a larger fleet increase. Finally, when there is an innovation for any of the rates, they can gradually adjust to their equilibrium on the BPI T/C route, while they will jump to the new equilibrium quickly on the BCI C7 route. It also indicates that the impacts of the innovations on the spot rate are the lowest one for both routes, which suggests the less contribution of the FFA prices on the fluctuation of the spot rate although they are cointegrated in the long-run. When there is a change for the spot rate, the FFA prices will change accordingly, while on the other hand, the volatile of the FFA prices has a slight impact for the fluctuation of the spot rate. This can provide a clearer understanding of the price interactions in the spot and FFA markets and lead to a better assessment of risk management.

7. Conclusion

Since the dry bulk spot and its FFAs play a significant role for shipping companies to secure profits and avoid risks in the volatile shipping market, it is very important to understand the dynamics and interactions among them and the major factors for their fluctuation. This study firstly analyzes the potential factors for the spot and FFA prices. In order to avoid the issues bring by time series data, it examines the existence of long-run relation between spot rate and FFA prices. After identifying the existence of cointegration, it employs the VAR and VECM model to analyze the lead-lag relationship between spot and FFA prices on the BPI T/C and BCI C7 routes. The empirical results identify the mean-reverting process on both routes although their adjusting mechanisms are different. In addition, the exogenous variables, such as fleet size and bunker price, have significant impact for the fluctuation of the spot and FFA prices. Furthermore, it also discovers the effects of direction and size asymmetries on both routes. Finally, the impulse analysis indicates that the response of the spot rate is less sensitive to innovations of the rates than those of the FFAs. This may explains the more volatility of the spot rate than the FFAs.

Although there are plenty of studies analyzing the forecasting, pricing, risk management, and dynamic relationships with spot rates, there have been few studies investigating the interactions and major factors for the volatility of the spot and FFAs. In this point of view, this study provides a reference to the participants in the FFA market on the interrelation between spot rate and FFA prices and the causes of fluctuations in the markets, which can be used to promote the risk management in the FFA market.

8. Acknowledgements

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Identifying Green Assessment Criteria for Shipping Industries

Taih-Cherng Lirn[1], Christina W.Y. Wong[2], Kuo-Chung Shang [3] and Y.T. Lee[4]*

[1]Department of Shipping & Transportation Management, National Taiwan Ocean University, Keelung, Taiwan
[2]The Institute of Textiles and Clothing, The Hong Kong Polytechnic University, Hong Kong
[3]Department of Transportation Science, National Taiwan Ocean University, Keelung, Taiwan
[4]Taiwan International Port Corp, Kaohsiung, Taiwan

Abstract

This study empirically identifies critical assessment criteria used by bulk carriers and container carriers in Taiwan, and how they perceived the importance of the criteria to their operations. Through an extensive literatures review, twelve green performance indicators are categorized into four underlying assessment criteria, namely carriers' green policy, cooperation between green shipping stakeholders, reverse logistics management, and green design and promise. An Analytical Hierarchical Process (AHP) approach was employed to pairwisely compare the degree of importance of these major green assessment criteria and used by the shipping industry. Further analysis by ranking the weight of each of the four major criteria indicated that carriers' green design and promise is the most important criteria in the ocean carriers' context, followed by, carriers' green policy, cooperation among green shipping stakeholders, and reverse logistics management. Differences between container carriers' and bulk carriers' perceptions on the importance level of the twelve green performance indicators are found. This study advances knowledge by empirically and theoretically validate the degree of importance of green shipping assessment criteria.

Keywords: Green Assessment, Green Shipping, Bulk Shipping, Container Shipping, Dynamic Momentum

1. Introduction

Although consumers are increasingly willing to pay more for green products and they view green performance as one of the most important criteria in selecting their service providers (van Kasteren 2008; Porter & van der Linde, 1995), many ocean carriers were not keen to employ green management practices in providing freight service before the 1990s. While study suggests that most of the SO2 emissions are generated by shipping fleet rather than by the land-based sources, and it is estimated that about 15% of the anthropogenic NOx emissions and 7% of the SO2 emissions are due to shipping (European Commission, 2002; Beecken et al., 2015;). It is reported that bulk ships and container ships using poor quality marine bunker are the major carbon and particulate matters emitters in the shipping industry which are responsible for approximately 60,000 cardiopulmonary and lung cancer deaths annually (MARINTEK 2000; Millar 2011). By studying the European shipping industry and its corporate social responsibility (CSR), Fafaliou, Lekakou, & Theotokas (2006) reveal that only shipping companies that are either subsidiaries of international conglomerates or owned by shipowners who are personally aware of the corporate benefits of being socially responsible would be conscious of their environmental impact. Psaraftis and Kontovas (2010) indicate that there can be significant trade-offs between the environmental benefits and economic benefits. According to the European Commission's report in 2013, EU-related emissions from shipping are expected to increase further by 51% by 2050 compared to 2010-levels. Thus it is important for the maritime transport sector to reduce CO2 emissions by 40% in 2050 compared to 2005 levels in order to reduce its environmental impact (Bailey & Solomon 2004).

Many shipping stakeholders are increasingly worried that shipping activities damage the environment and increase resource consumption. As a result, increasing number of shipping companies develops and implements green shipping practices to address the environmental concerns of shippers with hope to attract the use of their freight services. Recently, adoption of green management technology is becoming one of the major tools that shipping companies use to compete in the era of global warming.

Knowing the importance of carriers' performance due to green freight service criteria can help the ocean carriers allocate their valuable resources in implementing green practice. This can also provide an insights to governance for government agencies to improve their national carriers' green performance, and to help international organizations (e.g., International Maritime Organization and Marine Environmental Protection Committee[i]) and port states[ii] to make appropriate environmental protection guidelines to regulate cargo vessels' green performance. This research aims to examine the green performance assessment criteria identified in the literature, their performance impact, and compare differences between container carriers and bulk carriers on the assessment criteria.

2. Literature Review

One of the pioneering campaigns on green shipping is launched by Norwegian shipowners and research institutes that aim to reduce gas emission (NOx & SO2) and solid waste dumping into the ocean from ships. Emission from ship not only pollutes the air but also endangers the residents' health in the port community(Bailey and Solomon, 2004) and results in the global climate change (Krozer et al., 2003). An increasing numbers of researches findings indicated ships are moving polluted waters from one port to another. For example, grey water from the engine room, sewage water in the bilge, washing water from cargo hold cleaning in the dry bulker, oily waste water, and ballast water with hazardous bacteria and marine living organisms. Uncontrolled ballast water discharge might endanger the survival of indigenous marine micro organism and spread disease (Krozer et al., 2003; Matej & Gollasch, 2008; Lai et al, 2010). The U.S.A. has suffered from many fairway blockings by the zebra mussels brought by the uncontrolled ballast water from the visiting ships and the US government spent $3.1 billion USD on port water treatment system in order to remove the problem. Thus Michigan State firstly punishes ships calling Michigan ports without onboard ballast water treatment system $25,000 USD since 2007. IMO also promulgates BMW(ballast water management) convention in 2004 to control ballast water and sediment. Marine Environment Protection Committee (MEPC) of IMO addresses implementation issues and three guidelines on ballast water management treaty to eradicate the global spread of harmful organisms in ships' ballast water (MEPC, 1014; David & Gollasch, 2008; Psaraftis & Kontovas, 2010). Global efforts on protecting the marine environments are endowed by the United Nations Convention on the Law of the Sea and the MRRPOL 73/78 Convention[iii].

Although green consumption and green marketing are popular business research topics, the extant literature on green ports and port operators and on green shipping management are scarce (Chang & Wang 2012; Park & Yeo 2012; Lun 2011). Harilaos (2010) identifies three measures to reduce the greenhouse gas emission from ships: technical measures, market-based instruments, and operational options. The technical measures include designing the fuel-efficient ship hulls, using fuel-efficient marine engine and propeller, alternative fuel (fuel cell & bio-fuel), cold-ironing during berthing, scrubber, wind-sail (e.g. by Beluga Shipping). The market-based measures include emission trading system (ETS), and carbon levy scheme. ETS allocates certain amount of carbon emission quota to each shipowner and the shipowner can trade it. On the contrary, the carbon levy is solely charged to the shipowners by the Hong Kong government. The operation measures include using economic/ecological steaming speed, optimal routing, and fleet management. The Shipowners Association suggests government to charge the bunker levy to support the upgrading of the ship design and building technology (Ta Kung Pao, 2009).

Lai et al. (2010) six measures a ship owners can use to improve their green performance: (1) company policy and procedure, (2)shipping documentation, (3)shipping equipment, (4)shipping collaboration, (5)shipping material, and (6)shipping design for compliance. American Association of Port Authorities (AAPA) list eleven factors to measure the green performance of a port: (1)air pollution, (2) wet land conservation, (3)fishery resources conservation and endangered species protection, (4) waste water and rain water discharge, (5)traffic jam, (6)noise and light hazard, (7)culture heritage and historical sites preservation, (8) land and water pollution from oil spill, (9) gas emitted from chemical tanks and fumigation, (10) unregulated solid and hazardous waste dumping, and (11) earth and land erosion.

The majority of prior research on ports and shipping companies are confined to their efficiency and regionalization, and on shipper's and forwarders' decision-making behavior (Cullinane, Ping & Wang 2006; Noteboom & Rodrigue, 2005; Tongzon 2009). Recent studies on green shipping performance criteria and framework are largely qualitative (Wuisan, Leeuwen, and van Koppen 2012; Lai et al., 2011). These studies identify four factors influencing green performance of an ocean carrier, including: carriers' green policy, cooperation between GSM stakeholders, reverse logistics management, and green design and promise. Table 1 summarizes the indicators reflecting these factors which are previously reported in the literature.

3. Study Participants

Survey target respondents were the executives of major ocean carriers in Taiwan and were selected based on review of their corporate profiles on their websites. Carriers were chosen to participate in the study if they have implemented or plan to implement green shipping practices, or their executives have delivered speeches on green shipping management (GSM). It is found that the carriers with green shipping practices were mostly large carriers and are listed in major stock exchanges in Taiwan. Thirteen leading container carriers and seven major bulk carriers in Taiwan were targeted to respond to the survey. The portfolios of the respondents are shown in the following tables (Tables 2~4).

Table 2: Affiliations of Surveyees and Respondents

	Questionnaire Posted	Questionnaire Responded	Responding Rate	Response from Carriers & No-carriers
Container Carriers	13	8	61.5%	27.1%
Bulk Carriers	7	5	71.4%	
Freight Forwarders	7	2	28.6%	37.5%
Manufacturers	5	4	80%	
Scholars	5	3	60%	
The Others	11	9	81.8%	
Total	48	31	64.6%	NA

Source: this research

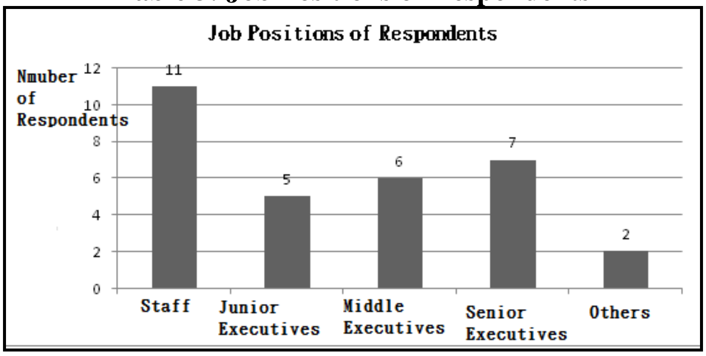
Table 1: Green Shipping Performance Criteria and Indicators

Criteria	Sub-criteria \ Previous Literature	Krozer et al.(2003)	Bailey & Soloman(2004)	Clarke (2006)	Fafaliou et al.(2006)	Bernal et al. (2007)	Le Rossignol (2007)	David & Gollasch (2008)	Matej, Gollasch(2008)	Frank et al.(2008)	MARINTEK(2008)	Alvik et al.(2009)	Eyring et al.(2009)	Sonak et al.(2009)	Chang et al.(2010)	Hall (2010)	Tzannatos (2010)	Psaraftis ,& Kontovas (2010)	Lai et al.(2010)	Enshaei & Mesbahi (2011)	Gregson (2011)	Kontovas & Psaraftis (2011)	Lun (2011)	Lai et al.(2011)	Melin & Rydhed (2011)	Osberg (2011)	Balland, Ore, Fagerholt (2012)	Bengtsson et al. (2012)	TDSM(2012) Hoffman et al.(2012)	USCG(2012)
Carriers' green policy (Criterion A)	Green business plan (A1)	*	*		*					*		*	*	*			*	*	*				*					*		*
	EP certification/ documentation (A2)	*			*							*		*				*					*	*						
	Regular EP practices (A3)									*								*					*	*						
Cooperation between green shipping management stakeholders (Criterion B)	Green procurement (B1)	*	*		*		*						*					*					*			*		*		
	Green delivery service (B2)	*	*		*																			*						
	Green promotions (B3)				*																			*						

Reverse logistics management (Criterion C)	Recycling recyclables (C1)	*				*		*	*	*					*			*			*		*							
	Waste disposables (C2)	*	*			*		*										*												
Green design and promise (Criterion D)	Green operation (D1)	*	*	*		*	*			*		*	*				*	*		*			*			*		*		*
	Emission reduction (D2)	*	*						*	*	*	*	*	*		*	*	*	*			*	*		*		*		*	*
	EP participation (D3)				*		*											*					*	*		*				
	Complying with green regulations (D4)		*	*	*				*			*	*	*	*		*		*	*	*		*	*						

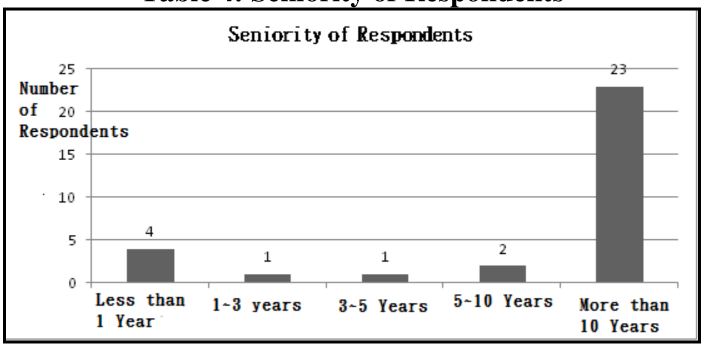
Note: EP (Environmental Protection)
*: found in the study

Table 3: Job Positions of Respondents



Source: this research

Table 4: Seniority of Respondents



4. Research Methodology

To understand the perceived importance of the assessment criteria and the performance of shipping companies of each criterion, two techniques were employed: the Analytic Hierarchy Process (AHP) technique and the Importance and Performance Analysis (IPA) technique. The AHP technique is firstly used to find the weight in terms of the importance of the green performance criteria, followed by the use of the IPA to illustrate the level of importance of the indicators.

4.1 AHP technique

The AHP technique is a popular Multi-Criteria Decision Method (MCDM) that is used to simplify a complicated system by constructing a hierarchic structure and help evaluate the performance of alternatives to be chosen (Ishizaka et al., 2011). A hierarchy can be composed of three levels: criterion, sub-criterion, and alternatives. A sub-criterion under a criterion should be correlated with the criterion in its upper level of the decision hierarchy, and judgments about the performance of an alternative in a hierarchy can be pairwisely compared or described by a set of measures. An AHP structure should follow the homogeneity axiom such that the elements being compared should not differ from each other too much in terms of their degree of importance (Forman & Selly 2002). Application of traditional statistics to analyze the survey responses simply does not meet the requirement of central limit theorem and the normal distribution. There is no requirement on the minimum number of respondents when the AHP technique is employed to make an empirical analysis.

There are three procedures in implementing the AHP technique: decomposition, comparative judgments, and hierarchic composition or synthesis of priorities. The pairwise comparison between each sub-criterion and criterion needs to satisfy a transitivity relationship but a perfect transitivity relationship is not required. When a transitivity relationship does not exist, the consistency index (C.I.) and consistency ratio (C.R.) are employed to test the degree of consistency of the respondent's responses. The C.I. and C.R. values are less than 0.1 if the respondent's responses are perceived to be consistent. Where C.I. = and C.R. = . λmax is the maximum eigenvalue of a comparison matrix and n is the number of criteria in the hierarchy. The random index (R.I.) values, exhibited in Table 2, increase with the number of decision criteria. AHP allows inconsistency. A higher than usual inconsistency ratio will result because of the extreme judgments necessary; thus, one can accept the inconsistency ratio even though it is greater than 10% under an extreme judgments scenario (Forman & Selly 2002).

Table 2: Random consistency indices for different number of criteria (n).

n	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
R.I.	0.00	0.00	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49	1.51	1.48	1.56	1.57	1.58

Source: Donegan and Dodd (1991)

4.2 IPA technique

Martilla and James (1977) were the first to propose the IPA technique to analyze automobile dealers' services and customers' patronage to the dealers' services. Service attributes with a high degree of importance and a low degree of customer satisfaction were suggested to invest resources by the car dealers to retain their customers' patronage. Although Sampson and Showalter (1999) indicate that importance is a dynamic construct that changes as perceptions of performance change, the IPA technique is still a useful tool for social science research to identify performance criteria that require an immediate improvement. By using the median or the mean value of the degree of importance and performance as the origin point of a matrix, four quadrants are formed in the IPA matrix (see Figure 1).

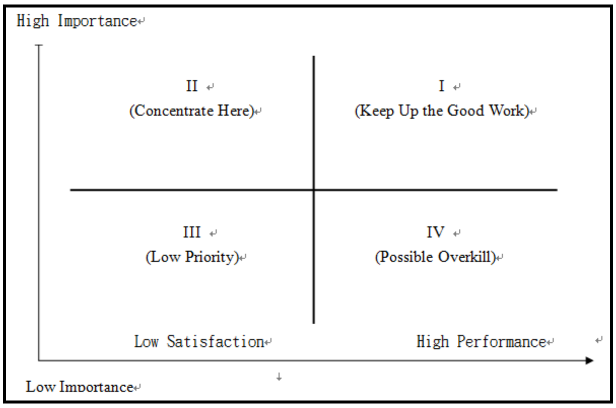


Figure 1: IPA Matrix

Source: Martilla and James (1977)

5. Results of Analyses

Based on the resource-based view of a firm, green shipping practices can be helpful to improve the shipping companies' overall performance (Lai et al. 2011). To investigate the green performance measurement of shipping companies, a set of four green performance criteria with a total of twelve green indicators were used to design the questionnaire.

In early 2011, questionnaires were posted to the 20 targeted carriers based in Taiwan, and 13 of them responded, resulting in a response rate of 65%. Of these 13 valid responses, 8 of them are container carriers and 5 of them are bulk carriers. Respondents included executives from eight container carriers and five bulk carriers. The degree of importance of these twelve sub-criteria and the four green performance criteria perceived by the ocean container carriers and bulk carriers are depicted in Table 3.

The threshold value 0.1 of the C.I. and the C.R. were employed to decide whether the respondents' replies were acceptable to proceed with the hierarchical analysis. Once a response was found above 0.1, the authors reviewed the replies from the respondent to find whether there was an inconsistent response. The respondents were contacted again to ask about the conflicting answers. The authors have to carefully explain where the confliction arises. If a respondent perceives 'carriers' green policy is three times more important than the 'cooperation among green shipping stakeholders', and (s)he also perceives 'carriers' green policy' is three times more important than the 'reverse logistics management', then the degree of importance between 'cooperation among green shipping stakeholders' and 'reverse logistics management' should be the same. The respondents then have to correct at least one of the conflicting answers and the problem was resolved.

Based on the findings, from the ocean carriers' viewpoints, none of the four green shipping performance criteria is located in the 'concentrate here' quadrant of Figure 2. Of the four green shipping performance assessment criteria, ocean carriers perceived 'green design and promise' as the most important (with 39.3% of global weight) as shown in Table 3.

Table 3: Perception on the importance and performance of the four major green assessment criteria by all Taiwan ocean carriers

Criteria	Weight	Performance	IPA Quadrants
Carriers' green policy	0.332	3.359	Keep up the good work
Cooperation among green shipping stakeholders	0.131	2.949	Low priority
Reverse logistics management	0.144	3.308	Possible overkill
Green design and promise	0.393	3.231	Keep up the good work
Average	0.25	3.212	Origin Point

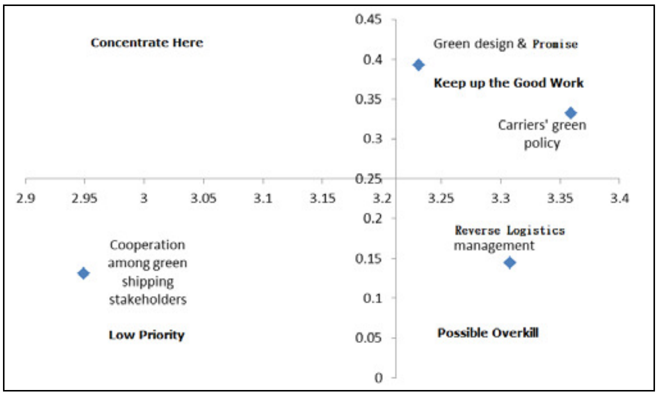


Figure 2: Ocean carriers' perception on the importance and perfromance analysis (IPA) of four major green shipping assessment criteria

Among the three indicators in the 'green design and promise' criterion, 'complying with green regulations' is perceived by container carriers to be the most important one, with 18.9% of global weight (see Table 4). As the Chinese proverb says, 'Law is the minimum standard of ethics, and ethics is the upmost standard of law'. Complying with the international green shipping regulations is one of the most important performance indicators because a violation of regulations not only damages the carrier's reputation, but also means they need to pay a large sum of penalty. For example, in 2005, the container shipping company Evergreen Marine Corp. paid $25 million to the U.S. Department of Justice (DoJ) as the largest-ever penalty for concealing vessel pollution (Anonymous 2010). Recently, the Italian Carbofin S.PA. agreed to plead guilty and pay a $2.75 million criminal penalty for falsifying oil record books aboard one of its ship to US DoJ in 2014 (Schuler, 2014).

Green business plan and emission reduction are perceived to be the second and the third most important performance indicators in evaluating container carriers' green performance (Figure 3). Many developed countries, such as the USA and Canada, have stricter environmental controls than the international regulation requires. The port states have regulations for emission control areas and SO_x emission control areas, as well as a compulsory shore power supply to make the port green (Knowler 2012). This evidences the increasing degree of importance of vessel emission reduction for container shipowners. Only shipowners with green business plan are likely to meet the requirements from various strict PSC environmental regulations.

The bulk carriers perceived that 'carriers' green policy' is the most important green shipping performance criterion, with an importance weight of 44.8%. The three performance indicators of this criterion, namely green business plan, regular environmental protection practices, and environmental protection certification, were perceived to be the three most important green shipping performance sub-criteria. Bulk carriers were requested to pass the International Safety Management (ISM) code auditing and certification by the beginning of July 1998, and container carriers were requested to pass the ISM external audit by mid 2002. According to the U.S. Coast Guard (USCG 2012), the objectives of the ISM Code are to ensure safety at sea, the prevention of human injury or loss of life, and the avoidance of damage to the environment, in particular, to the marine environment, and to property (Bailey & Solomon 2004).

Bulk ships are rovers and they travel around the world without any fixed service route or schedule. It is therefore very difficult for bulk carriers to understand all ports' environmental regulations from around the world. The best practice for bulk carriers is to adopt a green business plan to avoid violating the environmental regulations of a port state. So that bulk carriers broadly qualify for the green shipping requirement, it is also highly desirable for them to pass the ISO14001 certification for environmental protection. Bulk carriers are involved in many chartering activities, and a charter party often requires a contract of many pages. The charter party used in bulk shipping industry is a lengthy document and an electronic form of the documents would reduce the amount of paper used for printing. This is especially important to bulk carriers as they rarely visit their home port, which makes ship supplies replenishment difficult.

A cross-comparison of the ranking of the importance of the twelve indicators between container carriers and bulk carriers reveals that both types of carriers perceive the 'green business plan' as one of the three most important performance indicators as shown in Table 5. Most Asian ocean container carriers' major customers are large European and American importers who purchase Asian manufacturing products using the free on board (FOB) term. These importers control the decision of freight services and ocean carriers to move their imported cargoes, but they have to take their consumers' green expectations into consideration. Thus, container carriers have to meet such customers' demands of being environmentally responsible.

Major international retailers, such as Wal-Mart and IKEA, ask their freight service providers to move their cargoes in an environmentally friendly manner (Lai et al., 2011). Complying with environmental protection regulations and reducing emissions and liquid waste discharge from ships are two of the minimum standards that container carriers have to achieve to satisfy the green consumers' environmental protection demands. As container vessels have a faster speed than bulk carriers and consume more bunker fuel, they emit much larger amounts of CO_2, NO_x, SO_x, and PM (particulate matters). Thus, container carriers perceived emission reduction to have a higher degree of importance than did the bulk carriers as shown in Table 4. In addition, container carriers move manufactured products, and as many branded manufactured products are keen to have their brand considered green, 'green design and promise' are perceived to have a higher degree of importance from container carriers' viewpoint than that from bulk carriers' viewpoint.

A comparison of the perceptual difference between container carriers and bulk carriers is depicted in Table 5. There are perceptual gaps on the importance ranking of the four criteria and twelve green performance indicators between container carriers and bulk carriers. In the carriers' green policy criterion, three indicators of the carriers' green policy dimension are ranked as the top three important indicators by bulk carriers. On the other hand, two of the four indicators in the 'green design and promise' dimension are perceived to be the most important and the third most important green performance indicators as perceived by container carriers in this survey.

Table 4: Degree of importance of the criteria and indicators as perceived by ocean carriers

Degree of Importance								Degree of Performance	IPA Quadrants
Factors		Bulk Carriers		Container Carriers		All respondents		All respondents	All respondents
Major Criteria (Criteria weight of container / bulk carriers	Indicators	Global Weight	Ranking	Global Weight	Ranking	Global Weight	Ranking	Score	Quadrant
Carriers' green policy 0.263/0.448	Green business plan (GBP)	0.211	(1)	0.13	(2)	0.161	(2)	3.23	Keep up the good work
	EP certification (EPC)	0.118	(3)	0.07	(7)	0.088	(4)	3.13	Concentrat e here
	Regular EP practices (REPP)	0.119	(2)	0.063	(8)	0.083	(5)	3.03	Concentrat e here
Cooperation among green shipping stakeholders 0.11/0.161	Green procurement (GPROC)	0.07	(7)	0.04	(11)	0.051	10)	3.10	Low Priority
	Green delivery service (GDS)	0.044	(10)	0.028	(12)	0.034	(12)	3.03	Low Priority
	Green promotion (GP)	0.047	(8)	0.042	(10)	0.046	(11)	3.20	Possible Overkill
Reverse logistics management 0.142/0.134	Waste disposal (WD)	0.088	(5)	0.061	(9)	0.075	(6)	3.20	Possible Overkill
	Recyclables recycled (RR)	0.046	(9)	0.081	(6)	0.069	(7)	3.17	Possible Overkill
Green design and promise 0.485/0.257	Green operation (GO)	0.029	(12)	0.09	(5)	0.060	(9)	3.13	Possible Overkill
	Emission reduction (ER)	0.079	(6)	0.115	(3)	0.104	(3)	3.13	Concentrat e Here
	EP participation (EPP)	0.033	(11)	0.092	(4)	0.065	(8)	3.23	Low Priority
	Complying with green regulation (CR)	0.117	(4)	0.189	(1)	0.164	(1)	3.14	Keep up the good work
Average Score						0.0833		3.14	Origin Point

Note: Please see the appendix 1 for the definitions of the twelve green performance indicators.

'Green business plan' and 'complying with environmental protection regulation' are perceived by both bulk carriers and container carriers to be two of the top five important green performance indicators. Carriers can publish their green business plan on their websites, popular social media websites, and in their corporate social responsibility report to allow their employees clearly to not only take note of the green policy, but also understand how to achieve the target of this green policy. Regular issue of the environmental regulation notice from the carriers' office to their staff on board is helpful to update the seafarers' knowledge on environmental protection regulations, and finally, carriers' fleets can follow the international environmental regulations.

Table 5 Perceptual gaps of importance between container carriers and bulk carriers

Criteria	Weight ranking		Indicators (Abbreviation)	Weight ranking	
	Container Carriers	Bulk Carriers		Container Carriers	Bulk Carriers
Carriers' green policy	2	【1】	Green business plan(GBP)	【2】	【1】
			EP certification(EPC)	7	【3】
			Regular EP practices(REPP)	8	【2】
Cooperation among green shipping stakeholders	4	3	Green procurement(GPROC)	11	7
			Green delivery service(GDS)	12	10
			Green promotion(GP)	10	8

Reverse logistics management	3	4	Waste disposal(WD)	9	5
			Recycling recyclables (RR)	6	9
Green design and promise	【1】	2	Green operation(GO)	5	12
			Emission reduction(ER)	【3】	6
			EP participation(EPP)	4	11
			Complying with EP regulation(CR)	【1】	4

【n】to indicate the most important criteria and the three most important indicators in evaluating the performance of the green container carriers and the green bulk carriers.

Finally, the IPA technique was employed to find the green shipping performance sub-criteria located in the critical quadrant ('concentrate here' quadrant) where the degree of importance is high but the degree of performance is low. Figure 3 shows the overall importance and performance of these twelve green shipping performance indicators of the container carriers and bulk carriers.

Three of the twelve indicators are located in the 'concentrate here' quadrant, which implies that the 'environmental protection certification' (EPC), 'regular environmental protection practice' (REPP), and 'emission reduction' (ER) performance indicators urgently need improvement. There is an indicator located in the 'keep up the good work' quadrant, namely, 'green business plan' (GBP) suggesting that ocean carriers perform well in this performance indicator. Concerning the GBP indicator, the carriers show that they have set up a green vision and the top management support the operation of an environmental protection monitoring system and encourage inter-departmental green cooperation in the company. Based on the EPC performance indicator, carriers are advised to obtain the ISO14000 and ISO14001 environmental protection certification to attract and retain the patronage of large shippers. To reduce emissions (ER), ocean carriers might consider to acquire the detailed information of their ships' emissions (e.g., SO_x, and NO_x emission rate per ton-miles cargo carried) and provide a carbon footprint calculator on their website. When compliance with the regulations (CR) performance indicator is considered, the carriers have to follow the current international environmental protection regulations, for example, the London Convention (Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter (LDC), 1972), MARPOL73/78 (International Convention for the Prevention of Pollution from Ships) and 2004 BWM (Ballast Water Management Convention). The 'waste disposal' (WD) indicator is located in the possible 'overkill' quadrant. This criterion includes the disposal of the sewage water and bilge water from cargo holds. Part of the resources used for this possibly 'overkill' indicator could be moved to improve the green performance of the three criterion located in the 'concentrate here' quadrant and to maintain the good performance of the abovementioned two performance indicators in the 'keep up the good work' quadrant.

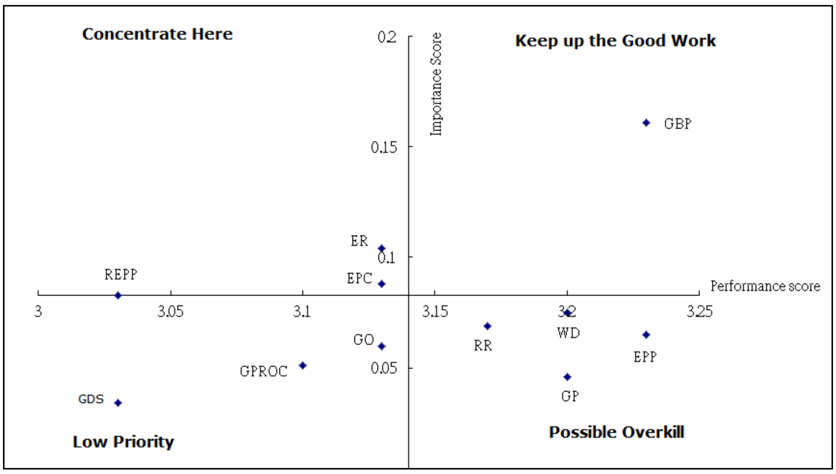


Figure 3: Ocean carriers' perception on the green shipping assessment indicators

Note: Green business plan (GBP), EP certification (EPC), Regular EP practices (REPP), Green procurement (GPROC), Green delivery service (GDS), Green promotion (GP), Waste disposal (WD), Recyclables recycled (RR), Green operation (GO), Emission reduction (ER), EP participation (EPP), Complying with regulation (CR)

6. Conclusion and Discussions

6.1 Discussion

Three contributions are made by this study. First, shipping companies should prepare for the prevalence of the green trend, but there are few extant green shipping studies that endeavor to establish a set of green shipping performance assessment criteria and indicators, and to provide constructive environmental governance and monitoring indicators to the maritime authorities. Second, the degree of importance of criteria influencing green performance of a shipping company is firstly reported by this research. Third, green performance determinants of the ocean carriers are for the first time identified in this research.

Four criteria and twelve performance indicators are identified related to green shipping practices. Applying Analytical Hierarchical Process (AHP) and Importance-Performance Analysis (IPA) techniques, this study found the perceived importance and carriers' performance on four major criteria and twelve indicators of green shipping management. As far as green shipping practices are concerned, ocean carriers perceive complying with green regulation, implementing green business plan, and following emission reduction regulation as the three most important green performance indicators. In addition, the findings indicated that there are perceptual gaps regarding the degree of importance of green assessment indicators between the container shipping sector and the bulk shipping sector. Bulk carriers and container carriers perceive implementing green business plan and complying with environmental regulation to be their most important green performance indicators, respectively. Finally, environmental protection certification (EPC), emission reduction(ER), and regular environmental practices (REPP) are perceived by all respondents to have lower degree of performance but a higher degree of importance. Shipping companies should spend more resources on these three performance indicators to effectively improve their green performance.

6.2 Conclusion

The two leading green shipping performance indicators, namely complying with environmental protection regulation and green business plan, have a global weight of 0.325 (0.164 + 0.161) in terms the degree of their importance. This implies an ocean carrier should firstly prepare its green business plan according to green regulations if it intends to implement green shipping practices. A theoretical implication for this finding is made as follow, look before leap if a green shipping practice is to be implemented. Ocean carriers should review international green regulations and have a green plan complying with regulations before the other green performance indicators can be effectively implemented. A future structure equation modelling research could be used to test this proposed theoretical implication. Another theoretical implication of this research in terms of the methodology includes the combination of AHP technique with the IPA model. Container carriers and bulk carriers are not only different in the types of cargoes they carried, but also in the degree of importance of their green assessment indicators they perceived.

There are several practical implications of the research findings. First, there are perception gaps regarding the importance of the four criteria and the twelve green shipping performance indicators between the ocean container carriers and bulk carriers. Bulk carriers perceive 'carriers' green policy' as the most important criterion in improving their green performance. Three indicators are included in this green criterion: green business plan, regular environmental protection practices, and environmental protection certification. The number of ports of call by bulkers is far less than the ones of container carriers. Thus, the odds of a bulker being checked by a port state's officers are lower than for container vessels. However, 'practice makes perfect'. As the bulkers do not have too many chances to be visited by the shore staff, bulk carriers' operators should improve their green performance by educating their seafarers on board when their seafarers are on their shore leaves.

Container carriers are regularly checked and visited by port state control inspectors. They perceive that the 'green design and promise' criterion as important in addition to the 'carriers' green policy' criterion. A sea-shore rotating work shift as adopted by the Evergreen Marine Corporation can allow seafarers work ashore for a short period after the seafarers complete each of their ocean-going service contracts. Thus, intensive training programs on international environmental protection practices and regulations can be provided to the seafarers during their shore-based working shifts.

Second, container carriers are used to providing a door-to-door freight service. Their green performance is revealed not only in their green ocean freight service, but also in the other transport mode service they provide. Slow steaming makes a greater contribution to the emission reduction of container ships than of bulk ships. Container ships' cruising speed is used to be around 24 knots and their owners can reduce speed from 24 knots to as slow as 15 knots when the bunker price is very high and the ships' charter hire is very low (Maloni, Paul, and Gligor, 2013), while dry bulk ships' regular sailing speed is used to be around 14 knots and can simply reduce their ships' speed from about 14 knots to as slow as 9 knots (Devanney, 2011).The branding value of container carriers and their corporate images are more conspicuous than those of bulk carriers. Thus, container carriers tend to invest more resources to improve their environmental protection practices and their corporate images.

Third, the study results show that most carriers can continue to invest resources in keeping their excellent performance in three sub-criteria, namely ER (emission reduction), and, in particular, there is still room for performance improvement in the environmental protection certification (EPC) and regular environmental protection practice (REPP) indicators for container carriers.

Green operation is experiencing continuing development in the ocean shipping industry. It involves legal, innovational, and managerial issues (Azzone & Noci 1998; Yang, Marlow, & Lu 2009). Chen et al. (2006) investigate information and electronics industries in Taiwan and indicate that the performances of green product innovation and green process innovation were positively correlated to the corporate competitive advantage. Thus, future studies may attend to two issues: The carriers' green innovation and their corporate performance. A comparative study of the perceptual gaps on the criteria and sub-criteria influencing the green shipping performance between global container carriers and major shippers is also highly encouraged in future research.

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[i] According to the United States Coast Guard, the Marine Environment Protection Committee (MEPC) is a committee of the International Maritime Organization (IMO). The committee meets every 9 months to develop international conventions relating to marine environmental concerns including ship recycling, controlling emissions, and invasive species.
[ii] Port state is the state to implement the inspection on both its national and foreign ships visiting the state's ports by PSC officers (inspectors) for the purpose of verifying that the competency of the master and officers on board, and the condition of the ship and its equipment comply with the requirements of international
[iii] Conventions (e.g. SOLAS, MARPOL, STCW, etc.). Thus both flag states and port states can regulate the green performance of ocean carriers.

The Role of the Taiwan Marine Sectors in the National Economy: An Input-output Analysis

*Shu-Man Chang[1], Yo-Yi Huang[*2] and Ting-Shiun Cheng[2]*

[1]Department of Air & Sea Logistics and Marketing, Taipei College of Maritime Technology, New Taipei 251, Taiwan
[2]Institute of Applied Economics, National Taiwan Ocean University, Keelung, 20224, Taiwan
[*]Tel.: +886-2-2462-2192 ext. 5412. E-mail: hyy@ntou.edu.tw

[*]*Corresponding Author*

Abstract

Economically, Taiwan depends heavily upon international trade. In order to examine the role of the Taiwan marine economy in the national economy, this paper employs an Input-output methodology to the marine sector over the period of 1991 to 2011. This analysis represents the first effort to quantify the inter-industry linkage effects, production multipliers, earning effects and employment multipliers in the marine sectors. Our major findings of the paper can be summarized as follows: (1) the marine sectors have a lower forward linkage effect and a higher backward linkage effect. (2) Of those sectors, transportation support services, domestic cargo transport and overseas cargo transport sectors have relatively high production inducing effect, earning inducing effect and employment inducing effect. This indicates that those three sectors have the greatest impacts on the Taiwan economy, and pinpoints those three sectors as targets for further development in the marine industry. They are crucial sectors with regard to intermediate input.

Keywords: Input-output analysis; Marine sectors; Industry linkages; multiplier; Taiwan

1. Introduction

Facing the scarcity of land resources, maritime states in the world engage in utilizing marine resources widely and adjusting their maritime policy actively. (Kwak et al. (2005), Kildow and McIlgorm (2010), Morrissey et al. (2011), Morrissey and O'Donoghue (2012, 2013) Strategically located in the middle of a chain of islands stretching from Japan in the north to the Philippines in the south, and only 160 km off the southeastern coast of the Chinese mainland, the island of Taiwan is a natural gateway to East Asia. It is rich in ocean resources, as it possesses 1,520 km of coastline and 548,898 km2 of territorial waters under its jurisdiction, which is 15.25 times the size of its land. Surrounded by the sea, Taiwan has continuously sought outward development opportunities, seeking to expand trade links with other countries as a main driving force of its economic growth. This has come to be known around the world as the "Taiwan experience." Between 1952 and 2014, the per capita GDP of Taiwan rose from US$213 to US$22,813; its GDP increased from US$1.7 billion to US$527.9 billion; and its foreign trade expanded from US$303 million to US$588 billion. Taiwan depends heavily upon its maritime transportation sector with more than 99% of its trade transported by sea. Therefore, Taiwan has witnessed the rapid development of marine resources, especially in the recent decade.

Evergreen Marine Corporation, a global containerized-freight shipping company headquartered in Taiwan, was founded in 1968. It began its first circumnavigation shipping services in 1984, and ranked as the largest container company worldwide by container ship fleet capacity in 1985. In 1984, the Port of Keelung ranked 7th in the world based on throughput. In the 1980s–1990s, the Port of Kaohsiung, which is the largest harbor in Taiwan, ranked as the third largest port in the world after Hong Kong and Singapore, handling approximately 10.59 million twenty-foot equivalent units (TEU) worth of cargo in 2013.

Since the early 1960s, Taiwan has developed excellent skills in aquaculture and even won the title of aquaculture kingdom of prawn in the 1980's. With its long history in the industry and new technological advantages in both hi-density indoor and offshore cage aquaculture, Taiwan will keep playing a key role in the global aquaculture industry in the century. Its fish catch exceeded 1.5 million tons. The total output value of fishing amounted to NT106.3 billion in 2011. Under the 10 infrastructural projected promoted by the Executive Yuan in May 1970, Taiwan established the China Shipbuilding Company. As one of the Four Asian Tigers, Taiwan utilized its high-quality labor and cheap lumber to become the yacht kingdom in the world.

Summing up, we learned that the marine economy has played an important role in Taiwan’s economic development, and has made significant contribution to people's well-being. The marine industry has had close linkage effects with other industries on the island. Even though it fell short of playing the role of a locomotive in leading the developments of all other sectors, the marine industry has played a crucial role in the overall economic development, particularly in regard to rising demands related to international trade created by ocean transportation.

The empirical evidence of the importance of marine resources will be needed in order to come to an understanding of public policies, governance and regulations across the sector. However, academic researchers in the past have focused mainly on the studies of individual sectors, such as fishery and maritime transportation. Little research has been done on an analysis of the overall marine industry to give an in-depth and overall look of the industry so crucial to Taiwan's economic development.

Morrissey and O’Donoghue (2012) points out that globalization has intensified industrial linkage effects, benefiting most notably the traditional maritime transportation and fishery sectors. Kwak et al. (2005) utilizes the Input-output methodology to analyze how the marine industry had contributed to South Korea's rapid economic development during the period of 1975 through 1998. In Morrissey et al. (2011) analysis of the Irish marine industry, he notes that Ireland's maritime industrial output had grown rapidly to contribute significantly to the country's economy, rising from 800 million euro in 2003 to reach 1.4 billion euro in 2007. Sharma and Leung (1986) examines the economic impacts of the allocation of catch from one non-longline commercial fishing trip to recreational fishing using the 1992 input-output model of the state of Hawaii. Briggs et al. (1982) modified to include nine fisheries sectors, was used to estimate the increases in income induced per dollar of sales for each fisheries sector.

In an analysis of the Irish industrial linkage effects conducted by Morrissey and O’Donoghue (2013), they note that the Irish marine industry, particularly its water transport sector, stood out well in the forward linkage effects. Those sectors demonstrating better backward linkage effects included seafood processing, water transport and water construction. In addition, in the analysis of the marine industry linkage effects in China's Tianjin port, Zhao (2013) notes that Tianjin's marine industry showed better forward linkage effects, with maritime chemical sector ranked first, maritime power sector ranking second and ocean transportation ranked 4th. Zhao found that marine communications and transportation industry, marine electric power industry, marine chemical industry are key industries in Tianjin’s economy.

In this study, we will utilize the Input-Output (here after I-O) methodology to conduct an analysis of the industry. We utilize data of the years of 1991, 1996, 2001, 2006, and 2011 to come up with an inter-industry interdependence coefficients matrix, which will elucidate on the forward linkages and backward linkages of the industry. By conducting a further multipliers analysis, we can learn the marine industry's respective contributions to Taiwan's total productivity, national income and employment.

The paper is presented in the following sequences. In the next section, an overview of the data requirements and data used within this paper are provided. Section 3 presents a formal overview of the I-O model and the derivation of backward and forward linkages. Section 4 discusses the results of the I-O analysis in terms of linkages, production effects, earning effects and employment multipliers for the marine sector. Finally, a brief conclusion is given in Section 5.

2. The Status of the Marine Economy of Taiwan

Since the 1960s, with the government actively implementing export-oriented policies, external trade has grown rapidly. Taiwan is a small, open, island economy, with a ‘trade to GDP ratio’ of 126.41 in 2012. Marine transportation is therefore an important input into economic activity, with 95% and 99% of the overall value and volume of goods traded passing through Taiwan seaports. It is important to note that within this paper maritime refers to water transportation based services and/or sector. Table 1 presents the economic structure of the Taiwan marine economy during 1991-2011.

Table 1: The GDP of marine economy during 1991- 2011 (Unit: Million NT Dollars)

Sectors\ Year	**1991**	**1996**	**2001**	**2006**	**2011**
Aquaculture	37611	41854	34819	36782	44590
Deep-sea fisheries	38562	51757	55614	52210	50295
Coastal fisheries	26608	27824	20600	20414	22052
Shipbuilding	41788	39142	41540	51126	61621
Ocean contraction	23857	29317	30597	33928	38389
Passenger transport	321	491	534	903	1801
Overseas cargo transport	85980	139276	145731	249670	176453
Domestic cargo transport	617	4775	4998	4697	2766
Transportation support service	58293	113280	124306	152946	221948
Total gross output of marine industry	313636	447715	458741	602678	619915
Marine economy (% of GDP)	2.5%	2.29%	1.89%	1.67%	1.4%
Total gross output of all industry	12853931	19649532	24264302	36131754	44433620

According to the statistics from the I-O table published in the Taiwan Directorate General of Budget, Accounting and Statistics (DGBAS) of Executive Yuan from 1991 to 2011, many phenomenon can be observed, especially the rapid rising gross domestic product (GDP growing 3.5 times), but increasing from the GDP of marine economy growing 2 times. According to the table 1 shown that the marine industry share of GDP has been on a declining trend during the period of 1991-2011.

Note that ranking by GDP of marine economy in the list of year 2011, transportation support service takes the 1st place by the GDP 221948, followed by overseas cargo transport of 176453. However, the dynamic pattern seems to reveal other important phenomenon. More specifically, marine industry that have experienced a growing GDP during the period from 1991 to 2011, include Ocean contraction (+14532), passenger transport (+1480), overseas cargo transport (+90473, growing 2 times), domestic cargo transport (+2149) and transportation support sectors (+163655, growing 3.5 times). On the contrary, sectors experiencing a fluctuation growing GDP include aquaculture, deep-sea fisheries. Therefore, in this research, we will focus on marine economy including the marine transport industry, shipbuilding industry and marine fishery industry.

3. Methodology

In this paper, we analyze the role of the Taiwan marine sector in national economy. I-O analysis allows us to study these marine sector structural changes in the economy.

The Taiwan marine sectors, however, have rarely been investigated separately through the use of I-O analysis. The final product of the marine industry is supplied to the industries consuming marine goods and services as intermediate goods and the demand for marine production is determined based on the levels of their production. Thus, marine supply has direct and indirect effects on their production activities. The effects of marine sector supply shortages are especially important since the marine industry, a social overhead capital, significantly affects other industries that consume marine goods and services as intermediate goods. Moreover, the analysis of direct and indirect influences of price changes of marine goods and services on price levels of other sectors should be emphasized. This section deals with an overview of the I-O analysis to analyze these pervasive effects.

3.1 General framework of the I–O analysis

The I-O model is a linear, inter-sectoral model which shows the relationships among the productive sectors of a given economic system. The basic balance equations of the I-O model consisting of N industry sectors can be expressed as

$$\begin{aligned} X_i &= (Z_{i1} + Z_{i2} + \cdots + Z_{in}) + F_i \\ X_n &= (Z_{n1} + Z_{n2} + \cdots + Z_{nn}) + F_n \end{aligned} \quad (1)$$

where X_i is the total gross output in sector $i = 1 \dots n$; Z_{ij} is intermediate demand for inputs between sector i and the supply sector j and X_j is the final output for sector i; and F_i the final demand for products in sector i. Thus, Eq. (1) describes the demand-driven model as viewing I–O tables vertically. With the letter X representing the column vector of total outputs, A the $(n \times n)$ matrix of technological coefficients, and F the column vector of final demands, the entire system of equations is expressed simply as

$$X = AX + F \,. \quad (2)$$

The matrix of technological coefficients is defined as: $A = a_{ij} = \frac{z_{ij}}{x_{ij}}$ (3)

where a_{ij} are direct input or technical coefficients which divide X_{ij} the inter-industry purchases of producing sector i from supply sector j by X_j total gross output in sector j.

$$X = (I - A)^{-1} F \quad (4)$$

where matrix I is an identity matrix, $(I - A)^{-1}$ (Eq. (4)) is known as Leontief's inverse matrix and represents the total direct and indirect outputs in sector i per unit of exogenous final demand, d for sector j.

3.2 Measures of inter-industry linkages

In the Leontief inverse matrix, each sector is directly and indirectly linked with all other sectors. For each sector i, these linkages are divided into two different types: 'backward linkage' describing the direct and indirect economic inputs of other sectors into sector i, and 'forward linkages' describing the direct and indirect economic inputs of sector i into all other sectors. The backward linkages of sector i are associated with the column i and its forward linkages are associated with the row i of the Leontief inverse. Therefore, the overall intensity of backward and forward linkages of sector i can be measured as sums of the components of the ith column and the ith row of the Leontief inverse. Thus, the column and row multipliers of the forward linkage and backward linkage can be defined as:

$$FL_i = \sum_{j=1}^{n} b_{ij} \quad (5)$$

$$BL_j = \sum_{i=1}^{n} b_{ij} \quad (6)$$

These characterizations can be used to identify key sector, those create an above-average impact on the rest of economy. Two main types of indices have been proposed:

(1). Power of dispersion for the backward linkages, measuring the degree to which a change in the sector of reference is greater than the average for all sectors.

$$IBLj = \frac{\sum_{i=1}^{n} b_{ij}}{\frac{1}{n}\sum_{i=1}^{n}\sum_{j=1}^{n} b_{ij}} \tag{7}$$

(2). Sensitivity of dispersion for forward linkage, measuring the degree to which a unit change in all sector's final demand would create an above-average increase in output in the sector of reference.

$$IFL_i = \frac{\sum_{j=1}^{n} b_{ij}}{\frac{1}{n}\sum_{i=1}^{n}\sum_{j=1}^{n} b_{ij}} \tag{8}$$

Moreover, the sum of all backward linkage and the sum of all forward linkages are equal to n, and the average linkage is equal to 1. Using these hierarchies of backward and forward linkage, we can divide sectors into four groups: (1) sector i is considered a 'key sector' if $IBL > 1$ and $IFL > 1$; (2) sector i is considered as 'a backward linkages oriented sector' if $IBL > 1$ and $IFL < 1$; (3) sector i is defined as 'a forward linkages oriented sector' if $IBL < 1$ and $IFL > 1$; and (4) sector i with both backward and forward linkages <1, is considered as a 'weak linkages oriented sector'.

3.3 Date and the reconstruction of marine economy

We have classified the 9 marine sectors (Table 2), according to the I-O tables compiled by the Taiwan Directorate General of Budget, Accounting and Statistics (DGBAS) in 1991, 1996, 2001, 2006 and 2011. As mentioned above, night marine sectors are all directly segregated from the I-O tables (554 sub-sectors) compiled by DGBAS.

Table 2: Classification of major marine industries and definitions

Major sectors	Sub-sectors	Definition
Marine fishery	Aquaculture	Refers to the farming of aquatic organisms such as fish, crustaceans, molluscs and aquatic plants. For example, eel, tilapia, carp, milkfish, bass, clam, oyster, giant fresh prawn and grass shrimp.
	Deep-sea fisheries	Deep-sea fisheries take place in both exclusive economic zones (EEZs) and in areas beyond national jurisdiction. These fisheries target demersal/benthic species using a range of gears including bottom and mid-water trawls, pots and longlines.
	Coastal fisheries	Includes coastal fishing and offshore fishing.
Marine contraction	Shipbuilding	Refers to the activity of building ocean vessels, offshore fixed and floating equipment with metals or non-metals as main materials as well as repairing and dismantling ocean vessels.
	Ocean contraction	The ocean contraction sector is composed of harbor construction and utilities construction sub-sectors listed in the Input-Output tables (554 sectors) compiled by DGBAS.
Marine transportation	Passenger transport	Refers to the activities of carrying out and serving the ocean-going passenger transportation with vessels as main vehicles.
	Overseas cargo transport	Refers to the activities of carrying out and serving the overseas cargo transportations with vessels as main vehicles.
	Domestic cargo transport	Refers to the activities of carrying out and serving the domestic cargo transportations with vessels as main vehicles.
	Transportation support service	Includes the customs clearance, shipping agency and freight forwarding, and water transportation supporting in port.

The marine fishery sector (166 major sectors) contains aquaculture, deep-sea fisheries, and coastal fisheries (554 sub-sectors). The marine transportation sector (166 major sectors) contains passenger transport, overseas cargo transport, and domestic cargo transport (554 sub-sectors). As we know, industries always go through structural changes at various times. Therefore, the miscellaneous manufacturing products sector is absent from the DGBAS 1991 Taiwan's I-O tables, and the unknown sector is absent from DGBAS 2006 and 2011 Taiwan's I-O tables. As mentioned above, night marine sectors are all directly segregated from the I-O tables (554 sub-sectors) compiled by DGBAS. But DGBAS only provided the sectoral data on intermediate consumption in the I-O tables (166 major sectors), so some estimates are needed to disaggregate the I-O tables. Under the assumption that the sub-sectors have the same ratio of input structure, we estimate the input of those sectors.

4. Results

4.1 Inter-industry linkages effect

Table 3 presents the backward linkage effects of all sectors in the period of 1991 to 2011. During 1991, the top three sectors with higher backward linkage score are transportation support services (1.5793), domestic cargo transport (1.5567) and petroleum and coal products, and fabricated metal products (1.4764). By 1996, the three leading sectors were petroleum and coal products, and fabricated metal products (1.4726), transportation support services (1.4359) and textile mill products, apparel and leather (1.4225). In 2001, the rankings came in the order of petroleum and coal products, and fabricated metal products (1.5744), domestic cargo transport (1.4917) and general machinery and equipment (1.4632). During 2006, the three leading sectors were transportation support services (3.2879), petroleum and coal products, and fabricated metal products (1.7297), and domestic cargo transport (1.4075). In 2011, the rankings came in the order of transportation support services (3.4829), petroleum and coal products, and fabricated metal products (1.4480) and primary metal products (1.4362).

Table 3: Backward linkage effects

Sectors	1991	1996	2001	2006	2011
Agriculture and forestry	1.0128	1.1144	1.0359	0.8685	0.8285
Mining and quarrying	0.9044	0.8543	0.8640	0.9647	0.8541
Food and kindred products and tobaccos	1.2073	1.2948	1.2020	1.0404	1.0323
Textile mill products, apparel and leather	1.3759	1.4225	1.4074	1.4017	1.2764
Paper and wood products, publishing, and reproduction	1.2017	1.1626	1.1483	1.1056	1.0965
Petroleum and coal products, and fabricated metal products	1.4764	1.4726	1.5744	1.7297	1.4480
Chemicals and allied products	1.1417	1.1009	1.1099	1.2386	1.2563
Nonmetal mineral products	1.2732	1.2555	1.2950	1.3500	1.2104
Primary metal products	1.4106	1.3762	1.3682	1.4043	1.4362
Electronic and other electronic equipment	1.4033	1.3307	1.2945	1.3233	1.3093
General machinery and equipment	1.4169	1.4060	1.4632	1.2708	1.1672
Precision instruments	1.3183	1.3714	1.3879	1.3842	1.3267
Transportation equipment	1.3355	1.3222	1.2468	1.2596	1.2280
Miscellaneous manufacturing products	-	1.3297	1.3230	1.2161	1.1972
Electric and gas services	1.0098	0.9767	0.9635	1.0175	1.0807
Construction	1.2502	1.2070	1.2276	1.1938	1.1663
Wholesale and retail trade	0.7279	0.7362	0.6964	0.5961	0.5760
Transportation and warehousing	0.7806	0.8639	0.9023	0.9039	0.9903
Hotel and restaurant services	0.6885	0.7531	0.7210	0.7884	0.7835
Communications	0.6439	0.6328	0.7354	0.6933	0.6751
Finance and insurance	0.7044	0.6744	0.7159	0.5316	0.5190
Real estate and business services	0.6297	0.6725	0.6037	0.5206	0.5009
Public administration and defense	0.8738	0.8410	0.9386	0.6276	0.6170
Education and health services	0.6904	0.6465	0.6033	0.6158	0.5778

Sectors	1991	1996	2001	2006	2011
Arts, entertainment, and recreation	0.8098	0.8007	0.9184	0.6194	0.6066
Other services	0.7704	0.7611	0.6841	0.6750	0.6589
Unknown	0.9248	1.0972	1.0070	-	-
Aquaculture	0.7503	0.8227	0.6652	0.5131	0.4276
Deep-sea fisheries	0.7630	0.5428	0.6026	0.4510	0.4454
Coastal fisheries	0.6449	0.6687	0.6486	0.4956	0.5526
Shipbuilding	1.1501	1.2393	1.3385	1.2671	1.2291
Ocean contraction	0.4683	0.4822	0.4582	0.3969	0.3726
Passenger transport	0.5740	0.5384	0.4882	0.4444	0.4043
Overseas cargo transport	0.5311	0.5313	0.5039	0.3960	0.9988
Domestic cargo transport	1.5567	1.2619	1.4917	1.4075	1.3583
Transportation support services	1.5793	1.4359	1.4560	3.2879	3.4829

Note: (1) The miscellaneous manufacturing products sector is absent from the DGBAS 1991.
(2)The unknown sector is absent from DGBAS 2006 and 2011.

As mentioned above, the majority of manufacture-based sectors have higher backward linkage effects. Of those higher backward linkage effect sectors, two marine-based sectors, transportation support services and domestic cargo transport, are ranked within the top three sectors with the strongest backward linkages. Secular trend shows that the IBL of transportation support services sector has increased significantly. Transportation support service, including the customs clearance, shipping agency and freight forwarding, and water transportation supporting in port, is considered as an indispensable key sector to foreign trade and shipping service. Specifically, from Table 3, one can see that the three marine sectors, shipbuilding, domestic cargo transport, and transportation support services, have the IBL score greater than one, implying that these three sectors play an important role in terms of input suppliers to other sectors and they could lead other industries to increase the production.

Table 4: Forward linkage effects

Sectors	1991	1996	2001	2006	2011
Agriculture and forestry	1.2183	1.2202	1.0099	0.8421	1.0027
Mining and quarrying	1.4943	1.4436	1.9548	3.2382	2.4375
Food and kindred products and tobaccos	1.1637	1.0848	0.9240	0.8051	1.2384
Textile mill products, apparel and leather	0.9668	0.8877	0.8130	0.6636	0.6325
Paper and wood products, publishing, and reproduction	1.4045	1.2489	1.2510	0.9237	0.8698
Petroleum and coal products, and fabricated metal products	2.9506	2.7644	2.8138	2.8633	5.2171
Chemicals and allied products	1.5817	1.4811	1.7863	2.3159	0.8844
Nonmetal mineral products	1.3639	1.3251	1.2224	1.0184	1.0836
Primary metal products	3.0302	2.7020	2.5555	3.4715	3.6855
Electronic and other electronic equipment	1.1527	1.3567	0.8925	0.8750	0.9958
General machinery and equipment	1.2860	0.9342	1.4386	1.2637	1.2183
Precision instruments	0.6678	0.8824	0.8654	0.7628	0.7570
Transportation equipment	0.7862	0.7993	0.7242	0.6439	0.6615
Miscellaneous manufacturing products	-	0.5834	0.6303	0.4387	0.4346
Electric and gas services	1.3095	1.2287	1.2764	1.3783	1.4228
Construction	0.7616	0.7504	0.7233	0.5973	0.5945
Wholesale and retail trade	1.4810	1.8689	1.6458	2.1724	2.2602
Transportation and warehousing	0.8938	0.9114	0.8972	0.8183	0.9430
Hotel and restaurant services	0.5337	0.4993	0.5081	0.5205	0.6244
Communications	0.6709	0.6556	0.7131	0.6674	0.6484
Finance and insurance	1.6857	1.7478	2.0386	0.9376	0.7870
Real estate and business services	0.7267	0.7764	0.7931	0.5554	0.5274
Public administration and defense	1.2083	1.3154	1.3739	1.3188	1.1600

Sectors	1991	1996	2001	2006	2011
Education and health services	0.5365	0.5536	0.4979	0.4147	0.3615
Arts, entertainment, and recreation	0.5812	0.5722	0.7789	0.3787	0.3671
Other services	0.6147	0.6607	0.8074	0.4596	0.4391
Unknown	0.8832	0.8185	0.9061	-	-
Aquaculture	0.5107	0.5041	0.4816	0.3869	0.3553
Deep-sea fisheries	0.4958	0.4791	0.4537	0.3662	0.3425
Coastal fisheries	0.4875	0.4967	0.4908	0.3843	0.3735
Shipbuilding	0.6641	0.6720	0.6515	0.4708	0.4387
Ocean contraction	0.4679	0.4684	0.4418	0.3580	0.3354
Passenger transport	0.4666	0.4675	0.4409	0.3562	0.3332
Overseas cargo transport	0.4677	0.4675	0.4409	0.3870	0.3593
Domestic cargo transport	0.4692	0.4850	0.4585	0.3652	0.3385
Transportation support services	1.0170	0.8873	0.8551	1.5806	1.5347

Note: (1) The miscellaneous manufacturing products sector is absent from the DGBAS 1991.
(2)The unknown sector is absent from DGBAS 2006 and 2011.

The forward linkage effects of all sectors in the period of 1991 to 2011 are shown in Table 4. From Table 4, one can see that the primary metal products has the highest forward linkage score (3.0302), followed by petroleum and coal products, and fabricated metal products (2.9506) and finance and insurance (1.6857) in 1991. By 1996, the top three industries in terms of IFL were petroleum and coal products, and fabricated metal products (2.7644), primary metal products (2.7020), and wholesale and retail trade (1.8689).The top three in 2001 in terms of IFL were petroleum and coal products, and fabricated metal products (2.8138), primary metal products (2.5555) and finance and insurance (2.0386). In 2006, the top three were in the order of primary metal products (3.4715), mining and quarrying (3.2382) and petroleum and coal products, and fabricated metal products (2.8633). By 2011, the top three industries in terms of IFL were in the order of petroleum and coal products, and fabricated metal products (5.2171), primary metal products (3.6855) and mining and quarrying (2.4375).

In general, the marine-based sectors have weak forward linkages except transportation support services. That means the forward linkages of transportation support services sector is above the average. Besides, secular trend shows that the forward linkages of the majority of Taiwan industries have been on the decline with the times, and so have the marine sectors. However, what is of interest is that only one marine sector, transportation support services, has the IFL score greater than one in the year of 1991, 2006 and 2011. The IFL scores of the other eight marine-based sectors are less than one over the years. It is worth noting that both backward and forward effects of overseas cargo transport have been relatively low, even lower than the effects of domestic cargo transport (especially for the backward linkage effect). At first sight, this seems puzzling, partly due to the phenomenon of flags of convenience. Another point is that the overseas cargo transport sector is a highly internationalized trade across countries. Therefore, in the Input-Output Transactions Table in DGBAS, we see key intermediate inputs of the overseas cargo transport sector, which includes petroleum and coal products, and fabricated metal products, shipbuilding, and transportation support services, while there is a lower demand for the other sectors. In contrast, domestic cargo transport refers to the final consumption by product and intermediate inputs within the domestic market. That the small IFL scores of those marine-based sectors are lower than those of the non-marine sectors reflects the fact that the marine-sector is not influenced much by business fluctuations and is a vital input to national existence. That is, for these marine-based sectors almost all of their goods and services are sold for final consumption.

4.2 Linkages within the marine sector

Table 5 shows the IBL and IFL of the marine sectors over the years and the classification. From Table 5, one can see that the transportation support services is considered as a ‘key sector’ for its $IBL > 1$ and $IFL > 1$ in the year of 1991, 2006 and 2011. And this sector can be placed in the intermediate manufacture classification. In other words, transportation support services is not only the economic artery of marine industry but also the key driving force to Taiwan's economic growth.

Although the output value of shipbuilding and domestic cargo transport sectors are smaller in Taiwan, the IBL of these two sectors are greater than 1 over the years. The domestic cargo transport has higher IBL may be due to that it can be used to transport goods for all industries. The shipbuilding and domestic cargo transport sectors are considered as 'backward linkages oriented sectors' for their $IBL > 1$ and $IFL < 1$, and can be placed in the intermediate primary production classification. That is, these two sectors are not influenced much by other sectors, but have the strong power of dispersion for other sectors.

The other six marine-based sectors, aquaculture, deep-sea fisheries, coastal fisheries, ocean contraction, passenger transport, and overseas cargo transport, with both IBL and IFL are less than one, are considered as 'weak linkages oriented sectors'. That is, these six sectors are not influenced much by other sectors, and has no power of dispersion for other sectors. These six sectors can be placed in the final primary production classification. The IBL of aquaculture and deep-sea fisheries is larger than IFL and on the decline with the times. That may reflect the depletion of fishery resources and Taiwan's deep-sea fisheries is less important now than in the past.

Table 5: Linkage effects of marine sectors

Sectors	Index	1991	1996	2001	2006	2011	classification
Aquaculture	IBL	0.7503	0.8227	0.6652	0.5131	0.4276	Ⅲ
	IFL	0.5107	0.5041	0.4816	0.3869	0.3553	
Deep-sea fisheries	IBL	0.763	0.5428	0.6026	0.451	0.4454	Ⅲ
	IFL	0.4958	0.4791	0.4537	0.3662	0.3425	
Coastal fisheries	IBL	0.6449	0.6687	0.6486	0.4956	0.5526	Ⅲ
	IFL	0.4875	0.4967	0.4908	0.3843	0.3735	
Shipbuilding	IBL	1.1501	1.2393	1.3385	1.2671	1.2291	Ⅳ
	IFL	0.6641	0.672	0.6515	0.4708	0.4387	
Ocean contraction	IBL	0.4683	0.4822	0.4582	0.3969	0.3726	Ⅲ
	IFL	0.4679	0.4684	0.4418	0.358	0.3354	
Passenger transport	IBL	0.574	0.5384	0.4882	0.4444	0.4043	Ⅲ
	IFL	0.4666	0.4675	0.4409	0.3562	0.3332	
Overseas cargo transport	IBL	0.5311	0.5313	0.5039	0.396	0.9988	Ⅲ
	IFL	0.4677	0.4675	0.4409	0.387	0.3593	
Domestic cargo transport	IBL	1.5567	1.2619	1.4917	1.4075	1.3583	Ⅳ
	IFL	0.4692	0.485	0.4585	0.3652	0.3385	
Transportation support services	IBL	1.5793	1.4359	1.456	3.2879	3.4829	Ⅰ、Ⅳ
	IFL	1.017	0.8873	0.8551	1.5806	1.5347	

The coordinate plane placed (1, 1) in the center point with the x-axis and y-axis represent IBL and IFL, respectively. Using the hierarchies of backward and forward linkage, we divide marine sectors into four groups (Ⅰ – Ⅳ) as shown in Table 5. In general, most of marine sectors are in the third quadrant, but transportation support services, shipbuilding, and domestic cargo transport are in the fourth quadrant. It is noteworthy that transportation support services transferred from the fourth quadrant to the first quadrant, implying that this sector not only leads the development of other industries but is also an indispensable sector to other sectors in terms of input suppliers. In other words, it is the key sector crucial to the overall development of the industry. In addition, overseas cargo transport transferred from the third quadrant to on the axle the fourth quadrant, implying that its power of supporting is increasing.

4.3 Production inducing effects of the marine sector

The results of production inducing effects over the years are summarized in Table 6. The top three sectors in 1991 were transportation support services (3.4822), domestic cargo transport (3.4323) and petroleum and coal products, and fabricated metal products (3.2552). In 1996, the top three were in the order of petroleum and coal products, and fabricated metal products (3.1506), transportation support services (3.0719) and textile mill products, apparel and leather (3.0434) The top three sectors in 2001 were petroleum and coal products, and fabricated metal products (3.5588), domestic cargo transport (3.3588) and general machinery and equipment

(3.3062). The transportation support services (9.2309), petroleum and coal products, and fabricated metal products (4.8563), and domestic cargo transport (3.9516) had the highest employment inducing effect in 2006. In 2011, the top three were in the order of transportation support services (10.4551), petroleum and coal products, and fabricated metal products (4.3466) and primary metal products (4.3113). Examining the magnitude of the multipliers for marine industries in more detail, transportation support services is 10.45 in 2011 which is the highest output total effect of 9 marine industries in Taiwan. This implies that $10.45 of the total value of production in all sectors of the Taiwan economy that is necessary in order to satisfy a dollar's worth of final demand for the output of transportation support services.

Of those sectors, two marine sectors, transportation support services and domestic cargo transport, are ranked within the top three sectors with the strongest production inducing effects. This indicates that stimulating investment in the marine sector would positively affect sectors that have the strongest impacts on the Taiwan economy.

Table 6: Production multipliers

Sectors	1991	1996	2001	2006	2011
Agriculture and forestry	2.2330	2.3842	2.3461	2.4384	2.4870
Mining and quarrying	1.9941	1.8277	1.9019	2.7085	2.5639
Food and kindred products and tobaccos	2.6619	2.7702	2.7135	2.9210	3.0987
Textile mill products, apparel and leather	3.0336	3.0434	3.1833	3.9353	3.8317
Paper and wood products, publishing, and reproduction	2.6496	2.4872	2.5957	3.1040	3.2916
Petroleum and coal products, and fabricated metal products	3.2552	3.1506	3.5588	4.8563	4.3466
Chemicals and allied products	2.5172	2.3553	2.4853	3.4774	3.7712
Nonmetal mineral products	2.8073	2.6859	2.9255	3.7902	3.6333
Primary metal products	3.1103	2.9442	3.0961	3.9426	4.3113
Electronic and other electronic equipment	3.0941	2.8469	2.9300	3.7152	3.9303
General machinery and equipment	3.1240	3.0080	3.3062	3.5678	3.5039
Precision instruments	2.9067	2.9339	3.1401	3.8864	3.9826
Transportation equipment	2.9447	2.8288	2.8222	3.5365	3.6863
Miscellaneous manufacturing products	-	2.8447	2.9915	3.4143	3.5937
Electric and gas services	2.2265	2.0895	2.1674	2.8566	3.2440
Construction	2.7564	2.5823	2.7232	3.3516	3.5012
Wholesale and retail trade	1.6049	1.5750	1.5740	1.6735	1.7290
Transportation and warehousing	1.7211	1.8482	1.9928	2.5378	2.9727
Hotel and restaurant services	1.5180	1.6112	1.6294	2.2136	2.3519
Communications	1.4197	1.3537	1.6568	1.9466	2.0267
Finance and insurance	1.5531	1.4428	1.6229	1.4926	1.5579
Real estate and business services	1.3883	1.4388	1.3617	1.4617	1.5035
Public administration and defense	1.9267	1.7993	1.9851	1.7621	1.8523
Education and health services	1.5222	1.3830	1.3665	1.7290	1.7346
Arts, entertainment, and recreation	1.7854	1.7129	2.0792	1.7390	1.8211
Other services	1.6986	1.6284	1.5408	1.8951	1.9779
Unknown	2.0391	2.3473	2.2759	-	-
Aquaculture	1.6543	1.7601	1.5068	1.4405	1.2837
Deep-sea fisheries	1.6824	1.1613	1.3655	1.2661	1.3369
Coastal fisheries	1.4219	1.4305	1.4694	1.3915	1.6588
Shipbuilding	2.5359	2.6513	3.0272	3.5576	3.6894
Ocean contraction	1.0326	1.0316	1.0391	1.1142	1.1185
Passenger transport	1.2656	1.1518	1.1065	1.2476	1.2135
Overseas cargo transport	1.1710	1.1366	1.1425	1.1117	2.9983
Domestic cargo transport	3.4323	2.6997	3.3588	3.9516	4.0774
Transportation support services	3.4822	3.0719	3.2914	9.2309	10.4551

Note: (1) The miscellaneous manufacturing products sector is absent from the DGBAS 1991.
(2) The unknown sector is absent from DGBAS 2006 and 2011.

4.4 Earning inducing effects of the marine sector

The results of earning inducing effects over the years are shown in Table 7. In 1991, the top three sectors in terms of income multipliers were transportation and warehousing (9.0823), transportation support services (8.2434) and food and kindred products and tobaccos (5.5202). In 1996, the top three were in the order of transportation support services (12.6144), domestic cargo transport (5.8089) and food and kindred products and tobaccos (5.6219). The top three in 2001 were domestic cargo transport (11.3842), petroleum and coal products, and fabricated metal products (6.9755) and transportation support services (6.8645). By 2006, the transportation support services has the highest income multipliers score (24.2964) , followed by overseas cargo transport (18.8293) and petroleum and coal products, and fabricated metal products (11.8492). The top three sectors in 2011 were transportation support services (17.3693), petroleum and coal products, and fabricated metal products (15.9771) and primary metal products (6.2949).

Of those sectors, three marine sectors, transportation support services, domestic cargo transport and overseas cargo transport, are ranked within the top three sectors with the strongest earning inducing effects. This indicates that stimulating investment in the marine sector would positively affect sectors that have the strongest impacts on the Taiwan economy.

Table 7: Earning multipliers

Sectors	1991	1996	2001	2006	2011
Agriculture and forestry	1.9059	0.6156	0.6441	2.0400	2.0913
Mining and quarrying	1.6361	1.5194	1.6199	2.6596	2.1220
Food and kindred products and tobaccos	5.5202	5.6219	4.8941	4.8093	5.5986
Textile mill products, apparel and leather	3.1008	3.4383	3.4133	3.8205	3.6521
Paper and wood products, publishing, and reproduction	2.7076	2.6096	2.6358	3.1518	3.3165
Petroleum and coal products, and fabricated metal products	4.7293	4.8615	6.9755	11.8492	15.9771
Chemicals and allied products	4.4107	4.9381	5.3891	9.4814	3.9358
Nonmetal mineral products	2.7787	2.8287	2.9818	3.7337	3.7102
Primary metal products	3.7971	3.8249	4.0585	5.0986	6.2949
Electronic and other electronic equipment	3.3876	3.8546	3.0862	3.9855	4.2001
General machinery and equipment	3.5166	3.6378	5.0576	5.6117	5.4906
Precision instruments	2.7246	3.5317	3.5885	4.6824	5.1787
Transportation equipment	3.7120	4.1186	3.3426	4.6885	4.7255
Miscellaneous manufacturing products	-	2.9551	2.9729	2.9337	2.9191
Electric and gas services	2.9349	2.9119	3.3282	3.1175	3.8546
Construction	2.4029	2.4130	2.5570	2.8103	2.7551
Wholesale and retail trade	1.3394	1.3652	1.3251	1.3897	1.3923
Transportation and warehousing	9.0823	1.5214	1.5704	2.0997	2.1110
Hotel and restaurant services	2.1666	1.2799	1.2874	1.6979	1.6802
Communications	1.2922	1.3174	1.8056	1.9438	1.8885
Finance and insurance	1.4926	1.4033	1.6014	1.4412	1.4449
Real estate and business services	1.8826	3.8509	2.8203	4.1017	3.6622
Public administration and defense	1.4267	1.4138	1.7223	1.3300	1.3440
Education and health services	1.1660	1.1343	1.1154	1.2134	1.2108
Arts, entertainment, and recreation	1.5960	1.5616	1.8019	1.4207	1.3565
Other services	1.2731	1.2665	1.2163	1.3236	1.3316
Unknown	4.0647	4.1294	6.1277	-	-
Aquaculture	1.2196	1.2658	1.1928	1.3510	1.1004

Sectors	1991	1996	2001	2006	2011
Deep-sea fisheries	1.3304	1.0937	1.5316	1.2848	1.2122
Coastal fisheries	1.1179	1.1387	1.1739	1.2050	1.1955
Shipbuilding	1.5235	2.2138	1.5540	1.6572	2.7672
Ocean contraction	1.0258	1.0187	2.5838	2.2177	0.0930
Passenger transport	1.0977	1.0657	1.0334	0.0876	0.1680
Overseas cargo transport	1.0968	1.4058	1.0548	18.8293	4.2562
Domestic cargo transport	1.5535	5.8089	11.3842	6.3046	0.1314
Transportation support services	8.2434	12.6144	6.8645	24.2964	17.3693

Note: (1) The miscellaneous manufacturing products sector is absent from the DGBAS 1991.
(2) The unknown sector is absent from DGBAS 2006 and 2011.

4.5 Employment inducing effects of the marine sector

In employment multipliers analysis, the results of employment effects of the marine sector over the years are summarized in Table 8. Food and kindred products and tobaccos (9.7402), precision instruments (8.1987) and general machinery and equipment (6.5904) were the top three sectors with the highest employment inducing effects in 1991. By 1996, the top three sectors in terms of employment multipliers were domestic cargo transport (9.7981), food and kindred products and tobaccos (8.5680), and precision instruments (8.3672).The top three in 2001 in terms of employment multipliers were domestic cargo transport (18.4882), general machinery and equipment (6.4579) and food and kindred products and tobaccos (6.3189). In 2006, the top three were in the order of domestic cargo transport (16.4173), precision instruments (11.1750) and petroleum and coal products, and fabricated metal products (10.2155). The petroleum and coal products, and fabricated metal products (17.3249), overseas cargo transport (15.8751), and general machinery and equipment (7.7283) had the highest employment inducing effects in 2011.

Table 8: Employment multipliers

Sectors	1991	1996	2001	2006	2011
Agriculture and forestry	1.5051	1.6157	1.5846	1.7027	1.7071
Mining and quarrying	2.9913	2.4188	3.5763	7.8457	4.1768
Food and kindred products and tobaccos	9.7402	8.5680	6.3189	5.3950	5.2054
Textile mill products, apparel and leather	3.5999	2.9664	2.7664	3.0998	2.6802
Paper and wood products, publishing, and reproduction	2.9851	2.3372	2.4403	2.8126	2.5699
Petroleum and coal products, and fabricated metal products	4.7546	4.6385	5.5974	10.215	17.325
Chemicals and allied products	3.9885	3.5762	4.1586	9.4732	3.1826
Nonmetal mineral products	2.5241	2.1946	2.2439	2.8883	2.6484
Primary metal products	3.2910	3.0780	3.3030	4.5939	4.6873
Electronic and other electronic equipment	2.2766	2.2928	1.6645	1.8659	1.8987
General machinery and equipment	6.5904	6.4964	6.4579	9.3738	7.7283
Precision instruments	8.1987	8.3672	6.2692	11.175	6.4205
Transportation equipment	3.8329	3.5819	3.0681	3.9577	3.6512
Miscellaneous manufacturing products	-	2.6749	3.0825	3.2494	1.9408
Electric and gas services	4.0511	3.5697	3.8575	5.6357	7.3471
Construction	2.2353	2.2696	2.2029	2.9197	2.3829
Wholesale and retail trade	1.1992	1.2066	1.2037	1.4881	1.3487
Transportation and warehousing	1.5653	1.5602	1.6419	1.1836	2.1633
Hotel and restaurant services	1.9317	1.2043	1.2216	1.6335	1.5821
Communications	1.5331	1.4303	2.1231	3.8397	2.0218
Finance and insurance	1.4717	1.3914	1.6573	1.5564	1.4676
Real estate and business services	1.3676	3.1608	2.8171	3.3785	2.7224
Public administration and defense	3.3881	3.0674	2.0450	2.1133	1.8450

Sectors	1991	1996	2001	2006	2011
Education and health services	1.3905	1.3477	1.3613	1.4179	1.4455
Arts, entertainment, and recreation	1.3619	1.3383	1.8909	1.4365	1.4951
Other services	1.9708	2.1507	2.7071	2.0501	1.8526
Unknown	1.7462	1.8405	1.9732	-	-
Aquaculture	1.4326	1.3483	1.1901	1.0990	1.1056
Deep-sea fisheries	1.4890	1.1462	1.4320	1.0833	1.3397
Coastal fisheries	1.1012	1.1058	1.1263	1.1996	1.1235
Shipbuilding	2.6296	2.2444	2.6017	3.5818	4.0768
Ocean contraction	1.0854	1.0697	1.0728	1.3451	1.0610
Passenger transport	1.1281	1.0649	1.0539	1.2374	1.3361
Overseas cargo transport	1.4892	1.5476	1.8053	1.2564	15.8751
Domestic cargo transport	3.2491	9.7981	18.4882	16.4173	6.5034
Transportation support services	2.5429	2.4074	2.4143	7.2000	5.9419

Note: (1) The miscellaneous manufacturing products sector is absent from the DGBAS 1991.
(2) The unknown sector is absent from DGBAS 2006 and 2011.

Of those sectors, two marine sectors, domestic cargo transport and overseas cargo transport, had the highest employment inducing effect and were the first highest sector across the whole economy in the period of 1996 to 2011. This indicates that the marine sector has the greatest impacts with the Taiwan service sectors.

5 Conclusions

Economically, Taiwan depends heavily upon international trade. The analysis explores the economic development trend of Taiwan's marine industry, utilizing data over the years to analyze the changing trends in the industry year on year. It indicates that Taiwan's marine industry has become a rather mature sector in the overall economy with its steady development over the years. In order to examine the role of the Taiwan marine sector in the national economy, this paper employs an I-O methodology to the marine sector over the period of 1991 to 2011.

First, our study found that the marine industries have a higher backward linkage effect and a lower forward linkage effect. From a viewpoint of dynamic, one can see that the transportation support service is considered as a key sector. Secular trend shows that the importance of transportation support services sector has increased significantly. Transportation support service, including the customs clearance, shipping agency and freight forwarding, and water transportation supporting in port, is considered as an indispensable key sector to foreign trade and shipping service. The shipbuilding and domestic cargo transportation sectors are considered as backward linkages oriented sectors. It is noteworthy that the overseas cargo transportation has the potential to be a backward linkage oriented sector because its output value is the largest compared to the other marine sectors. But, relative to data limited, its importance of inter-industry linkage effect is limited. The fishery related sectors, such that as aquaculture, deep-sea fisheries and coastal fisheries, are considered as weak linkages oriented sectors and their importance of inter-industry linkage effect are on the decline with the times.

Next, our study also represents production multipliers, earning effects and employment multipliers in the marine sectors. It shows that employment multipliers have the greatest impact on the Taiwan economy. As a whole, transportation support services, domestic cargo transport and overseas cargo transport, with the strongest earning inducing effects and employment inducing effects, have the greatest impacts on Taiwan's economy. The effects of other marine-based sectors are smaller and less than the average of Taiwan's overall industry.

Finally, there is a stream of literature on the relationship between marine sectors and national economy for the Irish and Korea, that is, to a certain degree are lightly related to our study. Our analysis found that the marine sectors have a lower forward linkage effect and a higher backward linkage effect. In this line of research, the results are consistent with the analysis conducted by Morrissey and O'Donoghue (2013) and Kwak et al. (2005). We also found something that has not been documented before and that is unique to this study. Specifically, the overseas cargo transport sector is a highly internationalized trade in both of the production and consumption ends. Therefore, the overseas cargo transport sector has relatively lower linkages with other industrial sectors in Taiwan. Hence, we divided the water cargo transport sector into the overseas and domestic cargo transport sub-sectors. Hopefully, this can better elucidate on the separate roles each sub-sector plays in the domestic industrial linkages, and provide an analysis that will be valuable for the country's policy makers.

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