



International Forum on Shipping, Ports and Airports (IFSPA) 2012

Transport Logistics for Sustainable Growth at a New Level



Conference Proceedings

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Hong Kong



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Proceedings of the
International Forum on Shipping, Ports and Airports
(IFSPA) 2012

Transport Logistics for Sustainable Growth at a New Level

27 - 30 May 2012

Hong Kong, China

Edited By:

Tsz Leung Yip

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Adolf K.Y. Ng

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The "**International Forum on Shipping, Ports and Airports**" (IFSPA) is an annual international conference jointly organized by the Department of Logistics and Maritime Studies and the C.Y. Tung International Centre for 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 event also serves as a good platform for networking and promoting academic-industry collaboration. It has established itself into a large-scale, globally reputed international conference.

The roots of IFSPA can be dated back to 2006, starting as a workshop to bring together researchers in the fields of maritime and aviation studies with the objective to promote high-quality research papers. The IFSPA had since evolved into one of the world's premier conferences in maritime, transport and logistics research. It has provided an important platform for exchanging ideas among academics and practitioners in the fields of aviation studies, maritime studies, port management, supply chain management, and transport logistics.

Preface

The Fifth International Forum on Shipping, Ports and Airports (IFSPA 2012) was successfully held from 27 to 30 May 2012, in Hong Kong, China. IFSPA 2012 has received over 110 submissions and this proceedings contains a collection of 55 papers presented at the Conference. The topics covered include shipping economics, port strategy, airport management, logistics development in Asia, environmental issues in logistics, port efficiency and competition, and maritime safety and security.

In the midst of growing environmental concerns, this conference theme, "**Transport Logistics for Sustainable Growth at a New Level**", drives research agenda to develop innovative research and create added value to meet the emerging needs for environmental-friendly transport logistics. Industry-wide initiatives are formulated to enhance sustainable growth of society, making the industry as climate-friendly and resource-efficient as possible.

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, further advancing 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 glad that the event has secured massive support from local governmental agencies and institutions on its coordination and implementation. Conference participants now include the world's leading maritime and aviation experts and professionals.

Hong Kong is an important and leading international logistics and transportation hub, with growing connections to the Chinese mainland with a number of logistics centres and parks recently established to support the rapid growth of manufacturing and services industries.

The Conference gratefully acknowledges the supports from the Hong Kong Marine Department, Hong Kong Shipowners Association (HKSOA), the Chartered Institute of Logistics and Transport in Hong Kong (CILT-HK), International Association of Maritime Economists (IAME), Orient Overseas Container Line (OOCL) and House of Innovation, Logistics Research Centre and Shipping Research Centre of The Hong Kong Polytechnic University.

The IFSPA 2012 Organizing Committee greatly appreciates the invaluable contribution from the invited speakers, paper authors and paper reviewers.

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

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The Research on Relationship between China's Hub Airport Traffic and Delay based on Queue Theory

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Abstract

The paper uses the queue theory to analyse the relationship between the number of flights and delay. The nonlinear relation is concluded and demonstrated, which means that the delay time will increase dramatically when inbound and outbound flights is near to the theoretical capacity of airport, and meanwhile the distribution of delay is hard to determined. Finally, the paper verifies the relationship by simulation tool, real situation and queue theory.

Keywords: Capacity, Delay, Airport, Queue theory

1. Introduction

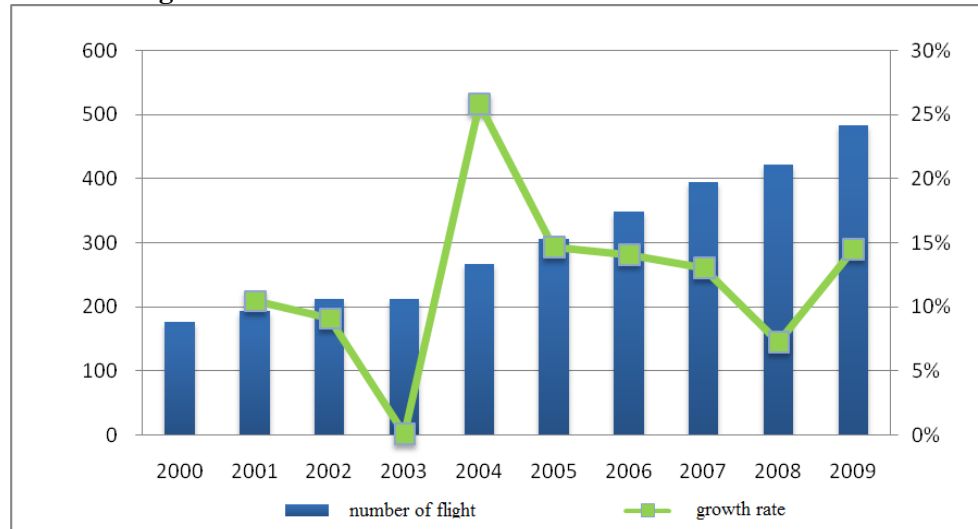
With the rapid development of China air transportation, the delay time of flights at the large- and middle-hub airports increases quickly. According to public data, the number of flight in China of 2000 is only 1.75 million, the recent data has reached 4.84 million flights by 2009, the annual average increasing rate is almost 10.7%.

At the other hand, the delay of flight also increases rapidly. According to statistical data, the number of delayed flight expands from 152183 in 2000 to 317411 in 2009, the average annual growth rate is 7.63%. The delay time grows sharply, too. The total delay time of flights in 2009 is nearly 350 thousands hours, if all the flights in 2009 are considered; the average delay time per flight is 11.9 minutes. If only the delayed flights are considered, the average delay time per flight reaches to 65.4 minutes. The quality of customer service also cannot improve under the situation, so the delay of flight has not only been concerned by airport, air traffic controller and airlines, but also by the society and government.

A lot of reasons can cause the flight delay, but the basic principle is that the capacity provided by air traffic management and airports is below the demand of air traffic. But the relation between the delay time and the demand of flight is still unknown. With the rapid growth of fleet of china in the future, the passenger by air transportation will keep a high annual growth rate 11% in the following 5 years according to prediction by CAAC. But how about the delay will be is concerned with the high growth of passenger.

The paper will discuss the problem by using queue theory. Firstly, the structure will be proposed, then the relation between the delay and the number of flight will be analyzed by comparing theory and practical delay time, finally, TAAM simulation tool will be used to verify the result.

Figure 1: The Flights from 2000 to 2009 Statistical Data on Civil Aviation of China (2011)



2. Structure Of Analysis

2.1 Analysing Tools for Airport Capacity And Delay

A lot of tools are developed to analyze relation between capacity and delay since 1960s (Odoni, 1997 and Hu, 2010).

2.1.1 LMI Runway Capacity Model

LMI is a common stochastic model to analyze the capacity of runway system. The idea comes from the capacity and delay model proposed by David (1998). LMI model mainly uses 4 points in the capacity curve of runway at the airport to calculate maximum capacity envelope curve by considering every possibility of arriving and departing proportion.

The core character of LMI model is the stochastic process. For example, the flight speed, the occupation time of runway and the communication time between air traffic controller and pilot are seen as the random variables in the model. Another feature is the viewpoint of controller; the result is the capacity of real operations at the runway under the 95% confidence level. The disadvantage of the method is that it can only be applied for single runway airport.

2.1.2 FAA Airfield Capacity Model

FAA airfield capacity model is a method to calculate the capacity of runway which is usually called as maximum airport capacity. The method can evaluate peak hour capacity from single to multiple runways on the basis of different runway's layout and operation pattern. There are many extensive tools based on FAA airfield capacity model. The hybrid method can be used to estimate more complex runway and airport system. On the whole, the method is a useful tool in the field of airport capacity and can calculate the sensibility of different variables, such as the number of runway, aircraft mix, and ATC separation requirements.

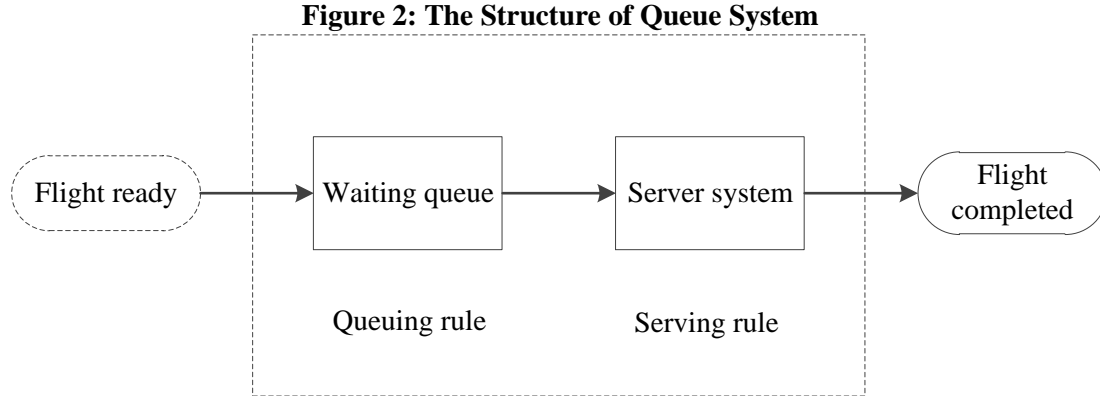
2.1.3 TAAM

TAAM (Total Airspace & Airport Modeler) is a large scale detailed fast-time simulation package for modeling entire air traffic systems. TAAM can be used to analyze the project feasibility, simulate most function of air traffic management and produce real scene demonstration. The most fame is the precise simulation of gate to gate.

TAAM also provides an interactive figure tool to demonstrate simulation result of airport by 2D or 3D. The simulation can be terminated easily and the operation rules, such as conflict solving and resource distribution can also be modified when simulation is under process. The package is a full function tool to analyze relation between airport capacity and delay of flights.

2.2 Queue Theory

Queue theory is the science to analyze queue length, especially those under influence of random factors, such as single server, multi-servers and network. In the field of airport capacity and delay, when there is a runway at the airport, the flights ready to take off and land in can be seen as single server system. The structure of the system can be described in Figure 2.



There are 3 parts in the system: input process, queuing rule and server system. Input is used to describe the flight's pattern to landing in or take off. The airport system can be seen as a waiting system and the serving rule here is presumed to be first come first serve. The randomness of system is reflected by the stochastic ready flight.

2.2.1 Average Arrival Rate of Flight

From the viewpoint of scheduling theory, the arrival time of flight is uncertain, the flight may be influenced by some other uncontrollable reasons, the arrival of flight is random. Here poisson distribution is supposed to describe the flight which satisfy the requirement, such as unfollow-up effect, the arrival is independent on little time. The main parameter of passion distribution is the average arrival rate which is defined as λ . The method to calculate λ is to analyze and estimate the real flight flow, such as flight timetable, for the inbound flight, the object is landing-in time, for the outbound flight, the object is take-off time.

2.2.2 Number of Server

The server number in the paper is defined as the number of runway, because it is unusual that the apron is the neck bottle of the system in most airports. The runway and taxiway is usually the core factor to slow the system's operation.

2.2.3 Average Service Rate

Because the randomness of flight, the service rate can been regarded as negative exponential distribution, which is described by average service rate parameter μ . The methods to determine μ consist of runway capacity calculated by FAA airfield capacity model or TAAM software.

2.2.4 Output

From a queue system, the most concerned index of output is queue length which is the average flight number

in the whole queue, waiting length which is the average number of waiting flight ready to get service, waiting time which is the average waiting time of flight, and dwell time of flight which is the average service time of flight. The delay of flight is represented by waiting time.

Based on the character of single runway airport and flight operation, the whole airport can be modeled as:

- ✓ one server because of one runway;
- ✓ the flight ready to land-in or take-off comes to the queue on the average arrival rate λ as poisson distribution;
- ✓ when server is busy, the ready flight will be waiting in the sky;
- ✓ the time interval between consecutive two flights and the service time are both negative exponential distribution and average service rate is μ .

$$\text{queue length } L_s = \frac{\lambda}{\mu - \lambda} \quad (1)$$

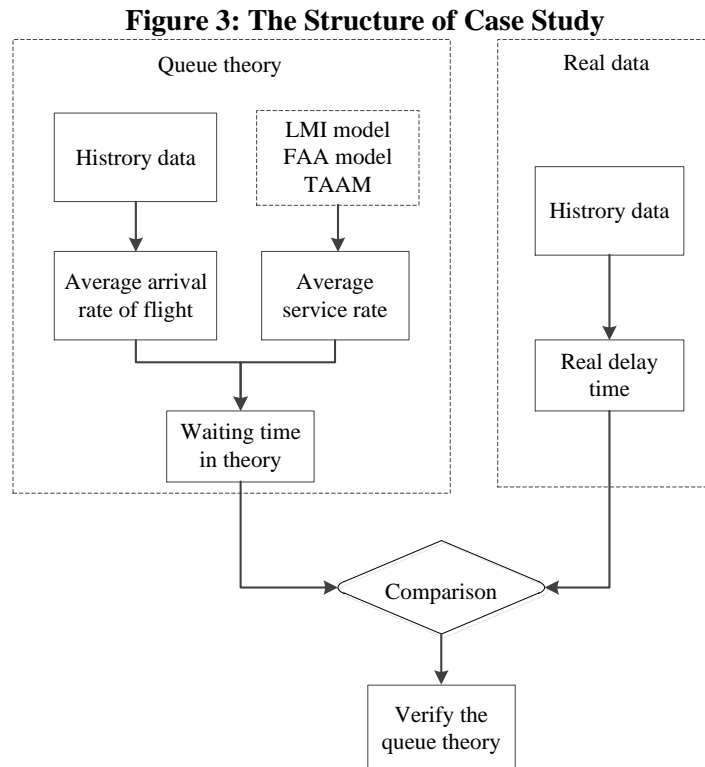
$$\text{waiting length } L_q = \frac{\lambda^2}{\mu(\mu - \lambda)} \quad (2)$$

$$\text{waiting time } W_q = \frac{\lambda}{\mu(\mu - \lambda)} \quad (3)$$

$$\text{dwell time } W_s = \frac{1}{\mu - \lambda} \quad (4)$$

3. Case Study

Airport D will be studied as a case to verify the queue theory and other simulation tools. The airport has one runway and now links with 13 countries and 89 cities. In 2010, the number of passenger has reached 10 million and the number of flight is more than 100000. From volume of airport's throughput, airport D is a typical local hub airport in China. The structure of case study is described in Figure 3.



3.1 Average Service Rate at Airport D

In order to calculate the gap between the theory and practice, the FAA method is used here:

$$C^*(DA) = C_A(DA) + C_D(DA) = \left\{ \frac{1}{\sum_{i=1}^n \sum_{j=1}^n p_{ij}(T_{ij} + S_{ij})} \right\} \times [W + \sum_{i=1}^n \sum_{j=1}^n p_{ij}(k_{ij\max} + G)] \quad (5)$$

Where

$C^*(DA)$ is the capacity of runway when arrival and departure of flight is combined;

$C_A(DA)$ is the number of arrival flight;

$C_D(DA)$ is the number of departure flight;

$T_{ij} + S_{ij}$ is the interval matrix of flight;

p_{ij} is the safe space between the sequential flights, the head is i and the following is j ;

$K_{ij\max}$ is the maximal flights between the sequential flights;

G is the ratio of departure and arrival flight, when a departure flight is inserted after an arrival flight, $G=1$,

When two departure flights are inserted after an arrival flight, $G=2$, etc.

W is the ratio of arrival and departure flight, the similar definition as G .

According to formula (5) and practical parameter at airport D, the theoretical result shows that the capacity of the airport is 30 flights, which means the airport can reach the maximal 30 flights of arrival and departure flight in one hour, so here $\mu=30$ flights/hour.

3.2 Average Arrival Rate of Flight At Airport D

By analysing the history data at airport D, the average flight in one hour is between 22 and 24 in the busy period, such as from July to October, and sometimes the flights in one hour can reach 30, but the number is out of consideration in the paper because it is the extraordinary phenomenon. In fact, according to statistical data, from July to August, the average flight more than 22.7 is over 50% at the peak time, so the average arrival rate of flight here is 22.7 flights/hour, so here $\lambda=22.7$.

3.3 Waiting Time in Theory

According to formula (3), the waiting time in theory

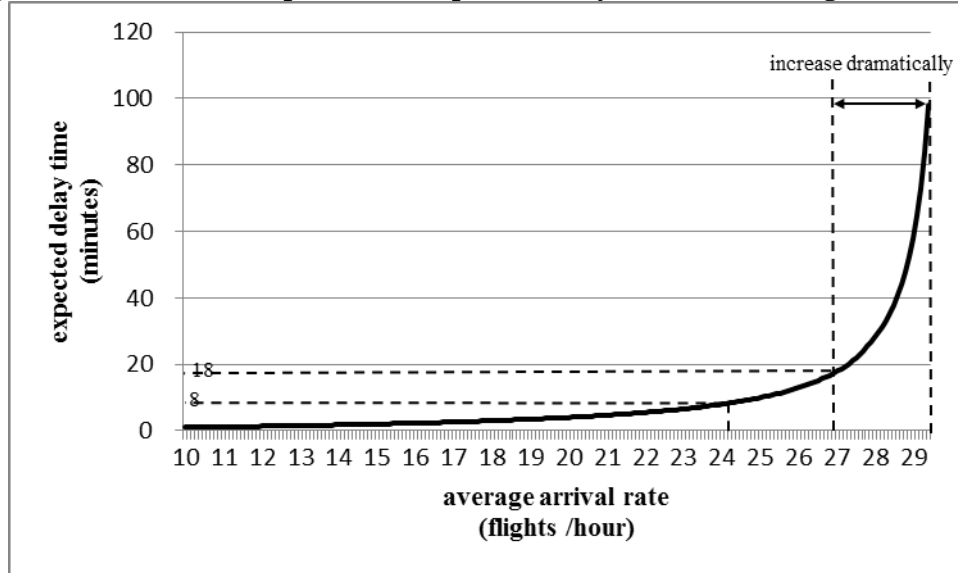
$$W_q = \frac{\lambda}{\mu(\mu - \lambda)} = \frac{22.7}{30 \times (30 - 22.7)} = 6.2 \text{ minutes}.$$

Here the delay time is presented as the time interval between the real arrival or departure time and ticket time. In the condition of busy day, normal weather and labour, the real delay time at airport D is 12 minutes on the average by analysing the history data. From the experience from other busy airports, the delay at airport D is not very serious, but it still has the aim to improvement: the delay time can promote from 12 to 6.2 minutes in theory and the airport efficiency will promote nearly 1/2.

3.4 Dynamic Analyses

In fact, if the average service rate at airport is determined, the expected delay time will be calculated too by formula (3), and the Figure 4 shows the result of example. The case demonstrates the relationship between the delay time and average arrival rate is nonlinear. At the beginning of curve, the expected delay time increases slowly, when the arrival rate is 24 flights per hour, the expected delay is 8 minutes; when arrival rate is 27 flights per hour, the expected delay is 18 minutes, which is still acceptable, but from this point, the following delay time increase dynamically, so the conclusion can be drawn that the delay will be increase rapidly after some limitation of arrival flights.

Figure 4: The Relationship between Expected Delay Time and Average Arrival Rate



The simulation tool TAAM is used to simulate the situation under the condition of airport's layout, safe separation and flight procedure, the flights all the day is 326 flights in airport D, the peak hour is from 11:00 to 14:00. Table 1 demonstrates the result by simulation, real data and queue theory. Based on 326 flights per day, the flight is increased by 10%, 20% and 25%, the result shows that the airport still has the necessity to promote performance.

Table 1: Result of Simulation, Real Data and Queue Theory

Flights all the day	Flights per peak hour	Average delay time by TAAM (minutes)	Average delay time by real data (minutes)	Average delay time by queue theory (minutes)
326	22.7	17.4	12	6.2
+10%(356)	26	18.2		13
+20%(386)	27.3	24.9		20.2
+25%(399)	27.6	33.7		23

3.5 Promotion Advice

From the analysis of the relationship between flights and delay time, the conclusion and suggestion are proposed.

Firstly, the runway cannot be kept at the high level of utilization for long time; otherwise, the longtime delay will occur frequently.

Secondly, when the runway is at the high utilization condition, the airport system will become unstable. Flight delay time will change dramatically due to any minor unexpected factors, if some urgent situations happen, the whole airport system will be in chaos.

Finally, if the runway's capacity is near to saturation, the delay of flight will tend to more changeable, and this will influences heavily on evaluation and measurement of airport and airline's service.

4. Conclusion

The delay of flights at the hub airport in China increases quickly in recent decade, and the air transportation service quality has caused some social criticism. Queue theory is used to analyse the relationship between

number of flights and delay time in the paper. The nonlinear of the relationship is supposed and demonstrated by queue theory. In fact, the delay time will increase dramatically when flights are near to maximal capacity of the airport. Then some suggestions are provided according to the result and conclusion. Finally, the conclusion of the relation between the flights and delay is verified by simulation tool, real data and queue theory.

Acknowledgements

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The DEA Application to Evaluate the Airports in China

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Abstract

The traditional method to evaluate the efficiency of airports in China is usually the volume of transportation and some productivity ratios, which are more concerned about exterior performance without considering the internal operation or management issue. In order to overcome the weakness, data envelopment analysis is used to evaluate the efficiency of some large airports in China, the input data consists of the index of local population, economy, the construction and configuration of airports. The output is the quantity of transportation. The result of the method can be used to evaluate the overall performance of airports to complement the traditional methods.

Keywords: Data envelopment analysis, Airport efficiency

1. Introduction

In China, air transportation is developing dramatically and the country has been the second air passenger and cargo freight country just behind USA on the basis of traffic volume since 2010. In the system of air transportation, the airport is a very important part because all other components including airplanes, passengers all reach and depart from it, so the evaluation of airport has begun to be accepted as an important issue in aviation industry recently. In China, most airports are enterprises owned by either local government or state company, so the concern of investment and funding's efficiency is urgent. The traditional method to evaluate the airport is the quantity of passenger and cargo, which is easy to calculate but will cover some problems, especially internal performance. For example, the number of passenger at a small airport maybe less than some airports, but its management efficiency still has the possibility and chance to exceed those big airports.

The paper will use Data Envelopment Analysis (DEA) method to evaluate the airports. The reason is described as: the data is easy to get and all the airports can be ranked by a common pattern of weight no matter which one's huge or small volume; the method proves to be robust and suitable to compare efficiency and performance of system hard to describe and calculate itself mathematically.

There are a lot of applications of the evaluation of airports by DEA. Juan and Concepcio (2001) apply DEA to analyse the technical efficiency and performance of each individual Spanish airport and discuss the result of privatization policy. The capacity of 35 Brazilian domestic airports are analysed by DEA method to determine which of them are efficient in terms of the number of passenger processed. The method is used to reflect

which of airport used airport resources efficiently (Elto and Pacheco, 2002). Yuichiro and Hiroyoshi (2004) employ DEA and endogenous-weight TFP to evaluate the efficiency of regional airports in mainland Japan and reply the criticism of inefficient public investment. Sergio and Tomas (2010) finished the evolution of productive efficiency in the Latin America Region based on a unique dataset by DEA. Many factors are considered in the paper, such as institutional variables, the socioeconomic environment and airport characteristics. The EDA's advantage is shown to be appropriate to the evaluation of airport. Wang et al. (2011) also use DEA to analyse the data of year 2009 and rank the technical efficiency and performance of big 20 airports in China, but there are no economic indicators to be considered, the paper will improve the structure of input data in 2010 and then compare the efficiency between two years.

2. DEA Model

DEA is proposed by Charnes and Cooper (1978) firstly which is a systemic evaluation method based on the concept of relative efficiency. The most important aim is to draw conclusion to evaluate the efficiency and performance of the organization according to similar input and output data.

The common method of DEA is C²R model which is also supposed here (Wang, 2011). There are n DMU_j ($j=1, 2, \dots, n$), and the input and output data are

$$x_j = (x_{1j}, x_{2j}, \dots, x_{mj})^T > 0, j = 1, 2, \dots, n$$

$$y_j = (y_1, y_{2j}, \dots, y_{mj})^T > 0, j = 1, 2, \dots, n$$

To evaluate the DMU_j , firstly normalize the input and output data, set the weight:

$$v = (v_1, v_2, \dots, v_m)^T$$

$$u = (u_1, u_2, \dots, u_n)^T$$

Calculate $h_j = \frac{u^T y_j}{v^T x_j} = \frac{\sum_{k=1}^s u_k y_{kj}}{\sum_{i=1}^m v_i x_{ij}}$ as the efficiency evaluation target of j th decision making unit DMU_j . For evaluating the DMU_j , the C²R model is finished.

$$\bar{v}_p = \max \frac{\sum_{k=1}^s u_k y_{kj0}}{\sum_{i=1}^m v_i x_{ij0}}$$

$$(\bar{p}) \dots \text{ s.t. } \begin{cases} \frac{\sum_{k=1}^s u_k y_{kj}}{\sum_{i=1}^m v_i x_{ij}} \leq 1, & j = 1, 2, \dots, n \\ u_k \geq 0 & k = 1, 2, \dots, s \\ v_i \geq 0 & i = 1, 2, \dots, m \end{cases}$$

The meaning is that: some u and v can be selected to make $h_j \leq 1$, for DMU_{j0} , the large h_{j0} shows DMU_{j0} can generate more output when less input is provided.

The advantage of DEA model includes: the dimensionality is not the problem when every unit use the same index; no weight need to be pre-determined, so the result is more objective. The disadvantage of DEA is that the result is only relative efficiency, and still cannot replace the traditional ratio method.

3. Data and Results

It's very important to choose the data in DEA method, there are two types of data: input and output. The input data is the basic input to the system which must be the same definition to all the units. The output data is the production or service from decision making unit. Here, the data about the airports are provided.

3.1. Input Data

In the paper, input data composed of the number of the runway which is the most essential infrastructure, the

local population which can provide the source of passenger, the GDP which can determine the demand of local air transportation, GDP per capita which has the same meaning of GDP, and passengers' average purchasing ability. These data are the accessible resources to produce the output.

Table 1: Input Data of Airport in 2010

Airports	Number of runway	Population (10 thousand)	GDP (1000 RMB)	GDP per capita (RMB)
Beijing	3	1245.83	121530000	70452
Guangzhou	2	651.59	91382135	89082
Shanghai Pudong*	3	1400.7	150464500	78989
Shanghai Hongqiao*	2	1400.7	150464500	78989
Shenzhen	1	245.96	82013176	92772
Chengdu	2	1139.63	45026032	35215
Kunming	1	533.99	18086467	25826
Xi'an	1	781.67	27240800	32411
Hangzhou	1	683.38	50875530	63333
Chongqing	2	3275.61	65300100	22920
Xiamen	1	177	17372349	68938
Changsha	1	651.59	37447641	56620
Nanjing	1	629.77	42302608	67455
Wuhan	1	835.55	46208600	51144
Qingdao	1	762.92	48538672	57251
Dalian	1	584.8	43495050	70781
Sanya	1	55.71	1733198	35750
Wulumuqi	1	241.19	10945200	38496
Haikou	1	158.24	4895519	26366
Zhengzhou	1	731.47	33085053	44231

Source: Urban Statistical Yearbook of China (2011)

*Shanghai has two top 20 airports in China, the data of local population and economy data is hard to be divided into precise and corresponding airport's proportion, so two airports will be combined as one virtual airport in the result of calculation: Shanghai airport.

3.2. Output Data

Output data are used to reflect the performance and easy to get commonly and coincidentally. The output here is comprised of number of passengers, tons of cargo and all traffic movement. The number of passenger is counted when a passenger arrives or departs by commercial flight, including the transit passenger, the tons of cargo is the quantity of goods transported via the airport. All traffic movement is the sum of passenger and cargo flights.

Table 2: Output Data of Airport in 2010

Airports	Passenger	Cargo	Movement
Beijing	73948114	1551472	517585
Guangzhou	40975673	1144456	329214
Shanghai Pudong	40578621	3228081	332126
Shanghai Hongqiao	31298812	480438	218985
Shenzhen	26713610	809125	216897
Chengdu	25805815	432153	205537
Kunming	20192243	273651	181466
Xi'an	18010405	158054	164430
Hangzhou	17068585	283427	146289
Chongqing	15802334	195687	145705

Xiamen	13206217	245644	116659
Changsha	12621333	108635	115635
Nanjing	12530515	234359	116087
Wuhan	11646789	110191	112521
Qingdao	11101176	163749	103975
Dalian	10703640	140554	91628
Sanya	9293959	45256	70575
Wulumuqi	9148329	95124	86491
Haikou	8773771	91667	73824
Zhengzhou	8707873	85798	84180

Source: Statistical Data on Civil Aviation of China (2011)

3.3. Result

Calculate the data of 20 top airports in china in 2010 by C²R model, the result is shown in Figure 1. According to the score, 8 airports are ranked as the first group because the score is between 0.9 and 1: Beijing, Shanghai, Shenzhen, Kunming, Xiamen, Sanya, Guangzhou and Haikou; 7 airports are ranked as the second group because the score is between 0.6 and 0.9: Xi'an, Chongqing, Chengdu, Wulumuqi, Hangzhou, Changsha and Nanjing; 4 airports are ranked as the third group because the score is less than 0.6: Wuhan, Qingdao, Dalian, Zhengzhou.

In the first group, the rank of Beijing ,Shanghai, Guangzhou and Shenzhen's score is consist with the GDP, but the Kuming, Xiamen, Sanya, and Haikou's GDP is not very powerful, and the most possibility is that these cities are the most popular travelling destination, so the prosperous passenger transportation does not have much relationship with local economy. Especially the Sanya and Haikou which are both in the same southern island of China have the same situation, the conclusion is more convincing.

In the second group, the rank of these cities is more correlative to the local population and GDP, the exception is Chongqing and Wulumuqi. Chongqing has the most population and top 5 GDP, but the efficiency does not match, Wulumuqi is the opposite, the rank of airport's efficiency is ahead of local population and GDP.

The cities in third group is similar to the rank by passenger transportation, the reason is that the region influenced by these cities' economy is not obvious than other cities.

Figure 1: The Rank of Airports in 2010

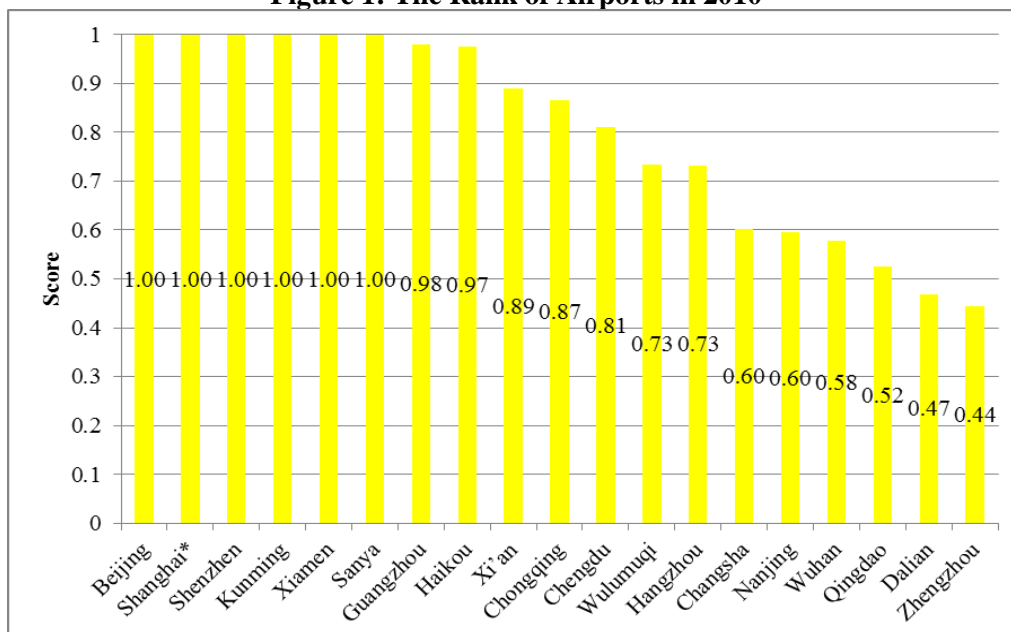


Table 3 shows the results of data in 2010 and 2009 by Wang et al. (2011). Because the result of data in 2009 doesn't consider the local economy data, the column of "rank without 2010 economy data" is the new result by this paper's method without economy data. Because DEA calculates the relative efficiency, the rank in the same group is meanful.

By comparing three groups of result, Shenzhen and Sanya have the best efficiency though different year and method. Beijing, Shanghai and Guangzhou have a little difference between 2009 and 2010, Kunming, Xiamen, Haikou and Chongqing is ranked ahead by DEA with economy data, which means that these cities' local economy has more influence than other input data. Changsha, Nanjing and Wuhan's economy don't contribute more to local airport.

Table 3: Result of Rank by DEA Comparing 2010 with 2009

Airports	Rank with 2010 economy data	Rank without 2010 economy data	Rank without 2009 economy data (Wang, etc 2011)
Beijing	1	3	4
Shanghai*	1	4	1
Shenzhen	1	1	1
Kunming	1	5	5
Xiamen	1	8	8
Sanya	1	1	1
Guangzhou	7	6	6
Haikou	8	13	13
Xi'an	9	7	7
Chongqing	10	19	19
Chengdu	11	14	15
Wulumuqi	12	17	*
Hangzhou	13	9	9
Changsha	14	11	11
Nanjing	15	10	12
Wuhan	16	12	10
Qingdao	17	15	14
Dalian	18	16	16
Zhengzhou	19	18	17

* Wulumuqi is not in the list of top 20 airports in 2009

4. Conclusion

Compared with traditional method including the volume of transportation and productivity ratio, DEA method considers more relative efficiency. The paper supposes DEA method to analyze the internal efficiency of top 20 airports in China by calculating the data in 2010. Input data composed of the number of the runway, the local population, the GDP, GDP per capita. The output here is comprised of number of passengers, tons of cargo and all traffic movement. After calculation, the paper discusses the results by different data in 2009 and 2010. The result shows that Shenzhen and Sanya both have the best rank in 2009 and 2010 even though without the economy data. In the future, the relation between local economy and the score of efficiency should be analyzed deeply.

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An Analysis of Airport Charges Characteristic

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Abstract

Charges are used as instruments to anticipate any change in traffics and other economic variables. Accordingly, charges needs to be analyzed and predicted for anticipating future needs of airport operational and investment. Generally, an airport planner or management concern about the charges rates movement in the past. Base on empirical data of airport service charges, it had seen irregular or unclear charges movement pattern. This pattern is influenced by variable parameter of charges. As the cost-based concept, cost is a critical rule in making the value of charges for airport user. Other variables that are concerned in making charging design are level of facility utilization and quality of services. Both variables have correlation with congestion issue and user satisfaction in the airport. This paper explore airport pricing base on these variables and analyze their relationships by making structure causality. By using Bayesian Network (BN) method, a graphical model for probabilistic relationships, we can more change to examine uncertainty issues based on causality matters. As the output, we propose a BN graphic structure that provide conditional probability of charges variables.

Keywords: Airport Charges, Cost-based, Congestion and Level of Service

1. Introduction

Charges certainty is an major issue in the airport pricing strategy. As an influential factor of airport performance, charges is used as an instrument to anticipate any changes in traffic demand and cost. In an order to develop pricing strategy, an airport analyst needs to make charges prediction refer to historical data.

Based on empirical data of airport charges rate movement, such as passenger service charges and landing charges, we can find that the charges movement had an unclear pattern. In fact, this pattern was influenced by the volatility of variable parameters. As result, it is not easy to analyze and make an operational and investment planning

There are many researches that examine the airport charges and their parameter variables, such as Zhang and Zhang (1997), Clayton (1997), Carlsson (2003), and Ivaldi et al. (2011). Zhang and Zhang (1997) examined the effect of the aeronautical operational and concession factors to the pricing. Then Clayton (1997) designed a pricing system by including aspect of airline involvement. Next Carlsson (2003) developed an optimal pricing model by involving aspect of external marginal cost, i.e. environmental charges. Other, Ivaldi et al.

(2011) studied airport pricing by involving factor interaction between airlines and passengers. There are also many studies related to airport pricing optimization by using sensitivity analysis approach. However, it is seen that there are not many airport pricing studies by reviewing and examining of the charges characteristics. The uncertainty is strongly influenced by space and time, so the study needs to be more comprehensive, by conducting some assessments of problems in the past. By knowing more deeply about the variables that influence airport pricing, it will be increased conviction in analyzing the problem. For an airport planner, it will give benefit, especially for making decisions related to pricing policy strategy.

There are some approaches or methods to analyze uncertainty issues. One of the approaches that have been widely used to examine causal relationships between variables is Bayesian Network (BN) method. BN has power in conducting variable learning by using historical data as quantitative information and involving qualitative information derived from the analysis of belief. Therefore, BN is an effective analytical tool to assess the relationship between the variables in the model. BN model is built by developing relationships among variables graphically and followed by determining the conditional probability distributions based on the graphic that was created (Demirer et al. (2006)). In the process of building a BN model, the development stage of the model structure is a critical part. This section is part of qualitative analysis, which includes the identification of variables and determine how the functional relationship (Kjærulff and Madsen, 2008).

The paper objective is to analyze characteristic of airport charges by learning their variable relationships. The basic philosophy of airport pricing is the cost-based concept, that the charges are determined based on the costs needed for the provision of service to users. Therefore, the characteristic of airport charges can be discovered by making analysis of the influence of each variables. Paper discussion divided into four sections. First, it begins by examining airport pricing regulation and policy. It recognize factors that significantly influence tariff structures. Second, it explores some issues in tariff structure. This section is a part discussion about identifying important variables that influences airport charges. Third, it analyzes structure relationships of variable charges using BN. This section give details how the process of making the graph structure of BN, which presented the causal relationship of each variables In the last part of this section, we propose an example BN graphic structure that provide conditional probability of charges variables. Last, the result of investigation and some remarks are presented in conclusion section.

2. Airport Pricing Regulation and Policy

Regulations or rules of airport pricing is aimed to protect the airport operator and service users (airlines and passengers) from unfair price. An airport is a form of natural monopoly, so the cost for terminal and landing services need to be controlled (Gillen et al., 2001). On the other hand, non-aeronautical service charges do not require the rules or regulations. As described by Trethway (2001), the case in many countries, only the revenue service flight activity imposed pricing regulations, while the commercial services that have high levels of market competition does not require the pricing regulations. Basically, pricing regulation is used as guide for price design and adjustment mechanism. Several studies have been conducted to assess the airport pricing mechanism, such as Forsyth (2003), Basso (2008) and Currier (2008). They make researches to examine the pricing mechanism by making comparison. Forsyth (2003) examines the implications of the two forms of regulatory mechanisms governing the charges at the airport, i.e. the cost-plus and the price-cap. Each of these mechanisms was tested advantages and disadvantages, especially in terms of minimizing cost and maximizing profit. He found that price-cap mechanism has advantages compared with the cost-plus. The price-cap mechanism will provide incentives for tariff policy during rush hour, so it will be able to increase airport revenues. While, Basso (2008) examine how the policy of airlines can effect airport pricing. He linked the regulation of charges and airport capacity. Studies made on the model of vertical relationships between airports and airlines. The airport which didn't regulate pricing will result in higher charges at the busy airport, however, the high charges may reduce the delay at the airport operation. Then, Currier (2008) conducted a study as well as carried out by Forsyth (2003) that examine the pricing regulation. He investigated the price-cap scheme which explored the potential pareto improvement on a single-till and dual-till. Similarly, Czerny (2006) examine price-cap that is associated with a policy of single-till and dual-till. He tested the implications for welfare, as well as compared to Ramsey charges. According to the results of the study, the single-till is more dominant than the dual-till. There are still other interesting studies that investigate pricing regulation

issues. Accordingly, it can be summarized that the airport pricing is an important topic to be discussed considering the matter necessarily determine the policy and tariff structure.

Pricing mechanism that set out in regulations is used by the airport management to establish airport pricing policy. Pricing policies will affect the amount of charges levied from the service users at the airport. Until now, there is no standard form in setting pricing policies airport. It can be proved that there are various forms of airport pricing policy, as applied to airports in several countries. Pricing policy is generally influenced by traffic and also the form of ownership. Determination of airport charge on its implementation is often different from the principle of economy in general, due to a variety of problems. Therefore, it needs an adjustment according to the existing characteristics (Button and Stough, 2000). In determining the airport pricing policy, we need a study of cost behavior. International Civil Aviation Organization (ICAO) has issued policy guidelines related to pricing at the airport, as in document ICAO's Policies on Charges for Airports and Air Navigation Services (Doc 9082/7). The document explains that the amount of airport charges is determined by the cost, or known as cost-based charging. The process for setting charges shall be in accordance with the accounting and costing principle. Based on economic theory, there are two cost types, that is short-run cost and long-run cost. As explained by Doganis (1992), Button and Stough (2000), both of cost types is very influenced by traffic and capacity factors. In assessment of cost factor, it consider short-run marginal cost (SRMC) and long-run marginal cost (LRMC), which have different analysis focus. SRMC is emphasized at how cost factor is influenced by operating cost of available capacities. In the other hand, LRMC is more emphasized at influence of long term investment (capital). Further discussion concerning type of cost is offered at next section.

Issues in the determination of airport charges policy, arises because of capacity constraints. Variability of traffic that occurs can result in a lower or exceeds use of its existing facilities capacity. Many things need to be considers before making a decision to increase the facilities, in case facility usage exceeds existing capacity. It is because the value of the investment required to develop the airport is huge while the future demand of traffic is still remain uncertain. Uncertainty of traffic demand is influenced by many factors, such as changing of global economic and growth of technology. Managing of traffic growth issue can be done by arranged capacities slot allocation, or by pricing techniques (Button and Stough, 2000). There are some studies that examine capacity limitation issue related to pricing policy. Yuen and Zhang (2007) studied airport congestion issue through pricing approach, where the considered factor is passenger time cost. In studying airport congestion problem use pricing approach as well as arrangement of slot allocation or capacity management, as in research done by Brueckner (2009) and Basso and Zhang (2010).

Considering the number of problems that must be addressed, an airport pricing analyst needs to assess some matters, such as the ownership of assets, operational funding, potential traffic and other eksternal matters. However, this paper is only focus on factors that are believed significantly influence in airport charges. They are cost, traffic, capacity, service quality and economic factor. The next section conducted a more in-depth discussion, in order to choose variables that is justified as main variables.

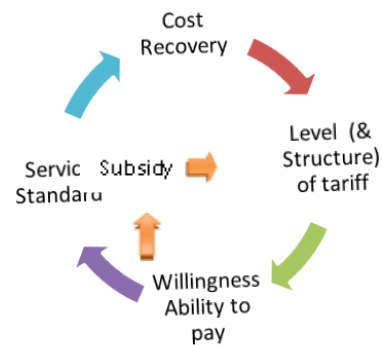
3. Airport Charges Variable

In the previous section, we recognize how the pricing regulatory and policy can affect the airport charges, and the main element that performs airport charge is variable cost. The following discussion examines these issues in more detailed. First, it considers the pricing issue based on the infrastructure pricing concept. Then, we discuss airport pricing based on economic theory. The end of this section present resume and chose main variables, believed that can affect airport charges significantly.

According to ADB (2008), there are two issues in term of pricing in infrastructures, i.e. the design of tariff and the tariff adjustment. The tariff design issues related to how value of tariff are determined, therefore the cost-recovery can be realized. There are five matters influence tariff balance, i.e. service standard, user's willingness and ability to pay, cost recovery, economic requirement, and subsidy availability from government. In order to get optimal value, these factors include in tariff design using iterative process. To produce optimal tariff level practically is difficult because there are some parties which keep their arguments upon their perception and interest. Variable charges and how its interactive process can be seen in the figure 1.

The second issues in the pricing is tariff adjustment. Tariff adjustment is needed because there are economy parameter changes. Practically, the balancing process looked complex although actually mechanism has been regulated. Tariff adjustment mechanism often couldn't be working well because some factors such as political risk and bureaucracy problem. As result, pricing uncertainty can arise, as a level of tariff adjustment uncertainty and timing of tariff adjustment uncertainty. Uncertainty of tariff level occurs because there is a tariff deviation between the real tariff and the expected tariff. While uncertainty of timing of price adjustment occurs as a delay of new tariff applied. Both uncertainties can make threat or risk.

Figure 1: Tariff Design Process



(ADB, 2008)

As a principal element of airport pricing, cost composition also strongly influences the charges. The key aspect that determine the size and characteristic of cost is the economic scale of the airport operation. According to Doganis (1992), cost per unit will decline with increasing traffic demand. Furthermore, costs are relatively fixed if the traffic demand is about three million or more. Besides, it also explained that the cost will be increase when the use of facility (utilization) is under the existing capacity, or when there is development of facility in order to increase its capacity. The scale economic issue should be concerned in pricing strategy, so an analyst of airport planning should be explore the investment timing issues associated with costs. Refer to Doganis (1992) and Button and Stough (2000), the following explanation describes divergence between short-run cost and long-run. Short-run cost is the cost based on the use of existing capacity. The level of cost will decline by increasing traffic, and reach the lowest level when the level of utilization up to 100% of capacity. But the level of cost will again increased when the using factor exceeds the existing capacity (overcapacity). While the long-run cost is the level of cost associated with adding capacity, where the higher traffic will reduce the cost until cost relatively fixed. Thus, the scale of economic factor greatly influences the level of charges at airport.

In the previous section, we have identified variables that affect the airport charges or cost. With the additional information obtained from the expert knowledge or other literature studies, these variables can be explored in more detail. The traffic can be said as the main factor that can affect the cost. Low or high traffic can contribute to a change in variable cost. When traffic become low, it makes problems for airport managements to cover the costs incurred (cost-recovery). Changing the existing conditions at the airport due to traffic change, is not easy. The number of employees, maintenance costs, costs of lighting and other costs, is not easy to directly reduced. On the other hand, the high traffic caused exceeds existing capacity also make problem for the airport. It needs more counters and employees to solve problems the long queues that occur at the terminal. So, traffic can be indicated as influential variables.

A factor which is directly influenced by the variation of traffic is called capacity. This factor is one important aspect need to be considered in formulating airport policy, particularly associated with problems of congestion. Generally, the indicators used to determine the value of this variable is the level of utilization. The higher the value of the indicator showed an increase in the use of facilities. Utilization level should always be monitored its value, because it is one of the main indicators for decision-making in the airport management. This variable was already widely explored in several studies which states that it have directly affects the value of cost.

The service quality is also a variable that have correlation with other variables. Assessment of service quality can be done from two ways, that are the level of operational standard and the user satisfactions. The level of operational standard is the standard rules that regulate the minimum or maximum standards to be met. There are several aspects to be considered, such as issues related to security, safety and service. Then, user satisfaction is valuation of service level from the user side, where more consider about how the airport can provide satisfaction to users. These factors are important because they are associated with user's willingness to pay. Many indicators of user satisfaction can be used to assess the existing service standards, such as service time indicator. Repeated flight delays or a long queue of passengers at the terminal may reduce the level of user satisfaction. As result, this factor could be included as a major factor affecting the cost.

Next, the economic variables such as inflation, interest rates and currency exchange rate have certainly affect cost change. As explained before, the economic factor is one of the key indicators in driving the price adjustment. We do not discuss further this factor because it has a lot of theories and formulas that describe the relationship between economic factors and price.

Based on the discussion, it can be concluded that there are two variables are indicated as the main factors that can conduct to changes in price equilibrium, i.e. the change of traffic demand and the variability of economic factors. With the existence of these factors, there are two variables that is used as reference in determining price adjustment, i.e. the level of the facility utilization and the level of service quality. The next section, the variable relationships are determined by designing a causality model using the BN method.

4. Structure Relationships of Variable Charges

In this section, we develop a model to examine the relationship among variables that affect airport charges. Methods of analysis which is used to examine variable relationships is the concept of Bayesian Network (BN). BN is an analysis method that combines graphical and probabilistic theory. The principle used in the BN method come from the principles of Bayesian inference (BI), which provides a systematic framework to be able to infer the model that is built based on observational data (Hofman, 2009). BN method is used to build a graphic structure that can present knowledge about the uncertainty problem. Graphic element, which are used to explain a phenomenon, is a node and edge, where node present random variable and edge present probabilistic dependencies between random variables. The relationship between the variable describe the *child-parent* or *depend-influence* relationships.

Building the structure model in the BN analysis is an important part, because it will make significant affect to the conclusions of analysis. There are two ways that can be taken to build the model structure, i.e. using expert knowledge and using historical data (Gemela, 2001). In this paper, the model structure will be constructed using by first option approach. The underlying matter is the number of variables and characteristics of the problem. In beginning, we need to identify variables in the model. Identification of variable models was done by variable grouping, based on the variable type. To indicate variable type, we use the classification of variables that is explained by Kjærulff and Madsen (2008). First, the background information variable is a background variable that influence or cause problems. Next, problem variable is a variable that will be determined the posterior probability base on variable information. Then symptom information variable is a variable that is a result or consequence of the problems.

Based on the discussion in the previous section, there are five variables that influence airport charges, i.e. cost, traffic demand, economic factors, facility utilization and service quality. To identify the type of variable, it will be seen how the position of the variable, whether as the only variable causes another variable, or as a variable is only affected by other variable, or as a variable that can be affected by other variable and cause other variable. Cost is the main variable in the model which reflects the value of charges (cost-based). High and low cost is strongly influenced by other variables, i.e. economic factor, facility utilization and service quality. Economic factor is the driving factor for the cost, especially from the financial aspect. For example, inflation is an important component that drives the increased cost. Similarly, facility utilization can also affect the cost. A low utilization or an excess capacity may affect the level of cost. At a case where over-utilization is occurred, it is required to perform additional resources to support operational activities. Then, service quality, as user perception toward the airport operating conditions, can also affect the changing of costs. For

instance, there is a claim for additional facilities to support the operational service, for both locations on the airside and in the terminal. Therefore, cost can be grouped into variable information symptom. Next, traffic demand is essential element which influences the performance of the airport, particularly to the facility utilization. The variation of traffic will significantly impact on the calculation performance of existing facilities. On the other hand, traffic is the main variable in the model. Therefore, traffic demand can be identified as a background information variable. Similarly, economic factors, i.e. inflation, interest rate, can also be grouped into the background information variable, because they can drive changes for other variables. Others, facility utilization can be classified as a problem variable, because it can be influenced by traffic, and can also affect the cost. Last, service quality can also be grouped into the problem variable, because its value depends on the facility utilization and can also affect the cost. Overall grouping of the variables can be seen in the table 1.

Table 1: Identification of Variable Type

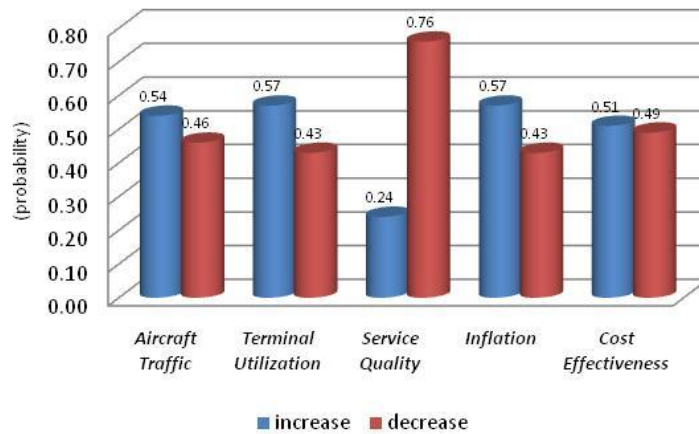
<i>No</i>	<i>Observing Variable</i>	<i>Variable Type in Model</i>	<i>Influenced Variabel</i>	<i>Affected Variabel</i>
1	Cost (C)	sympton information variable	(E), (F) dan (S)	None
2	Traffic demand (T)	background information variabel	None	(F)
3	Economic factor (E)	background information variabel	None	(C)
4	Facility utilization (F)	problem variable	(T)	(C), (S)
5	Service level(S)	problem variable	(F)	(C)

Based on the above identification, we can find which are "parent" variables and which are "child" variables. The relationship between these variables will be described in terms of "child-parent" and "depend-influence" relationships. The description of relationships will determine the output at the BN model, i.e. the marginal posterior probability. The directed acyclic graph in BN model that illustrates the causality among variables, is consists of nodes and arcs, which are describe random variables and conditional independence relations (Shenoy and Shenoy, 1998).

To determine the numerical link between these variables, we can use several ways, i.e. by using historical data, expert knowledge and beliefs. In this paper, the probability distribution at each node is determined using the concept of marginal probability distribution and conditional probability distribution, as described by Demirer et al. (2005). The marginal distribution is used for nodes that do not have a line arrow to that node point. On the other hand, the conditional distribution is used on nodes that have at least the arrow line towards nodes. Thus, the node for variable traffic and economic factors can be calculated the marginal probability distribution, and other variables can be calculated it's conditional probability distribution. For calculation of the probability distribution, we can also use several ways, such as by using the model equations, a discrete conditional probability table, and a continuous conditional probability distribution (Shenoy and Shenoy, 1998). It indicates that the concept of the BN model gives a lot of options in conducting the analysis. However, we must careful and need more thinking before choose the option, especially should consider about the expected output.

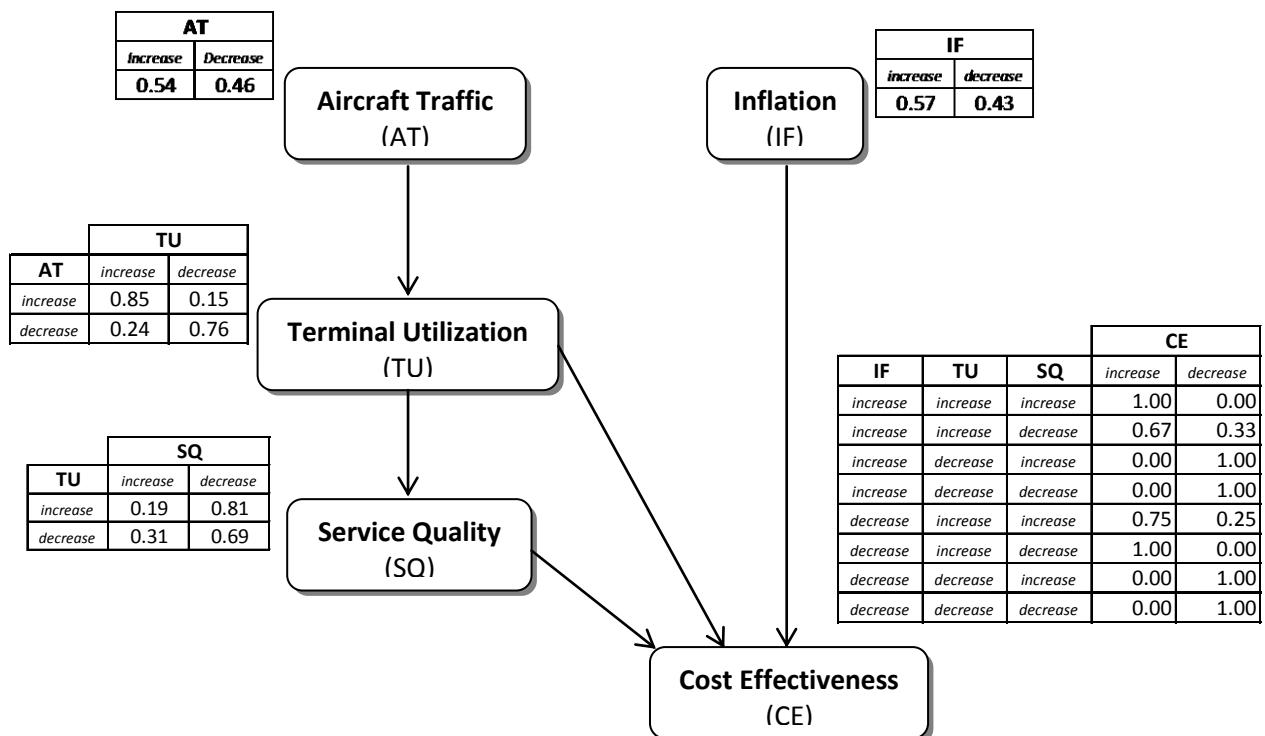
To illustrate building process of BN structure model for analyzing airport charges variable relationships, as a sample cases, empirical data was taken from an airport in Indonesia. Observation period for the data is from 2004 – 2010. Data collected from the airport is aircraft and passanger movement, runway and terminal capacity, level of services and financial reports. For economic indicator, data was obtained from Statistics Indonesia and Bank Indonesia. Next, the collected data arranged in a table, in which the columns form adapted to the analysis variables. In the discretization process, the data format is converted to an indicator or ratio. As a sample, the variables to be analyzed are aircraft traffic, terminal utilization, service quality, inflation and cost effectiveness. By calculating the data trend of each indicator variable, i.e. data comparing between before and after, we can obtain prior probability of each variable, as shown in the figure 2.

Figure 2: Prior Probability of Variables



Based on the identification of variable type (table 1), we classify variables into group of “parent” and group of “child”. Each variable can be as the “parent” or affected variable, or “child” or influenced variable, or both. Aircraft traffic and inflation are as the only ”parent” variable. Then, Cost effectiveness is as the only “child” variable. The rest of variables are as “parent” and “child” variables. Using these indications, we create the BN graphic structure which describes variable relationships. This graphic relationship and tables of conditional distribution can be seen in the figure 3. The first part of BN model has been done, by creating Directed Acyclic Graph (DAG) and table of conditional distribution of the variables. Next process is performing probabilistic inference. This analysis was used to determine the variables that can not be known directly by using other variables. In order to get posterior probability of variables, we use Bayesian Theory. However, this paper do not examine it.

Figure 2: Graphic Relationship and Tables of Conditional Distribution



Based on table of prior probability of variables, we can get some information about character of variables. All variables show same characteristic, except for service quality. If the other variables show similar trends, but not for service quality, where the trend shows the opposite direction. Besides that, the level of variability for this variable shows the figure of the large probability difference. There are another interesting case which the

probability of inflation variable (IF) and terminal utilization (TU) is equal. On the other hand, we know that there are no connecting line between these variables (independent). Thus, it can indicate that these variable have same characteristic. However, it still needs to be more examined in order to address question *how the posterior value of the terminal utilization variable?*, because we know that this variable is influenced by aircraft traffic variable.

BN model also allows to accommodate all the additional of the new qualitative and/or quantitative information. The analysis results generated from the BN model can be used as justification in assessing the characteristics of the variables observed based on believable evidence, and also it can be used as a consideration for judgment in making decision or prediction. Finally, related to airport pricing issues, the description given by the BN model will greatly assist an airport planner in making estimation or determination the future airport performances. By knowing the information provided from this model, it helps in planning and determining the future need for short-term and long-term period.

5. Conclusion

An airport, like other public infrastructures, require substantial funds and take long-term developments. It also have particular service standards to be met. Therefore a comprehensive plan is needed to take, by concerning factors that affect the performance of the airport. Airport pricing is an important issue in airport planning. Many variables need to be considered in determining the pricing strategy at the airport. To predict the value of airport charges, it is necessary a depth study concerned charges variables. Based on identification of some literatures related to the issue of airport pricing, we obtained some factors that affect airport charges. A main factor that directly influence charges is cost. The value of airport charges is determined based on costs incurred for the provision of services, which is known as term of cost-based pricing. Cost it self is influenced by several factors.

This paper provide a different method to analyze airport charges characteristic. We attempt to get information about how the relationship between each variable in airport charges. By applying Bayesian Network (BN) method to build of structure causality model, we can determine the joint probalistics among charges variables, in order to get relationship information. The results have been presented is an initial stage to further analyze these relationship. Some information about the characteristics and relationships of variables had been presented in the form of conditional distribution. Thereafter, we can use this data of prior probability to make further analysis or perform probabilistic inference. However, this stage is a crucial part and needs a better knowledge to make perceive airport charges problems.

Finally, we still need to do some works to investigate the characteristics of the airport charges. For the future, this research will be continued by expanding the variables and perform probabilistic inference in order to get more information about pricing uncertainty in the airport.

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An Analysis of the Pricing Decision under the Influence of Revenue Management and Market Condition - The Example of the Domestic Air Market in Taiwan

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Abstract

Revenue Management (RM) has become a common practice in the airline industry worldwide since American Airlines successfully implemented it in the mid 1980s to beat the entrants in the post-deregulation era. As a core technique of RM, price differentiation is put into practice through the multi-fare scheme, which results in significant price dispersion in the market. At the same time, the implementation of price differentiation is believed to be closely related to market condition. The objective of this study is thus to examine the relationship between revenue management and market condition through the example of the domestic air market in Taiwan. This empirical study establishes several multiple linear regression models, in which ticket discount is chosen as the dependent variable given the partially-deregulated environment for fare control. With an aim to conduct a comparative analysis, it is found that the result is in general consistent with those in the prior empirical studies focusing on the U.S. and Europe domestic air markets and provide more evidence from the practical viewpoint regarding how airlines react to market condition while making the pricing decision. In particular, this study further employs two interaction models to investigate the impact of one independent variable on another. The results show that the interaction models provide insightful explanations about how the implementation of RM is affected by other factors.

Keywords: Revenue Management, Price Differentiation, Market Condition, Regression Analysis

1. Introduction

The Airline Deregulation Act of 1978 significantly changed the environment of the domestic airline market in the U.S. Given the relaxed control on routes and fares, many new airlines aggressively entered the market. People Express was probably the most successful one. With minimal service and cheap labor, People Express considerably reduced airfares, not only lower than those of the existent major airlines, but also comparable to the fares offered by the intercity bus lines. The revenue of People Express increased dramatically throughout the early 1980s and reached one billion USD by 1985. After a failure in the initial price war, one of the major carriers, American Airlines, introduced the Ultimate Super Savers, a discount fare with restrictions, to compete against People Express for the price-elastic demands. This combined with the sophisticated computer reservation system for seat inventory control successfully defeated the low-price strategy of People Express and, at the same time, effectively secured the high-margin market for American Airlines. People Express, a new company without a high-end brand image, ceased operations in 1986 after losing its price advantage (Peterson and Glab, 1994).

Airline Deregulation has been cited as a success for free competition. Initially, the average airfare did decrease,

and the number of airline passengers increased. However, after years of practice under the “Open Sky”, many airlines have declared bankruptcy. The projection is for a handful of large airlines to dominate the airline industry in the future. There are several reasons why the Airline Deregulation did not live up to its advance billing or ended up with so many surprises as highlighted by Alfred E. Kahn (1988), an economist and the last Chairman of the Civil Aeronautics Board (CAB). However, price discrimination and other revenue management techniques, the key weapon used by American Airlines to defeat People Express, have certainly played a key role in the unexpected and undesired market concentration.

Although controversial, revenue management (RM, also known as yield management, YM) has become a global and common practice in the airline industry worldwide since American Airlines successfully implemented it in the mid 1980s to beat the entrants in the post-deregulation era. Not only is a strategic measure for price competition, RM is also an important operational technique for raising revenue. It has been estimated that RM practices have generated an additional revenue of 1.4 billion USD for American Airlines over a 3-year period around 1988 (Smith et al., 1992). Nowadays, it is difficult for a major airline to operate profitably without the use of RM, as according to most estimates that the extra revenue gained from the use of RM is about 4 - 5%, which is comparable to many airlines’ total profitability in a good year (Talluri & van Ryzin, 2004).

Airline deregulation has become a global trend, and Sinha (2001) and Chang et al. (2004) serve as excellent references for its development across countries and regions. In particular, the latter focused on the issue of ownership and control, which is believed to be the most important barrier for airline industry linearization. There were many research works that have examined the impact of deregulation specifically on airfare, which is probably the most immediate and concerned influence of linearization. For example, Morrison and Winston (1990), Borenstein (1992), Dresner and Tretheway (1992), Maillebiau and Hansen (1995), Marin (1995), Jorge-Calderon (1997) focused on the markets in North American or Europe, the regions with early introduction of aviation deregulation. More recently, for the Asia Pacific region, Manuela (2007) adopted a similar empirical framework and developed an econometric model for the case of Philippines.

Above research works have shown that airfare, in terms of the average value, generally decreased due to the competition brought by deregulation, but they did not address another important aspect: the price dispersion due to the application of the price discrimination, which is legally permissible and strategically desirable in the post-deregulation era. Price discrimination, one of the core techniques of RM, is implemented by offering multiple airfares with various terms and conditions and/or by changing the fares dynamically. Its application is believed to be affected by the market condition. Thus, the focus of this empirical study is to analyze the relationship between price discrimination, revenue management, and market condition. This paper is organized as follows. The next section reviews the related literature. The framework of the empirical analysis is described in the third section, and the results are presented in the fourth section. Finally, the findings of this study are summarized and conclusions are drawn in the fifth section.

2. Literature Review

Price discrimination is usually categorized in three types (Varian, 1996). In the first-degree price discrimination, also known as perfect price discrimination, a supplier sets the price according to the willingness-to-pay by individual consumers. In the second-degree price discrimination, consumers make the purchase decision regarding the options offered by a supplier. That is why it is sometimes referred to as self-selection. As for the third-degree price discrimination, a supplier segments the market with multiple prices and conditions that are based on the diverse characteristics of the consumers. Revenue management as adopted by airlines is usually referred to as a practice of the second-degree price discrimination, although some tickets targeting a specific group of travellers (such as senior citizens) are closer to the third-degree price discrimination category.

In a monopolistic market, a firm is the price setter and can maximize its profit through price discrimination. At the other extreme, in perfect competition a supplier is simply a price taker, and the price is equal to the marginal cost. Therefore, it appears that there is no price dispersion in perfect competition. So, if we take a competitive market between the two extremes, then the obvious conclusion based on simple extrapolation

should be that price dispersion will be reduced if competition increases. However, reality does not follow a rule this simple.

Some theoretical models instead concluded that price dispersion exists and may increase as a market moves from a monopoly to imperfect competition (*e.g.*, Valletti, 2000). In particular, for the airline industry, Gale and Holmes (1992a), Gale and Holmes (1992b), Gale (1993), and Dana (1998) used the advance-purchase requirement as a discriminatory device to investigate price dispersion under various market conditions. When competition is introduced into a monopoly market with price discrimination implemented, the pre-existing supplier is likely to lower the prices (especially for the lower-end products) so as to avoid giving room to the rivals. That is why it has been found price dispersion may increase as the market becomes more competitive. This phenomenon is even more apparent for the airline industry, in which the cost of holding inventory to meet demand is relatively high due to the associated demand uncertainty and supply non-storability.

Borenstein and Rose (1994) categorized price discrimination into “monopoly-type” discrimination and “competitive-type” discrimination. Consistent with the general concept of price discrimination, monopoly-type discrimination is related to the industry demand elasticity and generates more price dispersion if a market is closer to a monopoly. On the other hand, competitive-type discrimination is related to customers’ cross-elasticity of demand among different brands. Price dispersion becomes greater when a market is more competitive, since firms tend to offer deeper discounts when segmenting the customers based on demand elasticity across different brands. In their empirical study of the U.S. domestic airline market in 1986, price dispersion in terms of the GINI coefficient was found to be negatively related to market concentration, which was measured by the HHI (Herfindahl-Hirschman Index, defined as the square sum of the market shares in percentage). Thus, competitive-type price discrimination prevails over monopoly-type price discrimination.

Stavins (2001) conducted a regression analysis focused on the relationship between price dispersion and market condition in the U.S. domestic airline market, but with data that was collected in 1995. In addition, two ticket restrictions (Saturday-night stay-over and advance purchase) were included in the model. This was done because these two restrictions are very effective for segmenting the airline travellers based on their valuation of time and flexibility, and they are commonly used by the airlines in the RM system. Both discriminatory devices were found to be negatively related to airfares. In the basic (non-interaction) model, the restriction of Saturday-night stay-over was estimated to reduce the fare by 211.17 USD, and one day of advance-purchase gave a price reduction of 6.04 USD.

In the interaction model, Stavins (2001) examined the effect of the market condition on price discrimination further by including the product terms of these two ticket restrictions and the HHI in the regression model. The results showed that, for both restrictions, the higher the market concentration on a route, the lower the effect of price discrimination. For example, the estimated fare reductions for the restriction of the Saturday-night stay-over were 253, 233, and 165 USD for the 25th, 50th, and 75th percentiles of the HHI, when being sorted in increasing order (*i.e.*, from less to more concentration).

Using a regression model similar to that of Stavins (2001), Giaume and Guillou (2004) discussed the market for the intra-Europe flights originating from Nice, France based on the data collected in 2002. Airfare was once again used as the dependent variable, and the key independent variables (Saturday-night stay-over, advance purchase, and market concentration represented by the HHI) remained the same. However, they introduced several new independent variables (such as the presence of low-cost carriers) to reflect the unique situation in the European market. Although the study area was geographically smaller, and the deregulation movement was slightly later, the results obtained by Giaume and Guillou (2004) focusing on Europe were similar to those of Stavins (2001) for the U.S. In particular, the signs for the coefficients of the major variables in the regression models were found to be the same, although the coefficient of determination (R^2) was lower (0.40 in Giaume and Guillou, 2004 vs. 0.77 in Stavins, 2001).

A local version of the “Open Sky” policy was initiated in Taiwan in 1987, and several new airlines were established to serve the domestic airline market, which was experiencing an unprecedented demand. However, fare was still under a very strict control scheme, under which tickets were sold at the fixed published fare. Only until 1994, airlines were authorized for the first time to adjust the ticket price within 10% of the

published fare, and this permissible range was expanded several times later on. The fare-control regulations were further revised in 1999 such that the published fare became a price cap, and airlines were allowed to set a certain level of discount. Although several minor revisions have been made, the current regulations basically follow the form of the 1999 version (CAA, 2012).

To some extent, Taiwan has been following the global trend to deregulation, and the airlines gradually adopted the concept of revenue management. However, the liberalized domestic airline market in Taiwan was quite different from most markets in the literature. Taiwan is geographically a small country and has good infrastructure for most part of the island, but jet aircrafts (such as A320s, MD-80/MD-90s, B737s, and even B757s) are anyway used to serve many domestic routes. In addition, the fare regulations for the domestic airline market were only partially deregulated. Thus, it is of great interest to conduct an empirical study to examine the relationship between price discrimination and market condition and to conduct a comparative analysis with respect to different markets.

3. Framework of Empirical Analysis

Following the framework in Stavins (2001) and Giaume and Guillou (2004), this study established four linear regression models to perform the empirical analysis. The flights included in the analysis were operated by three airlines, Far Eastern Air Transport (FAT), TransAsia Airways (TNA), and UNI AIR (UNI), for the routes from Taipei, the capital and the economic center, to seven domestic airports. The basic information and the market condition of the routes are listed in Table 1. Given the airlines and the routes considered, the traffic volume included in the analysis accounted for 65% of the overall domestic airline traffic in Taiwan, or 82% of the traffic leaving or bound for Taipei in terms of the number of passengers (CAA, 2004). The information regarding the flights for a typical weekday in 2004 (Tuesday, August 10) was collected to serve as the data for the regression models from the website of a popular on-line travel agent, in which the above-mentioned airlines are suppliers for the domestic air markets.

Based on the fare-control regulations under the partially-deregulated scheme, an airline can discount fares within a regulated range for the flights it operates. Therefore, the discount for each flight was used as the dependent variable in all four models, and it was defined as (published fare - discount fare)/published fare (in percent). This dependent variable is different from the one (the airfare) used in Stavins (2001) and Giaume and Guillou (2004).

As for the independent variables, the RM technique for price discrimination and the market condition were considered first. Taiwanese carriers do not use a complicated RM system for the domestic market, and they deal with the diverse demand simply by dynamically adjusting the price, a practice adopted by many low cost carriers worldwide. The price offered on-line remains the same from the beginning of the booking period to five days before departure. The price then subsequently increases and becomes the published fare on the day of departure. Given this price adjusting scheme, the number of days for advance purchase was taken as one of the key independent variables in the regression model. To quantify market condition, the Herfindahl-Hirschman Index was used as the other key independent variable.

Table 1: Information of The Routes In The Analysis

Route	Location (Distance)	Annual Traffic (Both ways)	Airlines	Market Condition	HHI
Kaohsiung	West coast (183 miles)	2,652,629	FAT, TNA, UIA	Oligopolistic	0.380
Tainan	West coast (164 miles)	1,242,933	FAT, TNA	Duopolistic	0.504
Pingtung	West coast (177 miles)	109,833	TNA	Monopolistic	1.000
Hualien	East coast (75 miles)	634,018	FAT, TNA	Duopolistic	0.508
Taitung	East coast (161 miles)	587,165	FAT, UIA	Duopolistic	0.516

Makung	Offshore (156 miles)	753,975	FAT, TNA, UIA	Oligopolistic	0.352
Kinmen	Offshore (196 miles)	818,895	FAT, TNA, UIA	Oligopolistic	0.349

In the four models developed in this study, the basic model includes only two independent key variables: the number of days for advance-purchase and the HHI. The enhanced model incorporates additional factors related to domestic airfares. In addition, the two interaction models introduce the product terms of independent variables. The basic model is as (1), where $DISC_{ijk}$ is the discount of the k th flight of airline j on route i , ADV_{ijk} is the number of days for advance purchase discount of the k th flight of airline j on route i , and HHI_i is the HHI for route i .

$$DISC_{ijk} = \beta_0 + \beta_1 ADV_{ijk} + \beta_2 HHI_i \quad (1)$$

In order to address the factors related to the pricing decision of the airlines, four dummy variables were used in the enhanced model. The first one is whether a flight is popular. Since all seven routes are short for air transportation, many passengers make the round-trip on the same day. Thus, popular flights are defined as those with a scheduled departure time within 7:00 a.m. to 9:00 a.m. or 6:00 p.m. to 8:00, as they provide the most benefit to short-haul passengers. The second one is whether a route is bound for an offshore island. The concern is that the alternative transportation service is unfavorable, as the boat trip can take more than 12 hours, and the service frequency and comfort leave a lot to be desired. The third and fourth ones are the dummy variables for two airline brands (UNI and TNA), given that the largest airline in the domestic market, FAT, was chosen as the base category. The regression model is shown as (2), where POP_{ijk} is equal to 1 if the k th flight of airline j on route i is popular, $ISLD_i$ is equal to 1 if route i is for off-shore islands, and UNI_j as well as TNA_j represents the airline brands.

$$DISC_{ijk} = \beta_0 + \beta_1 ADV_{ijk} + \beta_2 HHI_i + \beta_3 POP_{ijk} + \beta_4 ISLD_i + \beta_5 UNI_j + \beta_6 TNA_j \quad (2)$$

For the independent variables used in the model, the maximum absolute value in the correlation matrix is 0.375, indicating that the multicollinearity issue is not a serious problem. In addition, some other factors possibly related to airfare have been tested, such as destination population, market share, flight frequency etc. However, all of them were found to be suffering from the multicollinearity problem or insignificant in the regression analysis.

The first interaction model was designed to determine the influence of the market condition on the implementation of price discrimination. A product term of the first two independent variables was introduced into the model as (3). The second interaction model was used to understand the impact of the airline, the decision maker, on the level of advance purchase discount. Two product terms of the first variable, representing the days for advance purchase, and the two airline dummy variables were introduced into the model as (4).

$$DISC_{ijk} = \beta_0 + ADV_{ijk} (\beta_1 + \gamma_1 HHI_i) + \beta_2 HHI_i + \beta_3 POP_{ijk} + \beta_4 ISLD_i + \beta_5 UNI_j + \beta_6 TNA_j \quad (3)$$

$$DISC_{ijk} = \beta_0 + ADV_{ijk} (\beta_1 + \gamma_2 UNI_j + \gamma_3 TNA_j) + \beta_2 HHI_i + \beta_3 POP_{ijk} + \beta_4 ISLD_i + \beta_5 UNI_j + \beta_6 TNA_j \quad (4)$$

4. Results of Regression Models

Based on the collected data, the results of the regression models are listed in Table 2. The summary and the discussion of the results are presented as follows.

Table 2: Results of the Estimations in Four Models

	Basic Model	Enhanced Model	Interaction Model I	Interaction Model II
Intercept	-1.86 (1.33)	-0.41 (0.99)	-2.79 (1.69)	0.88 (1.10)

<i>ADV</i>	2.21 (0.21) ***	2.87 (0.16) ***	3.66 (0.49) ***	2.42 (0.22) ***
<i>HHI</i>	12.66 (2.12) ***	10.13 (1.68) ***	15.15 (3.33) ***	10.91 (1.66) ***
<i>ADV×HHI</i>			-1.67 (0.96) *	
<i>POP</i>		-0.81 (0.64)	-0.81 (0.63)	-0.58 (0.62)
<i>ISLD</i>		-6.31 (0.68) ***	-6.76 (0.72) ***	-6.29 (0.67) ***
<i>UNI</i>		-3.00 (0.59) ***	-3.00 (0.58) ***	-6.98 (1.43) ***
<i>TNA</i>		-1.16 (0.64) *	-1.17 (0.64) *	-2.90 (1.55) *
<i>ADV×UNI</i>				1.00 (0.33) ***
<i>ADV×TNA</i>				0.48 (0.38)
Adjusted R^2	0.498	0.750	0.754	0.763
Observations	140	140	140	140

*Numbers in parenthesis are standard errors. * significant at 10% level, ** significant at 5% level, *** significant at 1% level.*

The basic model is not very satisfactory, since its R^2 is only 0.498. However, the t -statistics of both independent variables (the number of days for advance-purchase and the HHI) are large, indicating that the relation between ticket discount and each of these two dependent variables is significant. As expected to be positive, the coefficient of the variable ADV shows that the advance-purchase discount is about 2.21% per day.

The coefficient of the other independent variable HHI is 12.26%, and its positive sign indicates that the more concentrated a market is, the higher the ticket discount is. This result probably does not support the standard notion that market concentration raises fare level, or it is not in agreement with the conclusion in the first empirical study (Borenstein and Rose, 1994) that competitive-type price discrimination prevails over monopoly-type price discrimination. However, it is consistent with the results of the two later empirical studies, Stavins (2001) and Giaume and Guillou (2004).

Stavins (2001) did not discuss the cause of this result, but Giaume and Guillou (2004) provided an explanation in light of the unique features of the European air market. Airline deregulation in Europe had not come into effect for a long time, and there was a significant market share inequality for many routes. For example, in a duopoly market, it is common that one of the players is a large (flag-carrying national) airline and the other one is a small (new) regional airline. In that market the associated HHI are very high. Lowering the price appears to be the best strategy for the big one to drive out the new comer and for the small one to penetrate the crucial new market. Thus, the average fares are likely to lower than those in the markets with comparable market share among players.

As for the domestic airline market in Taiwan, this counter-intuition result is most likely caused by the demand level of the routes. As shown in Table 1, the HHI and the annual traffic are strongly correlated, and the correlation coefficient is -0.53. A high value of the HHI is sometimes an indication of insufficient demand (possibly due to a small population or favorable alternative transportation services). It is possible that, in order to maintain an acceptable load factor, airlines have to constantly offer deep-discount tickets, which make the airfare level low.

By including four more independent variables, the R^2 is raised to 0.750 in the enhanced model. The coefficient of the advance-purchase discount increases slightly to 2.87% per day, and the coefficient of the market concentration (HHI) remains positive. As for the new independent variables, the coefficient of the dummy variable for popular flights is -0.81%, but it is not very significant (p -value = 0.20). At the same time, the coefficient of the dummy variable for offshore-island routes is -6.31%, suggesting that airlines decrease the discount considerably for the inelastic travellers lacking alternative transportation modes. As for the dummy variables for the airline brands (UNI and TNA), the values are -3.00% and -1.16% respectively. The fact that the smallest discount offered by UNI Air may be partially attributed to the fact that it is the only airline in the

analysis with a giant parent company (EVA Airways as well as Evergreen Marine Corp.), and its brand awareness is relatively strong.

For the first interaction model, the coefficient of the product term (γ_1) is significant, and the sensitivity of the discount to the advance purchase is as (5). The negative value of γ_1 (-1.67) implies that the advance-purchase discount is reduced if the market concentration increases. This result is consistent with those in Stavins (2001) and Giaume and Guillou (2004), although the three studied markets are significantly different in terms of market size, geographic location, transportation infrastructure, and airline industry development. The product term of the advance purchase and the market concentration in the interaction model provides a good way to understand how market condition affects the implementation of RM and the air fare. To give a numerical example for the relation of (5), consider the cases of one, two, and three players with equal market share. The HHIs are 1.00, 0.50, and 0.33 respectively. The discount per day for advance-purchase increases from 1.99% to 2.83% if the market condition changes from monopoly to duopoly and becomes 3.11% per day for oligopoly.

$$\frac{\partial DISC_{ijk}}{\partial ADV_{ijk}} = (3.66 - 1.67 HHI_i) \% \quad (5)$$

For the second interaction model, the coefficient of the product term for UNI (γ_2) is significant; however, the other coefficient for TNA (γ_3) is basically insignificant (p -value = 0.21). The sensitivity of the discount to the advance purchase is as (6), in which the positive value of 1.00 for γ_2 suggests that, in addition to the base discount of 2.42%, UNI AIR (UIA) offers extra 1% per day for advance purchase. On the other hand, the sensitivity of the discount can also be addressed from the viewpoint of the airline as shown in (7). The base discount of -6.98% is once again an indication of the strong brand of UNI AIR, as it provides significantly less discount in general. However, at the same time, it adopts an aggressive approach in exercising the RM technique by offering more advance purchase discount.

$$\frac{\partial DISC_{ijk}}{\partial ADV_{ijk}} = (2.42 + 1.00 UNI_j) \% \quad (6)$$

$$\frac{\partial DISC_{ijk}}{\partial UNI_j} = (-6.98 + 1.00 ADV_{ijk}) \% \quad (7)$$

5. Conclusions

Price discrimination is a core technique of RM, and results in price dispersion in the market. At the same time, the implementation of price discrimination is closely related to the market condition. The objective of this study is to conduct an empirical study to examine the relationship between revenue management and the market condition, based on the example of the domestic airline market in Taiwan. The study established four linear regression models to conduct this empirical study. Ticket discount was chosen as the dependent variable given the partially-deregulated environment for fare control.

The basic model, consisting of only the independent variables related to revenue management (advance purchase) and market condition (HHI), was found to be insufficient. After introducing four more variables, the enhanced model was better able to explain the pricing decision of the airlines. Based on the first interaction model, the discount for advance purchase was reduced if market concentration increases. With an aim to conduct a comparative analysis, it has been found that the result is in general consistent with those in the prior empirical studies earlier empirical studies focusing on other areas (Stavins, 2001; Giaume and Guillou, 2004). In the second interaction model, a specific airline (UNI AIR) was identified by its aggressive role in the implementation of revenue management. We believe this study provides more evidence from the practical viewpoint regarding the pricing decision of the airlines under the influence of RM and market condition

During the past several years, there has been a critical impact on the domestic airline industry in Taiwan: the

high-speed rail, which was inaugurated on January 5th, 2007. The maximum speed of the trains is 300 kilometers per hour and the frequency of the service is high. The high-speed rail system carried 15.56 millions passengers for the first year, and the rate of growth is very promising (THSRC, 2012). All the domestic airline services for the west coast have been terminated thereafter. The business environment of the domestic airline market in Taiwan has been changed permanently. The airlines now have to focus on the services for the east coast and the offshore islands, where alternative transportation services are not competitive. An analysis of the pricing decisions of the airlines for these routes can be an extension to this study, but the issue must also be addressed from a public domain point of view. Government intervention is required for these potentially unprofitable routes, as the mobility of the people living in those remote areas should be protected.

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The Security System at European Airports – Tour d’Horizon

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Abstract

This paper aims to provide an analysis of the existing security system at European airports. At first, the security is defined and the considerations of the air passenger security on the ground and in the air are discussed. Subsequently, the current aspects shaping the European aviation security policy are introduced. A stakeholder analysis and their roles in aviation security is presented. The passengers’ perspective is of special focus. Next, security measures are discussed including physical security measures, personnel and other measures. Specific issues such as technology deployment, standards and passenger acceptance are discussed in the European context. New concept for security is introduced. The main conclusions are drawn from the analysis. The existing security system at European airports is rather reactive than proactive. The new concepts rely heavily on technological developments while it is crucial to increase the focus on intelligence gathering and passenger experience. Based on the identified gaps in the existing literature, further research should focus on CBA of European aviation security system as well as human drivers of (in)security.

Keywords: security, airport, passenger, system

1. Introduction

Since 9/11 the security of air passengers has become a major concern in many countries, including the Member States of the European Union. The national governments as well as the European Commission have taken a number of steps to ensure passenger security both at airports and in the sky. Nevertheless, security incidents happen occasionally. This has significant implications on air traffic, revenues and costs of airports and airlines, implemented security measures and feelings of (in) security. The regulation is often adapted as a response to the occurring events. The airports implement new measures and take new precautions. They spend millions of Euros on security equipment and security staff to ensure security at airports and in the sky. Passengers have to follow the rules and spend more time at security checks than ever before. With every security incident that receives enough attention from the media, the passenger traffic drops. After a rather short period of time, however, the passenger traffic returns to the level reached before the incident. Nevertheless, in order to prevent future security incidents, the decision makers react strongly to new threats and impose new rules and security measures only after the incidents take place (reactive policy). These, unlike rather short periods of drop in traffic, are implemented for months or years. In other words, the new role of governments is not designed to intervene in airline economic decisions but it rather contributes to long-term structural change in the aviation security (Bailey, 2002).

Traffic from/to and within Europe concerns the second most important air transport market after the US. The European airports handle nowadays approximately 400 million air arrivals per year. This will most probably increase further in the next years. According to a number of long term forecasts (Airbus Company, 2011; Boeing Company, 2011), the passenger air traffic as well as the cargo air traffic are expected to grow in the coming years. The growth for Europe, as compared to other world destinations, is rather moderate but steady. This growth might evoke consequences such as inefficiencies (queues, transfer time, lost connections),

increased pressure on security staff, overall deterioration of passengers experience (Boeing Company, 2011). Additional challenges might come not only from the increased passenger demand within Europe but also from arrivals from rest of the world (RoW). There are more than 300 million passengers crossing the EU borders via air travel each year (160 EU nationals, 140 third country nationals - TCN) (Frontex, 2011). Top four EU hub airports (Charles de Gaulle, Fraport, Heathrow & Schiphol) handled last year approximately 90 million transfer passengers. There are approximately 600 airports in the whole EU. The cargo growth figures have been even higher in the last years. It is expected that the freight traffic will nearly triple over the next 20 years due to international trade expansion and express freight development in China, India & Brazil (Airbus Company, 2011).

Aviation is the most regulated mode of transport, also from the point of view of passenger and cargo security measures. Aviation security is usually broken down into three main building blocks. These include measures with regard to technology, process and people. Over the last years the main focus was put on the technology with less attention on process and people (IATA, 2012). The existing and applied approach towards security goes back to the 1970's and the governments as well as the aviation operators underline the need for re-thinking the existing security approach. Terrorists find more elaborate and unpredictable ways to disrupt aviation operations. There is, therefore, a strong need to ensure a balanced combination of measures that would include all three elements (IATA, 2012). While it can be observed that security has been strengthened in terms of specific regulation, equipment and procedures, it is important to know whether the existing measures are focussed on the areas that are the most important for maintaining high security levels. In order to establish that, the existing security system in aviation is analysed in this paper.

2. Safety vs. Security

The term 'safety' differs significantly from the term 'security'. Safety addresses all the unintentional acts that may result in undesirable situations. These include for example aircraft deviation from the assigned path resulting from malfunctioning of a specific part due to an unintentional mistake during aircraft maintenance. Safety incorporates a set of regulations, procedures, rules and processes to ensure passenger safe travel. On the other hand 'security' can be associated with intentional harmful acts against civil aviation or using civil aviation. Detailed statistics on security incidents are rather scarce and, due to the sensitive nature of the subject, they are not publicly available. It is known, however, that the data on security incidents collected by the airlines and airports includes not only the terrorist actions but also unruly passengers. Terms safety and security differ but, at the same time, there are also many issues that link them. For example typical radar systems installed at various airports have the capabilities of detecting the exact position and altitude of commercial aircraft, general aviation aircraft and helicopters. They are unable, however, to detect small flying objects such as new generation unmanned flying objects. The new generation of radars having such capabilities is currently under development for the civil use (Sinbad project, 2010). Such new radars would encompass both safety and security features.

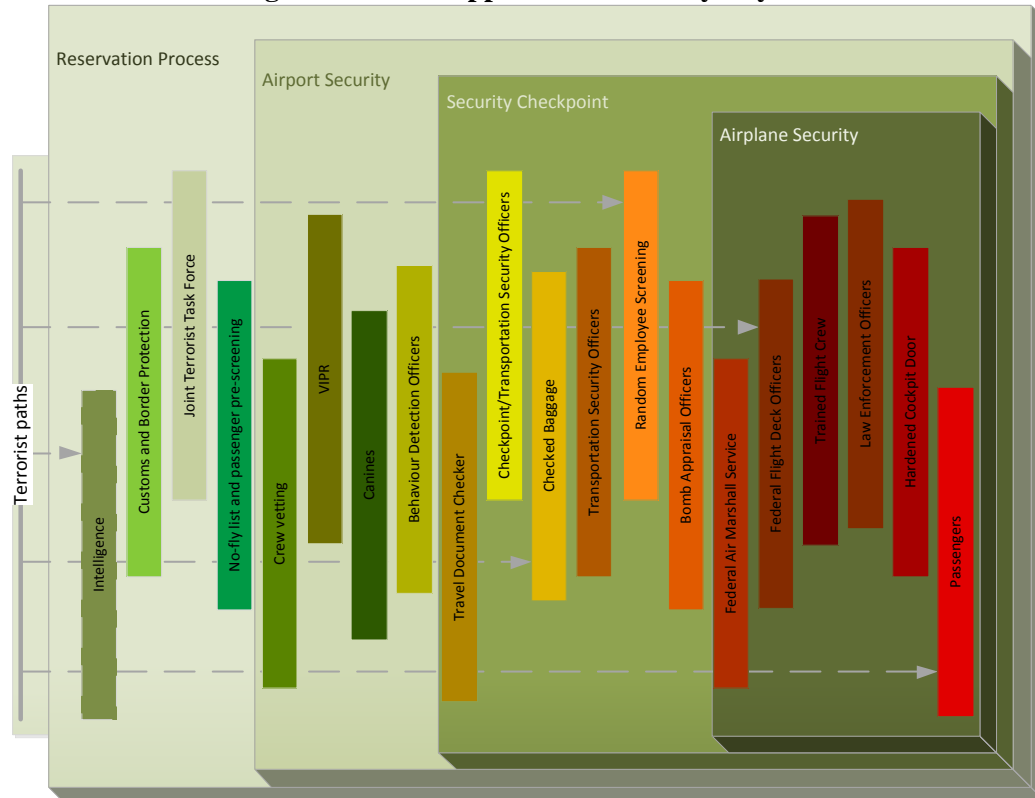
A security accident is not equal to a security incident. A security accident is an accident that happens as a result of acts of terrorism, violence or sabotage of civil aircraft. A security incident, however, is a situation in which a security accident almost happened. There are various types of security incidents which depend on the seriousness and on their impacts on the stakeholders involved and their operations. It should be noted that the probability of security incidents is higher than the probability of accidents. Additionally, it is important to mention that the number and severity of security accidents is different each year due to the low frequency of their occurrence and their specific characteristics. This means that the same number of aircraft movements might result in a different number and impact of accidents even when the security level remains the same. In a risk assessment approach, the security level is seen as a risk level with a certain probability of accidents.

3. Air vs. Ground

The aviation security does not only include the security checkpoint which all air passengers are familiar with but it includes a considerable number of other layers (TSA, 2012; IATA, 2012). The security layers include a number of measures which are implemented both on the ground as well as in the air. A passenger traveling from point A to point B has to go through a series of steps to get to her or his destination. The United States'

Transport Security Administration (TSA) has developed a layer approach aviation security. This approach underlines the variety and unpredictability of security measures. TSA Layers of Security include among others intelligence gathering and analysis, checking passenger manifests against watch lists, federal air marshals, etc. This list is not exclusive. Each of the layers applied may stop a security incident. In a holistic approach, the use of these security layers combined creates a stronger system and contributes to higher security levels. The European model is based on the ‘onion’ approach which defines various security layers encompassing other layers. Each of the ‘onion’ layers includes a number of security measures. Within the TSA approach the layers are not put on top of one another but rather implemented in different configurations in the overall security system. A combined approach of these two models is presented at Figure 1.

Figure 1: Onion Approach to Security Layers



Source: Based on TSA Layers of Security and IATA, 2011

The so called ‘Onion’ or ‘Layered Security Approach’ promoted by aviation stakeholders express their view on the importance of the enhanced coordination and information sharing between stakeholders. Additionally, airport processes including security, safety and border control related processes should be better integrated in order to reach these goals. Abeyratne (2010), Sweet (2008), and Frimpong (2011) research privacy concerns in security. These as well as other issues such as passenger name record (PNR)¹, biometrics, certification and conformity assessment of technologies (list non exhaustive) should be taken into account.

4. Quality of Security & Time

Security can be breached even in the extensively regulated sector such as aviation. Security incidents trigger the policy makers and the industry to develop and implement new security measures and regulations. A very

¹ Council Decision 2007/551/CFSP/JHA is an agreement between the EU and the US that enables to transfer and process 19 pieces of Passenger Name Record data by air carriers to the US Department of Homeland Security (DHS) (2007 PNR Agreement), the information includes for example names, travel dates, full itinerary, billing and baggage data.

relevant example is the UK/US airline bombing plot in August 2006. The terrorist tried to get liquids on the plane in order to build an improvised explosive device (IED). Only a few days later the EC (and TSA) banned the passengers from taking any liquids, gels and aerosols in their carry-on luggage on board of aircraft. Shortly afterwards, this ban was lifted and replaced by a regulation enabling the passengers to enter airports and aircraft with liquids, gels and aerosols in containers of maximum 100ml and in total not exceeding 1000ml stored in a plastic bag. The regulation was prepared in a very short period of time. The airports and security agents were not prepared for this and the duration of the whole security check process was extended significantly and affected (in a short term) the operations of many airports. For example in 2006 security was a primary departure delay cause in 2-3% of the overall causes in Europe while for some more busy airports it was the cause of up to 8% of delays (Eurocontrol, 2007). August was an exceptional month where extended duration of security checks was a major cause of delays in Europe. The temporary ban on liquids was planned to be resolved by the new technological inventions enabling to verify the chemical composition of the liquids carried by passengers. The technological development, driven by such incidents takes time. After the potential solution is invented, it has to be tested against strict criteria (that have to be developed). Finally, the equipment needs to get the passenger acceptance. Nevertheless, despite the technological innovations provided by the industry, after more than five years, the initially implemented regulation which was originally intended to be only temporary, is still in place while there is no comprehensive solution implemented in the whole EU. It proves that a lot of time is needed to develop thorough security measures and adequate legal provisions to enable the adequate response to a particular threat. The current security system at European airports is effective but also reactive.

The regulators and manufacturers need to develop smarter and faster aviation security devices and measures that can adapt to emerging threats and evolving passenger and cargo volumes. IATA stresses the importance of next-gen technology and equipment (IATA, 2012). The focus, however, should be put not only on equipment but on enhancing the flexibility of the overall security system and operational procedures (Jacobson et al., 2009) and enhanced cooperation of people from different stakeholder groups (Bemosa project, 2011).

The technology deployment differs per country and per airport. As a result, some airports can be the weaker point in the overall European security system. A streamlined technology deployment should be, therefore, ensured (IATA, 2012). Another aspect of ensuring the high security levels is the certification and conformity assessment of security equipment against common standards. This, however, needs further development (Ecorys, 2011; IATA, 2012). Producers often have to validate the same equipment against different standards in different countries which delays the deployment. In some cases, the airports cannot fully check the performance of the equipment as they do not have full access to the testing kits or the classified annexes of regulations (based on interview conducted with a Security Bureau Director at one of the European Airports).

5. Stakeholders Role in Security

There are various stakeholders involved in the aviation industry and some play a more important role with respect to maintaining high security levels than others. A passenger is one element of this system, it should be, however, the most important one.

5.1. Airport and ANSP

The role of the airport and air navigation service providers (ANSPs) is crucial in maintaining high security levels in aviation. A potential security incident that happens at an airport or affects the air traffic control ATC can have disastrous consequences both in terms of the number of people potentially affected as well as the impact on the operations and industry. It is the airport where a potential security threat can be detected and a person with malicious intentions can be prevented and apprehended. It is also the airport where an aircraft security breach attempt can be prevented. Due to the presence of security officers, police forces, border control and other relevant experts in one place, the airport enables their efficient cooperation and swift reaction. It is also the airport where the overall security of aircraft is maintained, including the ground handling operations, safety checks, maintenance and repairs. It is important to note that in order to maintain high security levels within the European aviation system, well-functioning security systems at airports and

ATC outside the EU are crucial. Passengers arriving in Europe from outside the EC need to go through a security check at the airport of departure. The European security system is, therefore, highly dependent on the functioning of security systems implemented at airports outside the EU. A leakage in the system somewhere at an airport for example in Yemen will affect security at for example Amsterdam airport. In 2009 a young passenger of Nigerian origin, Mr Umar Farouk Abdulmutallab, booked a flight from Lagos, Nigeria to Detroit, US with a transfer at Amsterdam Schiphol airport. He passed the security check in Lagos and arrived in the Netherlands. Later, he boarded the plane headed for the US. The passenger had explosives hidden in his underwear and made an unsuccessful attempt to blow up the aircraft with 290 people on board. This horrifying serious security incident shows the importance of every airport being a part of the overall aviation network. The airport belongs to a system of nodes, each of them being the most important place in the overall security system.

5.2. Airline and aircraft

An airline has to follow a number of rules, procedures and agreements including these on security. Airlines are obliged to prepare security plans which they have to submit to the national civil aviation authorities. They are not obliged, however, to present them to the airports (based on interview conducted with a Security Bureau Director at one of the European Airports). They also implement, according to the regulations or voluntarily in selected cases, a number of security measures such as hardened cockpit door or flight marshals. The personnel of the airline and aircraft is trained in the matters of security. In case of the so called “underwear bomber” it was the personnel and passengers that put down the fire and apprehended the attempted bomber. The airline and the aircraft play an important role in the aviation security system.

5.3. Security agent

Security agent at the airport plays a crucial role in ensuring high levels of aviation security. Security agents at various airports have a slightly different function and can be organized differently but they all perform the same role. At many airports in Europe the airport operators engage in agreements with private security companies that perform these activities. The examples can be found in the Netherlands or Spain. On the other hand, the security services can be provided by the military. The defence and security policies of selected countries, including France and Poland clearly indicate that this is the military (or its dedicated units) that perform these tasks. They have specialized military training and experience and, on top of that, they have additional legal power to use weapons or other resources when required. As private security agents have been performing their duties in a satisfactory manner at many airports, and, as their presence at airports is conditionally based on winning a specific tender, they can also be cheaper than the military. It is a reason for selected countries to reconsider the applicability of the military forces as security agents at airports. For example the Border Guards (part of military forces) are currently responsible for security checks at Polish Airports. It is expected that in the near future private security agents will be responsible for provision of security services at airports in Poland. This also concerns total visit costs of individual airports which is a competitive issue in airport benchmarking (see airport charges benchmark (SEO Economisch Onderzoek, 2008)).

5.4. Ground handling

Ground handling services include the services at the airport necessary for handling the aircraft, passengers and baggage. These include aircraft fuelling, catering and cleaning, push back, de-icing, etc. These services are provided by specialized ground handling companies. Their personnel and procedures meet various security standards and their proper and on time functioning is crucial to airline and airport operations. The baggage handling and cargo handling, however, are services critical from the point of view of maintaining high security levels in aviation. The passenger baggage handling is integrated with other services for handling civil passenger flights. The cargo handling, however, is handled separately (but can be loaded on civil passenger aircraft as well). The passenger aviation security is well organized and regulated. The procedures are well established and used widely. The cargo handling, however, is a relatively new and fast developing market that still requires further development in terms of security measures applied. It is important to note that these measures and procedures need not only to be applied at European airports but also airports outside the EU

where goods are loaded on board of aircraft in order to be brought to Europe. Only in October 2010 there was a plot which included two bombs placed on two cargo aircraft headed from Yemen to the US. Fortunately, the bombs were discovered during stopovers in UK and in Dubai and the tragedy was avoided. This shows the importance of ground handling agents in maintaining high security levels in the overall aviation system.

6. Security Measures

The security measures deployed and implemented at various airports in Europe include not only physical security measures visible to the passenger but also security personnel, specific processes and procedures as well as other measures such as paperless boarding pass or sniffing dogs (non-exhaustive list).

6.1. Physical security measures

Equipment used for maintaining or increasing aviation security levels is part of physical security measures. The equipment used includes technologies used for both disruptive security and continuous security (Ecorys, 2011). The typical examples of equipment categorized as serving disruptive security in aviation includes X-rays, bottled liquid (and gel) scanners, explosive detection systems, explosives trace detection, biometrics, imaging technology (so called security scanners or body scanners), etc. Some of them, such as the X-rays, are relatively well established and commonly used all over the world. Examples of equipment used for maintaining continuous security are for example camera systems.

Imaging technology (so called security scanners or more often named 'body scanners' in media), however, is deployed for tests at selected airports in Europe only. Formal trials of Security Scanners as a primary method for screening passengers were done in Finland, UK, in the Netherlands, France and Italy. The use of this technology is fragmented in Europe. The technology is capable of detecting a wide range of threats to transportation security. Its usage has been extensively debated in media and many issues regarding potential impact on health and privacy issues are still under discussion. Additionally, the EC expressed its concerns in its Communication from the Commission to the European Parliament and the Council on the Use of Security Scanners at EU airports of the 15 June 2010. Currently there are common rules in the field of aviation security in Europe² but there are no common European standards for the use of security scanners at airports. There are two main types of imaging technology - millimetre wave (passive and active) and backscatter (X-ray and X-ray transmission). There are also a few new technological developments under tests and development. Both millimetre wave and backscatter have been approved as safe for passengers in the USA and meet American health and safety standards (TSA, 2012). They also form part of the American layered security approach. In Europe, however, after a long period of tests, following the Commission Implementing regulation (EU) No 1147/2011 of 11 November 2011 amending Regulation (EU) No 185/2010 implementing the common basic standards on civil aviation security as regards the use of security scanners at EU airports, the security scanners which do not use ionising radiation have been accepted to be used at EU airports (in line with the Impact Assessment on the possible use of security scanners at EU airports). The approval for use of the X-ray backscatter and X-ray transmission imaging technology in the EU has been postponed until the impacts on human health are researched and the technology is confirmed to be safe.

Biometric security measures include retinal scans that enable identification of persons based on a unique set of identifiers such as fingerprints and iris scans. The development of these technologies is very recent (TSA, 2012). This technology is still under development and in the testing phase (deployed at a number of UK airports).

² Regulation (EC) No 2320/2002 of the European Parliament and of the Council of 16 December 2002 establishing common rules in the field of civil aviation security (OJ L 355, 30.12.2002) lays down European common standards for aviation security. Other relevant documents include the Annex 17 of the Chicago Convention. For further harmonization of the European rules, additional acts of implementing legislation were implemented. The 'One-stop security' in the European Union is a result of the common regulatory framework.

Bottled liquid scanner (BLS) screening systems are used for medically necessary liquids as well as liquids and gels at small quantities transported by passengers (deployed and tested at selected airports). The next generation BLS use light waves to screen sealed containers for liquid explosives.

Explosive detection systems (EDS) are used for screening passenger checked in and carry-on luggage. EDS equipment captures images of each bag and check if a baggage contains items that could be a potential threat. In case the system identifies such a potential threat, the bag is than checked by security officers at the airport at stake. In case a threat is confirmed, dedicated forces might have to be called in to prevent a security incident. At many European airports, especially hubs, these systems are automated. The industry is working on the development of new more efficient ones having more detecting capabilities.

Explosives Trace Detection (ETD) is technology used in order to detect traces of explosives both on baggage as well as on passengers. ETD is extensively used at many European airports and is part of the security onion approach as well as the layer approach used in the USA (TSA, 2012).

6.2. People

Aviation security relies on well trained and thoroughly selected people. The dedicated security staff working at airports is the selected group that assesses the risks, operates security equipment, etc. The security staff is crucial for maintaining high aviation security levels. It is not, however, the only group upon which the security relies. The people working for various stakeholders are also important part of the security system. The personnel of ground handling agents, the airport services employees, the airline employees have all basic training on security aspects and specific issues relating to their specific jobs. The Bemosa study aims at optimizing security and saving costs by minimizing false alarms and maximizing continuity of airport operations (Bemosa project, 2011). The preliminary results of the study stress the importance of development of realistic training based on actual behaviour in “normal” and “crisis” situations as well as better match between procedures and actual behaviour.

Passengers do not receive any security training. Being alert and resistant, however, can become crucial in preventing a security accident. According to (Smith, 2007), the passenger is the single security layer that is not costly and can prevent a repetition of events such as 9/11 accidents.

6.3. Other measures

The paperless boarding pass is a pilot tested by selected major European airports and airlines. The system enables the passengers to use their mobile phones or personal digital assistants (PDAs) to present their boarding pass in an electronic form. This system enables the passengers to save paper and time needed for printing the boarding pass and increases the ability to detect fraudulent boarding passes.

Threat Image Projection (TIP) is used throughout European airports. The security staff is tested on a daily basis whether they can detect explosives or weapons with the use of X-rays. This is done in order to make sure that the security staff is alert and does not fall into a routine trap. This provides additional basis for the assessment of staff as well as continuous improvement of the system.

Sniffing dogs are one more element in the overall system that is used to maintain high security levels. They are trained to detect not only drugs but also explosive materials.

7. Technology Deployment & Standards

As described above, the security system encompasses a number of advanced security measures. The equipment used for security protection differs significantly from airport to airport and its deployment depends on many factors. The deployment of equipment throughout airports in Europe is not even. Some airports use and test the most advanced technologies while others use mainly the well-established ones. Different security measures and procedures apply for example for flights to the USA or Israel from flights within the Schengen zone. The size of the airports differs significantly and, the time needed for security checks can differ as well.

Some airports, therefore, require more advanced technologies in order to be able to handle the increased number of passengers more efficiently while maintaining high security levels. This is often done with the use of the newest technological developments. According to IATA the acceleration in the deployment of next generation EDS, ETD, X-ray, and magnetometer equipment is key to maintaining high security levels at European airports (IATA, 2012).

The equipment implemented at European airports is certified by certification bodies selected and appointed by the European Civil Aviation Conference (ECAC). For example X-rays have been in use for many years now and standards and procedures for their use have been extensively tested and established. As for the new technological developments, such as the imaging technology, the standards are developed by producers while the certifying and conformity assessment bodies test the equipment and verify it against producers criteria but in fact, the users are often unable to confirm the performance of the equipment as described by producers. Additionally, due to lack of uniform standards for different countries, the producers often have to adapt each product to the needs of a specific client and certification body. This increases the costs of the product development.

The level of deployment of the new technological developments differs per Member State while “one stop security check” rule applies in the Schengen area of the European Union. The new technological developments can help in maintaining high security levels, while European wide standardization and deployment is under development.

8. Passenger Perspective & Acceptance

Over time, the security checks of the passengers have become more complex and in some cases longer. While various stakeholders are involved in maintaining high security levels in aviation, the passenger perspective might impact his or her decision on which airport or mode of transport to choose. In this way security quality and security costs also touch upon the issue of airport competition.

The goal of the airport security officer should be to maintain high security levels as well as to enable passenger facilitation. Airport security and facilitation is currently one of the main topics addressed by IATA, the syndicate of the airlines via its Passenger Experience Management Group (PEMG) and Airport Council International (ACI) via its Security Facilitation Committee (IATA, 2012).

The passenger acceptance of aviation security measures as well as the passenger privacy (Abeyratne, 2010), (Frimpong, 2011) have recently been heavily debated in media with respect to the newly developed imaging technology. It resulted in the changes in the technology and privacy issues related to this technology. As a consequence, the images from the equipment are nowadays sent to a separate room where a dedicated person can review them. The images do not show any intimate body parts but enable the detection of any materials that are placed on or within the body. Finally, the images are not stored for longer than for the time needed to assess the image. In Europe the studies on the acceptance of this technology conducted in the UK, NL and Finland show that security scanners are regarded to be a less intrusive method than full hand search (EC, 2011). It is important, however, that the passengers are satisfied with the services, including the security related processes. The customer satisfaction has been analysed in the literature. According to (Hunter, 2011) “smiling customer service within the airline industry builds customer loyalty, fosters profits, and helps reduce air rage”. His conclusions are that the outcomes of his study could be used to construct training programs that support developing airline personnel in particular areas of customer service, including frontline staff, flight attendants, and security personnel. The subject of the risk perception has also been reviewed extensively by Kaplan et al. (1974), Greco (1989), Yates (1992), Slovic (2000). The subject of the passenger perception of the security measures and procedures in relation with the actual security levels is addressed in a very limited number of publicly available scientific articles. A recent research project conducted for the EC (Brück, 2007) identifies a number of substantial gaps in the transport security research. Among others these include the human drivers of insecurity.

9. New concept - Checkpoint of the Future by IATA

The current security checkpoint concept relies on a number of different security measures while the passenger has to put the liquids together in a plastic bag, take out his electronic equipment from his carry-on luggage, take off his jacket, shoes, belt or watch, go through a metal detector or other detectors, etc. This process is lengthy and not very enjoyable to the passengers. IATA is currently developing the so called “Checkpoint of the future”. The new concept is based on a three security lanes concept that would feature embedded screening technologies defined by the level of risk associated with the passenger (IATA, 2012). The passengers who have registered and completed background checks would have expedited access while for the passengers for whom there is less information available or are at higher risk or have been randomly selected would have to go through more detailed screening. This concept relies on technology that is currently under development and which would enable the travellers to go through automated corridors without the need of taking any clothes off or putting their luggage on a separate belt for scanning. This concept would heavily rely on technology but should increase the passenger experience.

As described by Jacobson et al. (2009), there is a need for designing more flexible and agile security screening operations, balancing technology and human approaches to security operations, and using intelligence to focus appropriate levels of security resources on both stopping terrorists and stopping tactics.

10. Further Research

According to IATA, technology used for maintaining high security levels in aviation must be cost-effective. There is only a few number of studies that analyse the economic impacts and cost effectiveness of selected aviation security measures in the US (Hobijn, 2002; Stewart & Mueller, 2008A; US Government Accountability Office, 2009; Jackson et. al., 2011) and Australia (Stewart & Mueller, 2008B). There is, however, a very limited number of studies that would analyse the costs and the benefits of the European security measures. There are only few national studies in this field (Akhtar, 2010; UK Department for Transport, 2010; EC, 2011). Ten years after 9/11 the aviation industry is impacted by not only increasing fuel prices and environmental compensation but also by the increased costs of security. Before 9/11 the overall security costs borne by the airlines and passengers constituted 5-8% of the operating costs of the airlines while nowadays they are at the level of 32-35%. According to (Anderson, 2006) we do not know much about the costs and the benefits of security.

There is no Cost Benefit Analysis of the security measures and the overall system conducted so far for Europe. The detailed costs of security in Europe are also somehow neglected in the existing literature.

The aviation security can be broken down into the three I's of screening: Items (threats), Identity (passengers), and Intent (people) (Jacobson & Lee, 2010). The European wide security approach should focus not only on further technological improvements, but be much more oriented on people and flexibility of procedures.

Finally, little is known on the current perspective of passengers on the existing security measures as well as their perception on the current security levels. It is unclear how security accidents and incidents impact the human drivers of (in) security. It is proposed, therefore, to conduct a survey among passengers at one of the European leading airports to analyse the human drivers of insecurity in aviation.

11. Conclusion

The aviation security system in Europe has developed over time and it is important that this development is continued in a comprehensive way. The new concepts are under development. They are, however, heavily based on the technology rather than on people or information. The new technological developments can help in maintaining high security levels, but it is crucial to ensure equal focus on intelligence gathering as well as improved passenger experience. With current crisis and budget tightening every policy, the security policy will, come under increased scrutiny to yield benefits for the costs made. It is an issue that will be crucial for many years to come, at least until 2020. The costs made and benefits of the EU aviation security measures have not been thoroughly analysed so far. Before taking future decisions on making capital intensive investments, such an analysis should be done. Passenger experience as well as perception of (in)security should be analysed and taken into account in designing the systems and considered in the CBA research.

The terrorist activities enter new areas and become more challenging. The existing security policy in European aviation is rather reactive than proactive. There is a need for flexibility in designing the systems and operations in order to ensure high security levels.

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Effects of High-Speed Rail and Air Transport Competition on Prices, Profits and Welfare

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Abstract

This paper studies competition between air transport and high-speed rail (HSR). While airlines are assumed to maximize profit, HSR may maximize a weighted sum of profit and social welfare. We show that both airfare and HSR fare fall as the weight on welfare increases, while airfare decreases, and rail fare increases, in the airport access time. Furthermore, airfare decreases in the rail speed if the marginal cost of HSR with respect to the rail speed is not too large. On the other hand, whether rail fare increases in the rail speed depends on the marginal cost of HSR with respect to the rail speed as well as on the welfare weight. We further compare prices, profits and welfare between “with price discrimination” in which airlines price discriminate business from leisure passengers and “without price discrimination”. Welfare in the HSR system can be either higher or lower with price discrimination: In particular, the welfare is higher under price discrimination when the travel benefit difference is sufficiently larger than the time value difference between business and leisure passengers.

Keywords: Air transport; High-speed rail; Bertrand competition; Hotelling line; Price discrimination

1. Introduction

The first modern high-speed rail (HSR) went into operation in 1964 in Japan: the route between Tokyo and Osaka with a maximum speed of 210 km/h was very successful. In 1976, British Railways opened an HSR line between London and Bristol. France commenced the operation of its first HSR between Paris and Lyon in 1981. Since then, many European countries have built HSR lines, including Spain, Germany, Italy, Belgium, and the Netherlands.¹ In Asia, South Korea started its first HSR line between Seoul and Daegu in 2004 (which later was extended to Busan), and Taiwan started its first HSR service between Taipei and Kaohsiung in 2007.

Yet, the most ambitious HSR development so far is in China: Its original plan, first elaborated in a National Development Plan in 2003, was to build a 12,000 route-km HSR network by 2020, based on a network of four vertical and four horizontal trunk lines. The stimulus package launched by China in 2008 to mitigate the impact of the global financial crisis has more than doubled the investment funds available for railways for 2008-2010, enabling the Ministry of Railways to accelerate the HSR construction. The total investment in the HSR network is about USD 300 billion. As a result, the completion dates of several projects have been brought forward, and it is now planned to complete construction of 42 HSR lines by 2012, amounting to 13,000 km HSR coverage by 2012. This will give China the world's largest and most modern HSR network.

In this paper we investigate competition between air transport and high-speed rail. As train speeds become

¹ According to a recent report by the World Bank (Amos et. al., 2010), total length of dedicated HSR lines in Europe was, as of July 2010, about 5,500 km.

faster, HSR is likely to impose significant competitive pressures on air transport. Janic (1993) finds that HSR can compete with air transport over a relatively large range of distances from 400 to over 2,000 km. Rothengatter (2011) finds that *fierce* competition between air transport and HSR may occur on routes with distance up to 1,000 km, mostly likely between 400 and 800 km. In China, for example, all the flights between Zhengzhou and Xi'an (505 km) suspended in March 2010, 48 days after the opening of HSR service, while daily flights on the Wuhan-Guangzhou route (1,069 km) reduced from 15 to 9, one year after the HSR entry (Fu et al. 2011).

In particular, we consider a differentiated Bertrand duopoly in which two ends of the Hotelling line represent air transport and high-speed rail respectively. An important feature of our analysis is that air and rail operators can have different objective functions. With worldwide deregulation in the airline industry, airlines are, not surprisingly, profit maximizers. Due to the huge capital requirement, on the other hand, HSR networks around the world are typically invested or co-invested by governments. While governments may want to maximize social welfare, rail companies or authorities typically need to recover their costs. In other words, unlike airlines, the objective of HSR operators is likely to be a weighted sum of welfare and profit.

By first assuming homogeneous passengers, we show that both airfare and HSR fare fall as the weight on welfare increases, while airfare decreases, and rail fare increases, in the airport access time. We further find that airfare decreases in the rail speed if the marginal cost of HSR with respect to the rail speed is not too large. On the other hand, whether rail fare increases in the rail speed depends on the marginal cost of HSR with respect to the rail speed as well as on the weight on welfare in the HSR's objective function. In particular, we find that the only constellation where the rail fare decreases in the rail speed is when the marginal cost of HSR with respect to the rail speed is sufficiently small and the weight of welfare is sufficiently large.

We then extend the analysis to the case of heterogeneous passengers. In practice, passengers can be roughly divided into two groups: business and leisure travelers, with each group of passengers having different travel benefits and different values of time. Specifically, business travelers are expected to have higher travel benefit and higher time value than leisure travelers. We find that if airlines do not price discriminate business passengers against leisure passengers, then our main results obtained with homogenous passengers continue to hold. Next, we compare prices, profits and welfare between "with price discrimination," in which airlines engage in price discrimination between business and leisure passengers, and "without price discrimination". We find that the profit of air transport is higher with price discrimination than without price discrimination, while the profits of HSR remain unchanged. Furthermore, welfare in the HSR system can be either higher or lower with price discrimination: In particular, the welfare is higher under price discrimination when the ratio of travel benefit difference over time value difference is larger than a critical value.

Adler et. al. (2010) use a game theoretic setting to analyze competition between air transport and HSR in the medium to long distance transport market. They assume that airlines and HSR maximize their own profits. From the European case study, they conclude that the European Union (EU) should encourage the development of the HSR network across Europe. Rothengatter (2011) finds empirical evidence in EU on the competition between air transport and HSR, and points out the possibilities to increase the competitive power of HSR. By using the stated preference survey method, Park and Ha (2006) find that the opening of the first HSR line in South Korea has a significant impact on the domestic air transport industry. By applying experimental techniques to analyze the competition between air transport and HSR, Gonzalez-Savignar (2004) finds that HSR has a significant impact on the market share of air transport. Simulations reveal that total journey time is the most important determinant of market share. Roman et al. (2007) analyze the competition of HSR with air transport based on mixed revealed and stated preference data between Madrid and Barcelona. They obtain different willingness-to-pay measures for service quality improvement. While all the above papers utilize empirical or survey data to study the impact of HSR on air transport, our paper is purely analytical with the use of a Hotelling (differentiated Bertrand) model. Another distinct feature of our paper is that the objective of HSR is to maximize a weighted sum of welfare and profit rather than just profit.

The paper is organized as follows. Section 2 sets up the basic model. In Section 3 we solve the equilibrium results and examine the effects of welfare weight, airport access time and rail speed on airfare and HSR fare.

Section 4 extends the basic model to a more general setting which models two types of passengers and price discrimination. Finally, Section 5 contains concluding remarks.

2. Basic Model

Consider a competition model between air transport and high-speed rail (HSR) on a route. Total journey time is the sum of access time and travel time

$$t_i = \alpha_i + \frac{l}{s_i}, \quad (1)$$

where l is the route length, s_i is the speed of transport mode i and α_i is the corresponding access time with $i = a$ (air transport) or $i = r$ (HSR). (Note that the access time in the model includes the time of both accessing to and egressing from, the transport terminals.) It is reasonable to assume that $\alpha_a > \alpha_r$ and $s_a > s_r$. Furthermore, we consider s_a to be a constant: s_a is close to the speed of sound and has been relatively stable. On the other hand, rail speed can vary a lot and in practice, there are active debates on how fast HSR should be. Thus, s_r may be considered as a variable. Same as Adler et al. (2010), we shall consider medium to long haul routes such that $t_r > t_a$, i.e. total journey time is shorter with air transport than with HSR.

In the basic model, all the passengers are assumed to be homogeneous. The benefit of travel is b and the value of time is v . The Hotelling model is adopted to capture the product-differentiation aspect of the two transport modes. In particular, on the linear city line, air transport is located at 0 and HSR at 1. Consumers are uniformly distributed between 0 and 1 and for simplicity; we assume that b is sufficiently large such that all the consumers will travel. Passengers located at x are indifferent between taking air transport and HSR:

$$b - p_a - v \cdot t_a - \tau \cdot x = b - p_r - v \cdot t_r - \tau \cdot (1 - x) \geq 0, \quad (2)$$

where p_i is the price of transport mode i , and the disutility parameter τ measures disutilities other than value of time (e.g. comfort, safety).

The total market size is normalized to 1, and so the profit of air transport is

$$\pi_a = (p_a - c_a)x - f_a, \quad (3)$$

where f_a is the fixed cost, and c_a is the unit operating cost. Similarly, the profit of HSR is

$$\pi_r = (p_r - c_r)(1 - x) - f_r, \quad (4)$$

where f_r is the fixed cost, and $c_r = c_r(s_r)$ is the unit operating cost, with

$$\frac{\partial c_r}{\partial s_r} > 0. \quad (5)$$

While it is reasonable to assume that airlines maximize profit by choosing price p_a , the HSR operator may take also consumer interests into account in its decision making. The consumer surplus of HSR passengers is

$$CS_r = \int_x^1 (b - p_r - vt_r - \tau(1 - y)) dy. \quad (6)$$

It follows that social welfare in the HSR system is

$$W_r = \pi_r + CS_r. \quad (7)$$

We consider that by choosing its price, HSR maximizes a weighted sum of welfare and profit:

$$\theta W_r + (1 - \theta)\pi_r, \quad (8)$$

where $0 \leq \theta \leq 1$ is the weight on social welfare.

3. Effects of Welfare Weight, Access Time and Rail Speed

It is straightforward to derive the equilibrium solutions for the basic model described in Section 2 (* for equilibrium):

$$p_a^* = \frac{1}{6 - 5\theta} (4c_a + 2c_r + 6\tau + 2(t_r - t_a)v - \theta(2b + 4\tau + 3c_a - 2t_a v)), \quad (9)$$

$$p_r^* = \frac{1}{6 - 5\theta} (2c_a + 4c_r + 6\tau - 2(t_r - t_a)v - \theta(4b + 3\tau + c_a - (5t_r - t_a)v)), \quad (10)$$

$$x^* = \frac{1}{(6 - 5\theta)\tau} (c_r - c_a + 3\tau + (t_r - t_a)v - \theta(b + 2\tau - c_a - t_a v)). \quad (11)$$

In the above solutions we have implicitly assumed

$$0 \leq x^* \leq 1, \quad (12)$$

$$b - p_a^* - vt_a - \tau x^* \geq 0, \quad (13)$$

where (12) guarantees that both transport modes exist in equilibrium, and (13) means that both transport modes compete directly with each other; and all the passengers travel and receive nonnegative payoffs.² Inequalities (12) and (13) require that

$$\frac{c_r - c_a - 3\tau + (t_r - t_a)v}{b - 3\tau - c_a - vt_a} \leq \theta \leq \frac{c_r - c_a + 3\tau + (t_r - t_a)v}{b + 2\tau - c_a - vt_a}, \quad (14)$$

$$\theta \leq \frac{3(2b - c_r - c_a - 3\tau - (t_r + t_a)v)}{2(b - 3\tau - c_a - vt_a)}. \quad (15)$$

In what follows, the parameters are thus assumed in the ranges where (14) and (15) hold. First, we examine the effect of welfare weight θ on the equilibrium airfare p_a^* and HSR ticket price p_r^* :

Proposition 1. As the weight on social welfare increases, both airfare and HSR ticket price decrease.

Proof. Given that b is sufficiently large, it is straightforward to verify that

² This is a simplifying assumption that allows us to focus on the competition between air transport and HSR.

Alternatively, we may assume that b is sufficiently large such that air transport and HSR engage in direct competition and all the passengers travel.

$$\frac{\partial p_a^*}{\partial \theta} = -\frac{2}{(6-5\theta)^2} (6b-3\tau-c_a-5c_r-(5t_r+t_a)v) < 0, \quad (16)$$

$$\frac{\partial p_r^*}{\partial \theta} = -\frac{4}{(6-5\theta)^2} (6b-3\tau-c_a-5c_r-(5t_r+t_a)v) < 0. \quad (17)$$

Q.E.D.

Proposition 1 is rather intuitive: As the HSR authority puts more weights on social welfare, the rail fare will fall. In order to compete for passengers, the airfare will fall as well: note that the two “best response functions” are positively sloped in the price dimensions.

Since the airport access time is a very important decision for policy makers, we investigate the impact of access time to the airport on airfare and rail fare.

Proposition 2. Airfare increases in the airport access time, while HSR ticket price decreases in the airport access time.

Proof. Taking the first derivatives with respect to the airport access time α_a yields

$$\frac{\partial p_a^*}{\partial \alpha_a} = -\frac{2(1-\theta)v}{6-5\theta} \leq 0, \quad (18)$$

$$\frac{\partial p_r^*}{\partial \alpha_a} = \frac{1}{6-5\theta} \left((2-\theta)v \frac{\partial t_a}{\partial \alpha_a} \right) = \frac{(2-\theta)v}{6-5\theta} > 0. \quad (19)$$

Q.E.D.

Proposition 2 is expected: As the access time to the airport increases, the speed advantage of air transport decreases, and so the HSR becomes more attractive. As a result, airfare will fall and HSR fare will rise. Finally, we examine the impact of rail speed on airfare and rail fare:

Proposition 3.

(i) Airfare decreases in the rail speed if $\frac{\partial c_r}{\partial s_r} \leq \frac{vl}{s_r^2}$, i.e. the marginal cost of HSR with respect to rail speed is not too large. Otherwise, airfare increases in the rail speed.

(ii) Rail fare increases in the rail speed if $\frac{\partial c_r}{\partial s_r} \geq \frac{(5\theta-2)vl}{4s_r^2}$, i.e. the marginal cost of HSR with respect to rail speed is not too small. Otherwise, rail fare decreases in the rail speed.

Proof. Taking the first derivatives with respect to the rail speed s_r yields

$$\frac{\partial p_a^*}{\partial s_r} = \frac{2}{6-5\theta} \left(\frac{\partial c_r}{\partial s_r} - \frac{vl}{s_r^2} \right), \quad (20)$$

$$\frac{\partial p_r^*}{\partial s_r} = \frac{1}{6-5\theta} \left(4 \frac{\partial c_r}{\partial s_r} - (2-5\theta)v \frac{\partial t_r}{\partial s_r} \right) = \frac{1}{6-5\theta} \left(4 \frac{\partial c_r}{\partial s_r} - (5\theta-2) \frac{vl}{s_r^2} \right). \quad (21)$$

Clearly, we have

$$\frac{\partial p_a^*}{\partial s_r} \leq 0 \Leftrightarrow \frac{\partial c_r}{\partial s_r} \leq \frac{vl}{s_r^2}, \quad (22)$$

$$\frac{\partial p_r^*}{\partial s_r} \geq 0 \Leftrightarrow \frac{\partial c_r}{\partial s_r} \geq \frac{(5\theta - 2)vl}{4s_r^2}. \quad (23)$$

Q.E.D.

Proposition 3(i) says that as long as the marginal cost with respect to the rail speed is not too large, airfare falls as the rail speed increases. The intuition can be explained as follows. The higher rail speed leads to higher marginal cost, which puts an upward pressure on the rail price. Airfare also tends to increase as the rail speed increases. On the other hand, as the rail speed increases, the speed advantage of air transport becomes smaller, and so the higher rail speed puts a downward pressure on airfare. When the marginal cost is small, the latter effect dominates the former effect.

Proposition 3(ii) says that the HSR ticket price is increasing in the rail speed as long as the marginal cost with respect to the rail speed is not too small. Whether the rail fare increases in the rail speed depends on both the marginal cost and the weight on welfare θ . Note that when $\theta \leq 2/5$, then $\partial p_r^* / \partial s_r \geq 0$ always holds.

Suppose $\theta > 2/5$, then $\partial p_r^* / \partial s_r$ might become negative when $\partial c_r / \partial s_r$ is sufficiently small. The intuition can be explained as follows. As the rail speed increases, the unit cost of HSR increases, and so the rail fare tends to increase as well. When the weight on welfare is sufficiently large, the welfare-maximizing objective puts a downward pressure on the rail fare. Hence, the overall effect of the rail speed on rail fare is not clear, depending on which effect dominates.

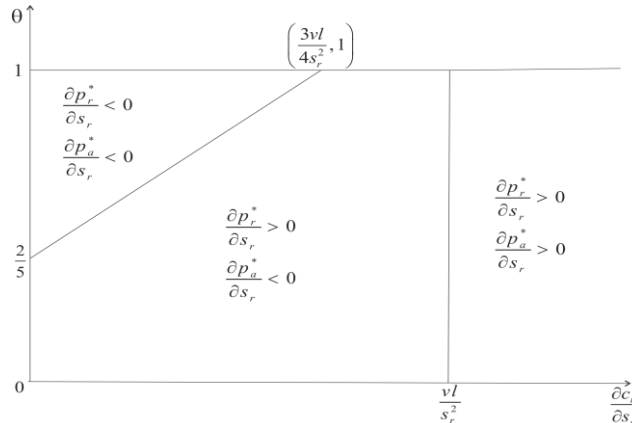
To summarize the impact of the rail speed on the airfare and the rail fare, we have

$$\begin{aligned} \frac{\partial p_r^*}{\partial s_r} < 0, \frac{\partial p_a^*}{\partial s_r} < 0 & \text{ when } \frac{\partial c_r}{\partial s_r} < \frac{(5\theta - 2)vl}{4s_r^2} \\ \frac{\partial p_r^*}{\partial s_r} > 0, \frac{\partial p_a^*}{\partial s_r} < 0 & \text{ when } \frac{(5\theta - 2)vl}{4s_r^2} < \frac{\partial c_r}{\partial s_r} < \frac{vl}{s_r^2} \\ \frac{\partial p_r^*}{\partial s_r} > 0, \frac{\partial p_a^*}{\partial s_r} > 0 & \text{ when } \frac{\partial c_r}{\partial s_r} > \frac{vl}{s_r^2}, \end{aligned} \quad (24)$$

which is graphically illustrated in Figure 1: If the marginal cost of HSR with respect to rail speed is sufficiently small (left upper corner), then both airfare and HSR fare decrease in the rail speed. If the marginal cost is sufficiently large (rightmost part), then both airfare and rail fare increase in the rail speed. Otherwise (middle part), HSR fare increases, while airfare decreases in the rail speed.

Figure 1: Impact of Rail Speed on Airfare and Rail Rare

(The horizontal axis is the marginal cost of HSR with respect to the rail speed, and the vertical axis is the weight on welfare)



4. Extensions

In this section, we extend the basic model to a more general setting where there are two types of passengers: the proportion $\beta \in (0,1)$ are business passengers and the remaining $1-\beta$ are leisure passengers. Let b_h and v_h denote the travel benefit and the value of time of business passengers, respectively. Similarly, the travel benefit and the value of time of leisure passengers are denoted as b_l and v_l , respectively. It is reasonable to assume that $b_h > b_l$ and $v_h > v_l$ (see, e.g., Morrison, 1987; Pels et al., 2003; Czerny and Zhang, 2011).

If airlines do not price discriminate business passengers against leisure travelers, then the main difference between the current setup and the basic model is that two Hotelling lines are now used (rather than just one line as in the single passenger type): one for business passengers and the other for leisure passengers. To differentiate with the basic model, we use “~” to denote the equilibrium solutions in the general setting. It can be shown (superscript N for “no price discrimination”):

$$\tilde{p}_a^* = \frac{1}{6-5\theta} (4c_a + 2c_r + 6\tau + 2(t_r - t_a)\bar{v} - \theta(2\bar{b} + 4\tau + 3c_a - 2t_a\bar{v})), \quad (25)$$

$$\tilde{p}_r^{N*} = \frac{1}{6-5\theta} (2c_a + 4c_r + 6\tau - 2(t_r - t_a)\bar{v} - \theta(4\bar{b} + 3\tau + c_a - (5t_r - t_a)\bar{v})), \quad (26)$$

$$\tilde{x}_h^{N*} = \frac{2c_r - 2c_a + 6\tau + (t_r - t_a)(6v_h - 4\bar{v}) - \theta(2\bar{b} + 4\tau - 2c_a - (5t_r - 3t_a)\bar{v} + 5(t_r - t_a)v_h)}{2(6-5\theta)\tau}, \quad (27)$$

$$\tilde{x}_l^{N*} = \frac{2c_r - 2c_a + 6\tau + (t_r - t_a)(6v_l - 4\bar{v}) - \theta(2\bar{b} + 4\tau - 2c_a - (5t_r - 3t_a)\bar{v} + 5(t_r - t_a)v_l)}{2(6-5\theta)\tau}, \quad (28)$$

where $\bar{v} = \beta v_h + (1-\beta)v_l$ and $\bar{b} = \beta b_h + (1-\beta)b_l$ are the average time value and the average travel benefit, respectively. Like the basic-model case, we have implicitly assumed that

$$0 \leq \tilde{x}_l^{N*}, \tilde{x}_h^{N*} \leq 1, \quad (29)$$

$$b_h - \tilde{p}_a^* - v_h t_a - \tau \tilde{x}_h^{N*} \geq 0, \quad (30)$$

$$b_l - \tilde{p}_a^* - v_l t_a - \tau \tilde{x}_l^{N*} \geq 0. \quad (31)$$

Comparing (9)-(10) with (25)-(26) reveals that the results of the basic model are still valid in the general setting without price discrimination. It is straightforward to verify

$$\tilde{x}_h^{N*} - \tilde{x}_l^{N*} = \frac{(t_r - t_a)(v_h - v_l)}{2\tau}. \quad (32)$$

Since $v_h > v_l$ and $t_r > t_a$, it follows that $\tilde{x}_h^{N*} > \tilde{x}_l^{N*}$: Compared with leisure travelers, business travelers have higher time value and so are more likely to take the faster transport mode. On the medium to long haul routes we are considering, air transport has shorter total journal time than HSR, and so business passengers are more likely to take the air mode.

In practice, airlines often price discriminate the two passenger types: they charge higher price p_{ah} to business passengers and lower price p_{al} to leisure passengers. On the other hand, HSR usually doesn't price discriminate:

it charges p_r to all passengers. For business passengers, we have

$$b_h - p_{ah} - v_h \cdot t_a - \tau \cdot x_h = b_h - p_r - v_h \cdot t_r - \tau \cdot (1 - x_h). \quad (33)$$

Business passengers located at x_h are indifferent between the air and rail modes. Similarly, for leisure passengers,

$$b_l - p_{al} - v_l \cdot t_a - \tau \cdot x_l = b_l - p_r - v_l \cdot t_r - \tau \cdot (1 - x_l). \quad (34)$$

The profit of air transport is given by

$$\pi_a = \beta(p_{ah} - c_a)x_h + (1 - \beta)(p_{al} - c_a)x_l - f_a, \quad (35)$$

whereas the profit of HSR is

$$\pi_r = \beta(p_r - c_r)(1 - x_h) + (1 - \beta)(p_r - c_r)(1 - x_l) - f_r. \quad (36)$$

The consumer surplus of HSR passengers is

$$CS_r = \beta \int_{x_h}^1 (b_h - p_r - v_h t_r - \tau(1 - y)) dy + (1 - \beta) \int_{x_l}^1 (b_l - p_r - v_l t_r - \tau(1 - y)) dy. \quad (37)$$

Analogous to the basic model, airlines choose p_{ah} and p_{al} to maximize profit (35), while HSR chooses p_r to maximize the weighted sum of welfare and profit (8). The equilibrium results are:

$$\tilde{p}_{ah}^* = \frac{8c_a + 4c_r + 12\tau + (t_r - t_a)(6v_h - 2\bar{v}) - \theta(4\bar{b} + 8\tau + 6c_a - (5t_r - t_a)\bar{v} + 5(t_r - t_a)v_h)}{2(6 - 5\theta)}, \quad (38)$$

$$\tilde{p}_{al}^* = \frac{8c_a + 4c_r + 12\tau + (t_r - t_a)(6v_l - 2\bar{v}) - \theta(4\bar{b} + 8\tau + 6c_a - (5t_r - t_a)\bar{v} + 5(t_r - t_a)v_l)}{2(6 - 5\theta)}, \quad (39)$$

$$\tilde{p}_r^* = \frac{1}{6 - 5\theta} (2c_a + 4c_r + 6\tau - 2(t_r - t_a)\bar{v} - \theta(4\bar{b} + 3\tau + c_a - (5t_r - t_a)\bar{v})), \quad (40)$$

$$\tilde{x}_h^* = \frac{4c_r - 4c_a + 12\tau + (t_r - t_a)(6v_h - 2\bar{v}) - \theta(4\bar{b} + 8\tau - 4c_a - (5t_r - t_a)\bar{v} + 5(t_r - t_a)v_h)}{4(6 - 5\theta)\tau}, \quad (41)$$

$$\tilde{x}_l^* = \frac{4c_r - 4c_a + 12\tau + (t_r - t_a)(6v_l - 2\bar{v}) - \theta(4\bar{b} + 8\tau - 4c_a - (5t_r - t_a)\bar{v} + 5(t_r - t_a)v_l)}{4(6 - 5\theta)\tau}. \quad (42)$$

Since the results of comparative statics in the general model with price discrimination are similar to, but more complicated than, those in the basic model, they are omitted. It is more interesting to compare the equilibrium results between “no price discrimination” (uniform pricing) and “with price discrimination”. First, the fare and passenger demand comparisons are given below:

Proposition 4. (i) $\tilde{p}_r^* = \tilde{p}_r^{N*}$, i.e., the rail fares remain the same with or without price discrimination.

(ii) $\tilde{p}_{al}^* < \tilde{p}_a^{N*} < \tilde{p}_{ah}^*$, i.e., the airfare for leisure passengers is lower than the uniform airfare, which in turn is lower than the airfare for business passengers.

(iii) $\tilde{x}_l^{N*} < \tilde{x}_l^* < \tilde{x}_h^* < \tilde{x}_h^{N*}$, i.e., less business passengers travel by air transport with price discrimination than under uniform pricing, while more leisure passengers travel by air transport under price discrimination than under uniform pricing.

Proof. (i) It is easy to see that $\tilde{p}_r^* = \tilde{p}_r^{N*}$.

(ii) Subtracting \tilde{p}_a^{N*} from \tilde{p}_{ah}^* yields $\tilde{p}_{ah}^* - \tilde{p}_a^{N*} = \frac{1}{2}(1-\beta)(v_h - v_l)(t_r - t_a) > 0$. Subtracting \tilde{p}_{al}^* from \tilde{p}_a^{N*} we obtain $\tilde{p}_a^{N*} - \tilde{p}_{al}^* = \frac{1}{2}\beta(v_h - v_l)(t_r - t_a) > 0$. It follows that $\tilde{p}_{al}^* < \tilde{p}_a^{N*} < \tilde{p}_{ah}^*$.

(iii) Subtracting \tilde{x}_h^* from \tilde{x}_h^{N*} yields $\tilde{x}_h^{N*} - \tilde{x}_h^* = \frac{1}{4\tau}(1-\beta)(v_h - v_l)(t_r - t_a) > 0$. Subtracting \tilde{x}_l^* from \tilde{x}_h^* we obtain $\tilde{x}_h^* - \tilde{x}_l^* = \frac{1}{4\tau}(v_h - v_l)(t_r - t_a) > 0$. Subtracting \tilde{x}_l^{N*} from \tilde{x}_l^* yields

$$\tilde{x}_l^* - \tilde{x}_l^{N*} = \frac{1}{4\tau}\beta(v_h - v_l)(t_r - t_a) > 0. \text{ Therefore, we have } \tilde{x}_l^{N*} < \tilde{x}_l^* < \tilde{x}_h^* < \tilde{x}_h^{N*}. \quad Q.E.D.$$

Proposition 4 is mostly self-explanatory. In particular, part (ii) shows that the discriminating fare in the business-passenger market always exceeds the uniform fare, while the discriminating fare in the leisure-passenger market is always lower than the uniform fare. This is consistent with the findings of Holmes (1989), who considered a differentiated Bertrand oligopoly and found that, price discrimination leads to a greater price in the “strong market” and a lower price in the “weak market.”

Next, we examine the effects of airline price discrimination on profits and welfare in the HSR system.

Proposition 5.

- (i) $\tilde{\pi}_a^* > \tilde{\pi}_a^{N*}$, i.e., the profit of air transport is higher with price discrimination than uniform pricing.
- (ii) $\tilde{\pi}_r^* = \tilde{\pi}_r^{N*}$, i.e., the profits of HSR are the same with or without price discrimination.
- (iii) $\tilde{W}_r^* > \tilde{W}_r^{N*}$ if and only if

$$\frac{b_h - b_l}{v_h - v_l} > \frac{5t_r + 3t_a}{8}, \quad (43)$$

i.e., the welfare in the HSR system is higher under price discrimination than under uniform pricing if and only if the ratio of travel benefit difference over time value difference is larger than a critical value given in (43).

Proof. (i) Subtracting $\tilde{\pi}_a^{N*}$ from $\tilde{\pi}_a^*$ yields $\tilde{\pi}_a^* - \tilde{\pi}_a^{N*} = \frac{1}{8\tau}\beta(1-\beta)(v_h - v_l)^2(t_r - t_a)^2 > 0$.

(ii) Since $\tilde{p}_r^* = \tilde{p}_r^{N*}$, we only need to compare the total numbers of HSR passengers. With price discrimination, the total number of HSR passengers is $\beta(1 - \tilde{x}_h^*) + (1 - \beta)(1 - \tilde{x}_l^*)$. Without price discrimination, the total number of HSR passengers is $\beta(1 - \tilde{x}_h^{N*}) + (1 - \beta)(1 - \tilde{x}_l^{N*})$. We have

$$\begin{aligned}
& \beta(1 - \tilde{x}_h^*) + (1 - \beta)(1 - \tilde{x}_l^*) - \beta(1 - \tilde{x}_h^{N*}) - (1 - \beta)(1 - \tilde{x}_l^{N*}) \\
&= \beta(\tilde{x}_h^{N*} - \tilde{x}_h^*) - (1 - \beta)(\tilde{x}_l^* - \tilde{x}_l^{N*}) = \beta(\tilde{x}_h^{N*} - \tilde{x}_h^*) - (1 - \beta)(\tilde{x}_l^* - \tilde{x}_l^{N*}) \\
&= \frac{\beta}{4\tau}(1 - \beta)(v_h - v_l)(t_r - t_a) - \frac{1 - \beta}{4\tau}\beta(v_h - v_l)(t_r - t_a) = 0.
\end{aligned} \tag{44}$$

In other words, the total number of HSR passengers with price discrimination equals to that without price discrimination. It follows that $\tilde{\pi}_r^* = \tilde{\pi}_r^{N*}$.

(iii) Subtracting \tilde{W}_r^{N*} from \tilde{W}_r^* yields

$$\begin{aligned}
\tilde{W}_r^* - \tilde{W}_r^{N*} &= (\tilde{\pi}_r^* + \tilde{C}S_r^*) - (\tilde{\pi}_r^{N*} + \tilde{C}S_r^{N*}) = \tilde{C}S_r^* - \tilde{C}S_r^{N*} \\
&= \frac{\beta(1 - \beta)(v_h - v_l)^2(t_r - t_a)}{4\tau} \left(\frac{b_h - b_l}{v_h - v_l} - \frac{5t_r + 3t_a}{8} \right).
\end{aligned} \tag{45}$$

It follows that $\tilde{W}_r^* > \tilde{W}_r^{N*}$ if and only if (43) holds.

Q.E.D.

Proposition 5(i) is intuitive: By price discriminating business passengers against leisure passengers, airlines can earn more profit. As shown in Proposition 4(i), the rail fare under price discrimination is the same as that under uniform pricing. Since HSR doesn't price discriminate its passengers, we only need to compare the total numbers of passengers in the HSR system. By Proposition 4(iii), more business passengers and less leisure passengers travel by HSR with price discrimination than uniform pricing. It turns out that the total numbers of passengers are the same in the two cases, and so the profits of HSR remain the same in the two cases.

Condition (43) simply means that the travel benefit difference between business and leisure passengers is sufficiently larger than the time value difference between business and leisure passengers. Because more business passengers and less leisure passengers travel by HSR under price discrimination than under uniform pricing, it follows that total consumer surplus in the HSR system is greater with price discrimination if condition (43) holds. Given that the HSR profits are the same, therefore, the welfare in the HSR system is greater with price discrimination.

5. Concluding Remarks

In this paper, we have studied the competition between air transport and HSR. Airlines are assumed to maximize profits, while HSR maximizing the weighted sum of welfare and profit. We find, with homogeneous passengers, that the ticket prices of air transport and HSR decrease in the weight on welfare. Furthermore, airfare decreases while rail fare increases in the access time to the airport. We also find that airfare decreases (rail fare increases, respectively) in the rail speed when the marginal cost of HSR is not too large (not too small, respectively).

The basic homogeneous-passenger model is then extended to a more general setting of two passenger types: business and leisure passengers. In the general model, we examine two different cases depending on whether airlines price discriminate business passengers against leisure passengers. Most results obtained in the basic model are still valid in the general setting. By comparing the results between “with price discrimination” and “no price discrimination”, we find that less business passengers travel by air transport with price discrimination than under uniform pricing, whilst more leisure passengers travel by air transport under price discrimination. Furthermore, the profit of air transport is higher with price discrimination than under uniform pricing, while the profits of HSR remain the same. However, the welfare in the HSR system can be either higher or lower. In particular, it is higher under price discrimination than under uniform pricing if and only if the travel benefit difference is sufficiently larger than the time value difference between business and leisure passengers.

The paper has also raised several issues and avenues for future research. First, we have focused on the competition aspect of air transport–HSR interactions. In practice, air transport and HSR might cooperate with each other to achieve a “win-win” situation. It would be an interesting direction to study both the competition and cooperation issues involved in the air transport–HSR interaction. Second, the objective of the government is likely to maximize the overall social welfare in both air and rail systems. Some central or federal governments might have the power or the influence to coordinate air transport and HSR. For example, the government might step in to regulate the ticket price of HSR. It is therefore practically relevant to explore this issue further.

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Market Conduct of the Three Busiest Airline Routes in China

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Abstract

This paper studies the market conduct of the three busiest routes dominated by the three largest airlines in China. The competition strategies of the three largest Chinese carriers are found to be different from each other. In general, the market behavior of Air China is consistent with that described in the Cournot solution. Both China Southern Airlines and China Eastern Airlines demonstrate competitive behaviors somewhere between Bertrand and Cournot. However, the former is closer to Cournot, whereas the latter is closer to Bertrand. We find that the Cournot model seems consistent with the competition between China Eastern Airlines and Air China. Our results suggest that Stackelberg competition develops with China Eastern Airlines as the leader and China Southern Airlines as the follower. We also find that China Eastern Airlines adopt low-price strategy to compete for market shares. Due to its lowest costs, Air China earns the highest profits among the three airlines. We also find that the competition among the three carriers becomes more intense over time.

Keywords: Market conduct, Conjectural variations, Air transport, Chinese airline industry

1. Introduction

China is the largest civil aviation market in Asia. Owing to the rapid development of the Chinese airline industry, Asia-Pacific overtook North America and became the largest global aviation market in 2009. That same year, data from the International Air Transport Association (IATA) showed that 647 million people in the Asia-Pacific region traveled by plane, surpassing the number of air passengers in North America for the first time. Brian Pierce, the IATA chief economist, said that more than half of the global aviation industry profits in 2010 came from the Asia-Pacific region, a phenomenon largely attributed to the strong growth in the Chinese market (Peirce, 2011). The aviation market in China attracted the attention of many international carriers, but failed to generate interest from the academe. We aim to fill this gap through this paper. To the best of our knowledge, this article is the first empirical study on the market structure and competitive behavior of the Chinese airline industry based on route-specific and firm-specific panel data.

In recent years, deregulation and consolidation of the Chinese airline industry led to the emergence of many local carriers and three major state-owned airlines, which are Air China (CA), China Eastern Airlines (MU), and China Southern Airlines (CZ). These three major carriers have had a domestic market share of about 80 per cent since 2000. By the end of 2010, the three big carriers had a share of about 84 per cent of the total number of domestic air passengers. The three airlines compete against each other and overlap one another's

traditional base cautiously. The economic data show that their profits experienced large fluctuations in the last several years. Debates center on the issue of whether the competition among the Chinese airlines is excessive, or whether the airline industry is becoming too concentrated. In this paper, we empirically investigate the market structure and competitive behavior in the Chinese airline industry by employing a “conjectural variations” approach.

We will focus on the three busiest airline routes that link Beijing, Shanghai, and Guangzhou. The three megacities have four of the largest hub airports in China, namely, Beijing Capital International Airport, Shanghai Pudong International Airport, Shanghai Hongqiao International Airport, and Guangzhou Baiyun International Airport. The routes in these three cities are the busiest in China, and the headquarters of the three major airlines are located in these three cities, namely, CA in Beijing, MU in Shanghai, and CZ in Guangzhou. From the *Statistical Data on Civil Aviation of China* published by the General Administration of Civil Aviation of China (CAAC, 2001–2011), we find that the total capacity of the four airports has been accounting for around 35 per cent of all airport capacity in China since 2000. The three routes linking Beijing, Shanghai, and Guangzhou are very profitable, resulting in all airlines wanting to operate flights on these routes. These routes have now been dubbed as the “golden routes.” To some extent, competition among the airlines on these routes is a microcosm of the tight competition in the entire Chinese market. The distribution of airline market power in these routes also reflects the market power in the whole market.

This article estimates the market conduct parameters of the three busiest Chinese airline routes that are dominated by the three major carriers, and aims to identify the market strategies and competitive behaviors of the three carriers. Our main finding is that the competition strategies of China’s three largest airlines are distinct from one another. In general, the market behavior of CA follows the Cournot model. The competitive behaviors of both CZ and MU are between Bertrand and Cournot. However, CZ behaves closer to Cournot, whereas MU behaves closer to Bertrand. This finding is distinct from what was obtained from the airline literature. A common conclusion found in the literature is that airlines are generally engaged in Cournot competition (Brander and Zhang, 1990, 1993; Oum et al., 1993). By contrast, our results show that the competition behaviors of both CA and CZ are reasonably close to the Cournot behavior, but the market behavior of MU is closer to Bertrand. We find that on the Shanghai–Guangzhou route, Stackelberg competition develops, with MU as the leader and CZ as the follower. On the Beijing–Guangzhou route, our data supporting the Cournot model seems consistent with the competition between CZ and CA. We also find that MU adopts a low-price strategy to compete with its rivals and to expand its market share. By keeping the costs low, CA is able to achieve the highest profits among the three airlines. We further show that the competition among the three airlines grows more intense over time.

The New Empirical Industrial Organization (NEIO) provides econometric techniques to study market conduct and market power by estimating parameters of conduct (referred to as conjectural variations or “CV”). The estimated values of conduct parameters can contribute to the empirical evidence on certain market behaviors, such as Cournot, Bertrand, and cartel. The CV approach has been widely used in many fields. Iwata (1974) provides a way to measure the numerical value of the CV, which is then applied in the study of the Japanese flat glass industry. Appelbaum (1979, 1982) applies a CV approach to the U.S. crude petroleum and natural gas industry, as well as the rubber industry. Hwang and Mai (1988) also use a CV method to examine the equivalence of tariffs and quotas. Azzam and Rosenbaum (2001) apply CV to the US Portland cement industry. Song et al. (2004) and López de Haroa et al. (2007) use CV models to analyze agents’ behavior in electrical power markets.

A number of empirical studies employ CV to investigate market power in the airline industry. Brander and Zhang (1990), by calculating the conduct parameters for 33 Chicago-based airline routes for the third quarter of 1985, determine that the Cournot model seems more consistent with the data than with the Bertrand or cartel models. Brander and Zhang (1993) also examine the dynamic interaction between United Airlines and American Airlines using a more accurate estimation of CV. In the study by Oum et al. (1993), the values of CV indicate that the duopolistic conduct lies between Bertrand and Cournot behavior, but much closer to Cournot. In the study of airport-pair markets from Atlanta by Fisher and Kamerschen (2003), the conduct in most airport pairs is found to be consistent with the Cournot solution. Fageda (2006) examines airline competition through the estimated values of CV using data from 67 air routes. The Spanish airlines are found

to behave in a less competitive way than is implied by the Cournot solution. Murakami (2011) investigates oligopolistic competition between full-service carriers and low-cost carriers in Japan by deriving the CV. Mizutani (2011) describes the merger effects on the competition structure of the Japanese air transportation market using conduct parameter, and provides empirical evidence of a leader-follower relationship among three carriers before the merger and an equal competitor relationship between two carriers after the merger.

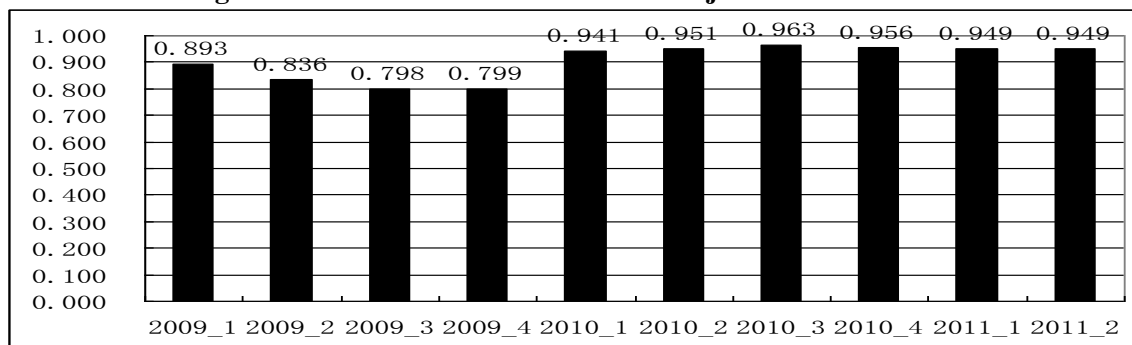
The paper is organized as follows. Section 2 provides an overview of the market power of the three big airlines. Section 3 presents the empirical model of the market structure and the main idea of the econometric methodology. Section 4 gives the estimation results. Finally, Section 5 offers concluding remarks.

2. Overview of Airlines' Market Power

Three major state-owned airlines in China have dominated the domestic aviation market for many years. The routes linking Beijing, Shanghai, and Guangzhou are the most important in China. All the airlines want to have flights on these routes, as they are very profitable. However, the three major airlines have been dominating these routes.

The average number of domestic passengers of the three major airlines on the three routes was calculated using quarterly data. In 2009, the market share of the three airlines was around 80 per cent in every quarter of that year. The market share increased from 79.9 per cent in the fourth quarter of 2009 to 94.1 per cent in the first quarter of 2010. This increase is not surprising because two mergers were completed in the first quarter of 2010. On January 28, 2010, MU completed the acquisition of Shanghai Airlines. On March 22, 2010, CA held a 51 per cent stake in Shenzhen Airlines. The market share of the three major airlines increased after the two consolidations. By merging and restructuring, the three airlines increased their market shares to around 95 per cent during the first quarter of 2010 and the second quarter of 2011, as shown in Figure 1.

Figure 1: Market Shares of the Three Major State-Owned Airlines



Source: <http://www.carnoc.com> (quarterly data)

We now look at the data of each company. During the first quarter of 2010, the percentages of connecting revenue passenger kilometers (RPKs) on the three routes of CA, MU, and CZ were 30 per cent, 27 per cent, and 37 per cent, respectively. The three companies seemed to share and control the market equally. However, a new scenario emerged after examining the data of each city-pair route.

Table 1 shows that the Beijing–Shanghai route is dominated by CA and MU, the Beijing–Guangzhou route is controlled by CA and CZ, and the Shanghai–Guangzhou route is dominated by CZ and MU. The market share of every dominant carrier is over 30 per cent on each route. Through a simple calculation, the market share of two dominant airlines is around 90 per cent on each route. Therefore, a very high market concentration on the three routes is evident. The three major airlines control the whole market. However, each city-pair route is characterized by *duopoly*.

Table 1: Percentages of Connecting Rpks on the Three Routes

Routes	Carriers	2010_1	2010_2	2010_3	2010_4	2011_1	2011_2
Beijing-Shanghai	CA	0.366	0.375	0.329	0.339	0.343	0.349
	CZ	0.026	0.023	0.025	0.026	0.027	0.023
	MU	0.556	0.548	0.605	0.586	0.572	0.568
Beijing-Guangzhou	CA	0.431	0.408	0.383	0.386	0.396	0.391
	CZ	0.478	0.498	0.541	0.528	0.51	0.529
Shanghai-Guangzhou	CA	0.062	0.081	0.098	0.083	0.1	0.065
	CZ	0.384	0.391	0.413	0.416	0.398	0.423
	MU	0.554	0.528	0.490	0.501	0.502	0.512

Source: <http://www.carnoc.com> (quarterly data)

(Note: MU does not operate direct flights between Beijing and Guangzhou)

3. Modeling

The degree of market concentration on the three big routes is very high. In theory, a small number of oligopolies gain high profits by limiting production outputs to keep the prices high. However, in practice, we do observe that some firms adopt low prices to compete with their rivals. Using a CV approach, oligopolistic competition among the three major airlines is modeled in this section, with the aim of finding out the corresponding types of competition the three airlines have engaged in.

3.1. Conduct Parameter

Assume that the three major state-owned airlines supply a homogeneous product on the same route. Recall that on each route, only two out of the three major airlines offer flights. In fact, even on the same route, different airlines offer different products, but drawing a distinct distinction among them is fairly difficult. Moreover, these airlines are all owned by the Chinese government, with their stocks listed on the stock exchange. Leadership and staff are often transferred from one airline to another, implying a slight difference in management capabilities and service levels among these three. Therefore, considering the flights provided by the three carriers on the same route as homogeneous is not unreasonable.

We first define the conduct parameter in the duopoly case. Let q_i be the quantity supplied by firm i , where $i = 1, 2$. Then $Q = q_1 + q_2$ is the total output. Let $p = p(Q)$ be the inverse demand function, and $C_i(q_i)$ be the total cost of firm i . The profit function of firm i can be written as

$$\pi_i = p(Q)q_i - C_i(q_i). \quad (1)$$

Following Brander and Zhang (1990, 1993) and Oum et al. (1993), the conduct parameter is defined as

$$\frac{dQ}{dq_i} = \frac{p - MC_i}{p} \cdot \frac{\eta}{S_i}, \quad (2)$$

where $\eta = -(dQ/dp)(p/Q)$ is the price elasticity of demand, $S_i = q_i/Q$ is the market share of firm i , and MC_i is the marginal cost of firm i . Different values of dQ/dq_i represent different types of oligopolistic competition. In the duopoly case, if the two firms have the same costs, then 0, 1 and 2 represent Bertrand competition, Cournot competition and cartel case, respectively. Larger values of dQ/dq_i indicate a more collusive conduct of firm i .

The conduct parameter is determined by the price, market share, marginal cost, and price elasticity of demand. As is defined, the conduct parameter increases in price and price elasticity, and decreases in market share and

marginal cost. The price and market share can be calculated directly from the statistical data; however, the marginal cost and price elasticity of demand must be estimated.

3.2. Marginal Cost

The estimated value of the route-specific marginal cost for each carrier is obtained using different methods. Fischer and Kamerschen (2003) and Mizutani (2011) first estimate a translog total cost function, and then approximate the route-specific marginal cost for each carrier. However, this method cannot be applied in this study because of some data issue. In China, the average annual salary per employee and some other costs are not available to the public. Another way to approximate route specific marginal cost for each carrier is proposed by Brander and Zhang (1990, 1993), Oum et al. (1993), and Murakami (2011). They use this methodology to estimate the route specific marginal cost for each carrier. They define the per-passenger cost of airline i on route k in period t as

$$MC_{kt}^i = cpm_t^i (D_k / AFL_t^i)^{-\theta} D_k, \quad (3)$$

where D_k is the distance of route k , AFL_t^i is the average length flown by carrier i in period t , cpm_t^i is the cost per passenger-mile of carrier i in period t , and θ is an unknown parameter in the cost function that ranges from 0 to 1. Based on several studies in the airline literature, Brander and Zhang (1990, 1993) use $\theta = 0.5$. Based on the data of American core airports, Oum et al. (1993) statistically estimate $\theta = 0.43$ using the maximum likelihood estimation method. Using the nonlinear least squares method, Murakami (2011) calculates that $\theta = 0.374$ in the Japanese airline industry.

Previous theoretical and empirical researches suggests that the value of θ is about 0.5, but this value varies in different countries. Below is a formal derivation for estimating θ . Using Eqs. 2 and 3, we obtain

$$p_{kt}^i = \frac{\{cpm_t^i (D_k / AFL_t^i)^{-\theta} D_k\} \eta}{\eta - (dQ / dq_i) s_{kt}^i}. \quad (4)$$

Eq. 4 can be transferred into

$$\ln \eta + \ln cpm_t^i + \ln D_k - \ln p_{kt}^i = \theta (\ln D_k - \ln AFL_t^i) + \ln (\eta - (dQ / dq_i) s_{kt}^i). \quad (5)$$

Let $y_{kt}^i = \ln \eta + \ln cpm_t^i + \ln D_k - \ln p_{kt}^i$, $x_{kt}^i = \ln D_k - \ln AFL_t^i$ and $c_{kt}^i = \ln (\eta - (dQ / dq_i) s_{kt}^i)$.

Denote $c = \text{mean}(c_{kt}^i)$, and let $\varepsilon_{kt}^i = c_{kt}^i - c$. Then Eq. 5 can be rewritten as:

$$y_{kt}^i = \theta x_{kt}^i + c + \varepsilon_{kt}^i. \quad (6)$$

If we know the estimated value of η , we can calculate the value of θ using ordinary least squares (OLS). In next subsection, we explain how to estimate the elasticity of demand.

3.3. Elasticity of Demand

To estimate the elasticity of demand, the demand functions are generally specified in log-linear or semi-logarithmic forms (Tretheway and Oum, 1992; Fisher and Kamerschen, 2003; Fageda and Fernandez-Villadangos, 2009). Taking the log-linear form, we specify the following demand function:

$$\ln(Q_{kt}) = b_0 - \eta \ln p_{kt} + \alpha \ln POP_{kt} + \beta \ln INC_{kt} + \gamma \ln DIST_k + \phi EXPO + \lambda_1 Spring + \lambda_2 Summer + \lambda_3 Autumn, \quad (7)$$

where Q_{kt} is the total passenger transport (passenger-km) on route k in period t , p_{kt} is the average price, POP_{kt} is the total population of the two cities linked by route k , INC_{kt} is the per capita income of the two linked cities, $DIST_k$ is the distance of route k , $EXPO$ is a dummy variable, which equals one on Shanghai-based routes during the Shanghai Expo period, and $Spring$, $Summer$ and $Autumn$ are dummy variables for the seasons.

Price and population are two essential variables of a demand function. Income per capita reflects the wealth of residents and affects the market demand. The coefficient of price is expected to be negative, whereas the coefficients of population and income are expected to be positive. The longer the travel distance, the more time can be saved using air transport compared with other transport modes. Hence, route distance has positive effects on passenger demand. The Shanghai Expo is a great boost for the Chinese civil aviation industry; thus, the dummy variable for the exposition should be included. Moreover, seasons are expected to have significant effects on passenger demand. In China, spring is generally considered as a slow season, whereas autumn is a busy season and is expected to have a positive impact on demand.

4. Empirical Results

The sample used in the empirical analysis includes observations on the three major domestic airlines in China from January 1, 2010 to June 30, 2011. The data used is a route-specific panel data set of the three busiest routes in China, the frequency of which is quarterly.

Information about the number of passengers on different fare classes carried by the given airline on each route has been obtained from the computer reservation system of TravelSky Technology Limited. The passenger demand data are restricted to non-stop services. The fare information is obtained from the Chinese Airfare Information Network (www.airtis.net) and other related websites, such as those of the three airlines. The data on the per capita income and population of Beijing, Shanghai, and Guangzhou are collected from the National Bureau of Statistics of China. Price and income are adjusted by the retail price index. The distances of the three routes and the market shares of the airlines in each route are obtained from the Civil Aviation Resource Net of China. Data on the main costs of carriers are obtained from the annual reports and the quarter reports of the three airlines. Total flight length, total number of flights, and RPKs are collected from the websites of the three airlines as well as from their annual reports. Based on these data, the average flight length and cost per passenger-km of each carrier for every season can be calculated.

The route-specific panel data of the three routes for six quarters are used to estimate the demand Eq. 7. The computation of the Durbin–Watson statistic reveals a significant autocorrelation in the models. The results of the White test and the LM test show that the heteroskedastic errors and cross-sectional correlations of the data are significant. Hence, the OLS estimation is biased, and the feasible generalized least squares (FGLS) method is used to estimate the model. The estimated equation (standard errors in parentheses) is

$$\begin{aligned} \ln(Q_{kt}) = & -44.81 - 0.90 \ln p_{kt} + 5.78 \ln POP_{kt} + 0.88 \ln INC_{kt} + 1.76 \ln DIST_k \\ & (3.33)^{***} \quad (0.43)^{***} \quad (0.40)^{***} \quad (0.38)^{***} \quad (0.14)^{***} \\ & + 0.23 EXPO - 0.19 Spring + 0.08 Summer + 0.17 Autumn \\ & (0.06)^{***} \quad (0.05)^{***} \quad (0.02)^{***} \quad (0.02)^{***} \end{aligned} \quad (8)$$

(Note: *** denotes significance at the 1 per cent level)

All the coefficients are significant at the 1 per cent level. The price elasticity of demand is 0.90. As expected, the air traffic on a route is greater for city-pairs with larger populations and higher income levels. Longer distance and the Shanghai World Expo have positive effects on passenger demand. The demand is lower during spring, and higher during summer and autumn.

We will use the estimated value of the price elasticity of demand to estimate θ in Eq. 6. The data set for estimating Eq. 6 is the carrier-specific panel data on the three routes for six quarters. The estimated values of θ and c are 0.390 and -0.198 , respectively (both are significant at the 1 per cent level). The estimated value of θ is very close to what Oum et al. (1993) and Murakami (2011) obtained.

Using data from the quarterly reports of the three airlines, we can calculate the costs per passenger-km of the three carriers in each quarter. As seen in Table 2, MU's cost is the highest, and CA's cost is the lowest.

Table 2: Cost per Passenger-Km of the Three Airlines (In RMB)

	CA	CZ	MU
2010_q1	0.511	0.540	0.626
2010_q2	0.555	0.556	0.664
2010_q3	0.524	0.539	0.612
2010_q4	0.564	0.614	0.709
2011_q1	0.561	0.580	0.636
2011_q2	0.574	0.632	0.701

Using Eq. 3, the route-specific marginal cost for each carrier can be estimated. The carrier-specific panel data on three routes for six quarters will be used to estimate the conduct parameters. Using Eq. 2, the conduct parameters of airlines dominant on each route are shown in Table 3.

Table 3: The Conduct Parameters of Dominant Airlines on Each Route

Routes	Carriers	2010_1	2010_2	2010_3	2010_4	2011_1	2011_2
Beijing-Shanghai	CA	1.001	1.057	1.262	1.044	0.905	0.915
	MU	0.436	0.559	0.571	0.383	0.450	0.410
Beijing-Guangzhou	CA	0.851	0.844	0.938	0.895	0.766	0.786
	CZ	0.528	0.611	0.623	0.502	0.561	0.428
Shanghai-Guangzhou	CZ	0.666	0.896	0.880	0.600	0.551	0.491
	MU	0.328	0.441	0.586	0.170	0.149	0.142

All the values in Table 3 are between 0 and 2. However, some values are close to 1 (Cournot behavior), while some are close to 0 (Bertrand behavior). Whether the three airlines follow Cournot or Bertrand behavior is unclear. Further analyses are necessary to study the competitive strategies of the three big carriers based on the estimated parameter values.

First, the conduct parameters of CA are around 1 in every quarter on each route. Hence, the competitive behaviors of CA are reasonably close to Cournot behavior. Moreover, the conduct parameters of CA are higher than those of the other two airlines on every route in every quarter. Table 2 shows that CA's marginal cost is the lowest among the three big airlines. Recall that everything else being equal, conduct parameters decrease in marginal costs, which partly explains why CA has higher conduct parameters. The annual reports of the three carriers reveal that CA earns huge profits. In 2010, the net profit of CA was over ten billion RMB for the first time, and was around half of the total profits of the three airlines. On the three routes studied, the profit of CA, which is above 40 per cent of the total profits of the three carriers, is also the highest. We may conclude that CA obtains supernormal profits by controlling costs to compete against its competitors.

Second, the conduct parameters of CZ are between 0.428 and 0.896, and the average is above 0.6. The competitive behavior of CZ is between Bertrand and Cournot behavior, but is closer to Cournot. To analyze specific CZ competition strategies, the correlation coefficients of the conduct parameters among the three

airlines operating on the same route are calculated. The correlation coefficient between the conduct parameters of MU and CZ is 0.945 on the Shanghai–Guangzhou route, and is statistically significant at the 1 per cent level. The result indicates that MU and CZ have similar competitive behaviors on the route. However, on the same route, the conduct parameter of CZ is larger than that of MU in every quarter, and all of the differences are about 0.4. As shown in Table 1, the market share of MU is much larger than that of CZ on the Shanghai–Guangzhou route, implying that Stackelberg competition develops, with MU as a leader and CZ as a follower. The correlation coefficient between the conduct parameters of CZ and CA is 0.450 on the Beijing–Guangzhou route, and it is not statistically significant. A colluding behavior between the two airlines is not proven. Note that all the conduct parameters of CZ and CA are close to 1 on the Beijing–Guangzhou route, indicating that the Cournot solution is consistent with the data.

Third, the conduct parameters of MU are between 0.142 and 0.586, and the average is only 0.385. We may conclude that the market behavior of MU lies between Bertrand and Cournot behavior, but is actually closer to Bertrand. The correlation coefficient between the conduct parameters of MU and its prices is positive and statistically significant. From the data set, we can observe that the prices of MU are clearly lower than those of its competitors. As clearly shown in Table 2, the costs of MU are the highest among the three major carriers. Table 1 also shows that the market share of MU is much higher than that of its main competitors. These results imply that MU adopts a low-price strategy to compete with its competitors and to expand its market share. This behavior is consistent to what the Bertrand model predicts, and can be partially explained by “vertical product differentiation.” MU’s safety record and overall service quality is the worst among the three airlines. On November 21, 2004, MU5210 crashed into a park shortly after it took off from the ground. This accident is the latest fatal plane crash among the three carriers, which significantly affects consumer confidence in the safety of MU. Moreover, being the last one among the three carriers to join a global airline alliance, MU did not join SkyTeam until June 21, 2011, which affected its convenience and network connectivity. Therefore, MU has to lower its fares to attract passengers.

Finally, the time trend of conduct parameters is studied. We first analyze conduct parameters on different quarters using the paired samples t-test. All the values are larger than 2, which suggest obvious gaps between the conduct parameters. In other words, the three airlines make apparent changes in their competitive behaviors because of off-peak season effects and time trend. The fact that conduct parameters in the peak seasons are higher than those in the off-peak seasons is significant, as it indicates a decrease in the competition among the three carriers during peak seasons. Second, we consider a linear time trend model for conduct parameters on each route: $CP = aT + b_1D_1 + b_2D_2 + c$, where CP is conduct parameters, T is a “time trend” variable with values from 1 to 6, D_1 is a dummy variable for the airline, and D_2 is a dummy variable with the value 1 for peak season and 0 for off-peak season. The estimated coefficients on the three routes with time trend are presented in Table 4.

Table 4: Estimated Coefficients of the Time Trend (Standard Errors in Parentheses)

Routes	Estimates	P-value	R-squared of the model
Beijing-Shanghai	−0.028 (0.015)	0.100	0.941
Beijing-Guangzhou	−0.020 (0.011)	0.093	0.903
Shanghai-Guangzhou	−0.064 (0.015)	0.003	0.912

All the coefficients of the time trend are negative. Hence, conduct parameters tend to decline on every route, and the competition among the three airlines becomes more intense. The results are consistent with the pattern of conduct parameters estimated in Table 3, especially on the Shanghai–Guangzhou route, where the time trend coefficient is most negative and significant at the 1 per cent level, and the conduct parameters decrease sharply.

The three carriers compete with one another more intensely over time. In practice, they try to enter into the traditional bases of rival airlines. For example, in May 2012, CA took over Shenzhen Airlines aiming to develop the southern China market. However, from the first quarter of 2010 to the second quarter of 2011, the market shares of the three carriers on each route did not undergo big changes. The three big players maintain a

duopoly competition on each route, and avoid fiercer competition to achieve higher profits in the whole market. To some extent, this duopoly behavior is a tacit understanding among the three airlines. High market concentration is generally not good for consumers and social welfare. Without enough competition, the Chinese airline industry is characterized by high prices and high costs. The General Administration of Civil Aviation of China seems to have realized the magnitude of this problem. After numerous attempts for many years, Spring Airlines, a low cost carrier, finally obtained the traffic rights on the Beijing–Shanghai route on September 30, 2011. However, the carrier only provides one round-trip flight per day, and the departure times of the flights are not very attractive. Hence, the effect of the carrier on the three big players is very limited. The administrator should gradually open the aviation market and promote fair competition, which will lead to better services and lower prices for the public.

5. Concluding Remarks

The market conduct of the three busiest routes dominated by the three largest airlines in China has been investigated. Whether the three carriers have a colluding behavior on a certain route is not clearly indicated. However, the three airlines appear to have a tacit understanding with respect to the entire market. The three dominant carriers try to avoid cutthroat competition on the same route when they divide the market. The data set shows that the competition model of MU is set to lower prices to beat its rivals and to get a bigger market share. CZ adopts different competitive strategies for different rivals. Stackelberg competition is found to exist, with MU playing the leadership role and CZ being the follower. CZ produces the Cournot output to compete with CA. CA achieves the highest profits by controlling its costs. Although the market share of MU is the largest, its profit is lower than that of CA, primarily because MU's costs are much higher than CA's. Hence, perhaps, the next step for MU should focus on lowering costs to earn higher profits instead of lowering prices to get more market share.

Today, China has one of the most advanced high-speed rail (HSR) networks in the world. HSR presents convenience and affordability to consumers, but it also poses a challenge to the survival and development of civil aviation. For example, all the flights between Zhengzhou and Xi'an (505 km) were suspended in March 2010, 48 days after the opening of the HSR service, whereas daily flights on the Wuhan–Guangzhou route (1,069 km) were reduced from 15 to 9, one year after the HSR entry (Fu et al., 2011). With the opening of more HSR services in major Chinese cities (for instance, the Beijing–Shanghai HSR route started to operate on June 30, 2011), the market structure and competitive strategies of airlines will be significantly affected. Therefore, it is interesting and important to study the impacts of HSR on the Chinese aviation market.

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Timetable Design of the Airport Coach with Dynamic Demand

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Abstract

In order to attract more passengers, many airports are operating the airport coach to transport passengers between the airport and the around cities. Although the network and timetable are both the most important parts for coach operation, there are few studies on timetable design compared to route design. The purpose of this paper is to create a method to design the timetable in terms of both passenger volume and coach operation cost. Firstly, the “time-space” network is established to provide a platform for the design. Secondly the impacts of the timetable in the operation cost and the passenger volume are analyzed. Thirdly, a timetable design model is built with the goal to minimize the operation cost and considering the interaction between the passenger volume and the timetable. Finally, we take the coach of Dalian airport as the example to design a timetable with the model and do a sensitivity analysis.

Keywords: timetable design, “time-space” network, airport coach, sensitivity analysis

1. Introduction

The rapid development of economy and the further reform of civil aviation have propelled the Chinese civil aviation industry into the circumstance of market economy. In the transition process, the number and the management mode of Chinese airports both change a lot. As there have been more and more airports constructed, the airport density has increased from 0.8 airports /mil.sq.km. in 1987 to 3.2 airports /mil.sq.km. in 2011 (Liu, 2011); At the same time, because of the Airport Localization Reform, most airports have been directly managed by local governments. In the circumstance, some small or middle scale airports can escape from the bondage of the planned economy and have a chance to develop by their own ideas. Therefore, the competition among the airports in China becomes fiercer. In order to expand the hinterland, many airports develop their landward access system to attract passengers from the cities around them (Yang, 2009). In all the traffic modes of the landward access system, the airport coach is a new and convenient one that has become an effective measure to connect the airport and the surrounding cities.

The airport coach is an extension of airport shuttle bus. It can provide the transportation between the airport and the surrounding cities. During its initial period, operators of the airport coach pay more attention on the market cultivation rather than the cost control. They made hard effort to attract the passengers, for example, they usually set a “point-to-point” network to let all passengers get to the airport directly. But it may result in deficits on the routes with few passengers. Therefore, they began to control the cost after the market is relatively mature. Then, the “point-to-point” network is being replaced by the “hub-and-spoke” one, which can realize the scale of economy through combining the branch lines and trunk line (Jou, 2011).

“Hub-and-spoke” network can help reduce the operating costs, but passengers in the end nodes have to transfer to the trunk lines (Wei, 2006). Thus, they must departure from the end nodes based on the flight schedule and the coach time of the trunk lines. Meanwhile, the coach times of the trunk lines are also restricted because the passengers from the end nodes must be transported together with the passengers in the hubs. In the circumstance, if the connection between the branch line and the trunk line is irrational or the passenger’s arrival time at the airport does not match with the flight schedule, passengers will give up the airport coach or even go to other airports. Hence, two issues should be tackled when operating the airport coach based on the “hub-and-spoke” network. One is controlling the cost and another is keeping the passenger volume. In practice, the best solution is to design a rational timetable, which can both satisfy the passengers’ demand and control the operation cost.

The operation of the airport coach can be seen as the production of a manufactory, the passenger volume of the coach can be regarded as the production volume, the ticket price equates the product price and most importantly the timetable equates the manufacturing plan. Because the passenger volume and the operation cost of the coach both change with the time-headway. It is important to design a rational timetable for the airport coach.

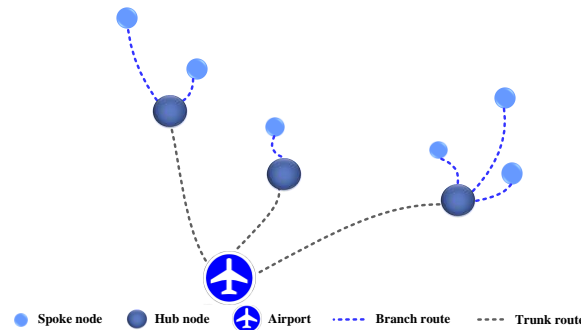
In the paper, firstly the influences of the timetable to the passenger volume and the operation cost are analyzed respectively. Secondly the relationship between the demand and the cost is described. Thirdly, the timetable design model is built with the goal to minimize the operation cost and considering its interaction with the passenger volume. Finally the case of Dalian airport is studied and a timetable is designed with the model and sensitivity analysis is carried out. More detailed description will appears in forthcoming sections. After the introduction of the “hub-and-spoke” and the “time-space” networks in Section 2, Section 3 describes the economic theory. Section 4 describes the model structure. Data and results are discussed in Section 5, while Section 6 dose the sensitivity analysis, and Section 7 summarizes the paper.

2. Airport Coach Network

2.1 “Hub-and-Spoke” Network

Because the passengers are sensitive to the transfer time, the “hub-and-spoke” network with single hub is usually adopted for airport coach. It can control the cost and reduce the transfer times. Fig. 1 shows the network structure, where the largest node is the airport, the larger ones are the hubs and the smaller ones are the end nodes. The end nodes are connected to the hub by branch lines, and the hub are linked directly to the airport via the trunk lines, while the hub does not connect with each other (Ashley, 1996). In the network, passengers in the hub can get to the airport directly. However, passengers in the end nodes must go to the hub first through branch coaches and then get to the airport along with the passengers in the hub by trunk coaches.

Fig. 1: Structure of the “Hub-And-Spoke” Network



The trip chain of the passengers in the end nodes from the origin to the airport includes four legs. First is the trip from the end node to the hub, second is the waiting process at the hub, and third is the trip from the hub to airport and finally the waiting process in the lounge. To design the timetable for the airport coach, we should consider the connectivity of the coach lines, the lines length and the passengers’ flight schedule. It is a two-

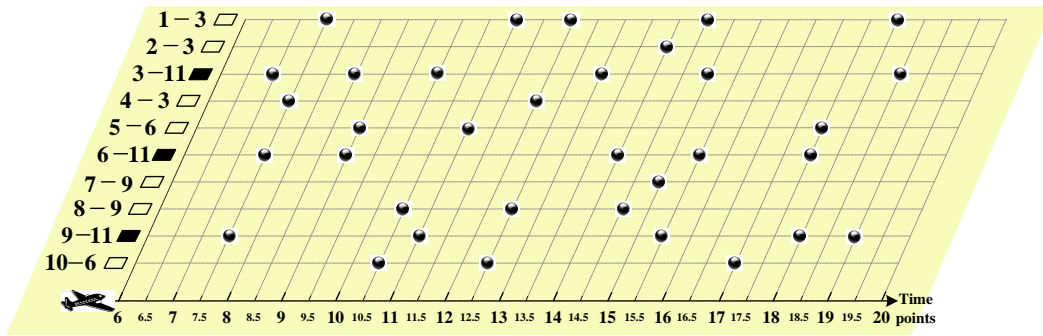
dimensional problem in which the time and space should be considered together (Deborah, 1999). In order to combine the time with the space, the “time-space” network is constructed to represent the trip chain on a one-dimension platform.

2.2 “Time -Space” Network

The “time-space” network (Kliewer, 2006) is shown in Fig. 2. It can present the temporal and spatial information on one plane. Its forefront describes the structure of the coach line network. The figures represent the nodes (1~10 are the cities and 11 is the airport), the rows stand for the coach lines, the first column is the origin and the second is the corresponding destination, the third column represents the attribute of the coach line (the solid square means the branch line and the hollow one means the trunk one). The two kinds of lines connect with each other to compose the airport coach network. For example, Node 1 is connected to the airport firstly through branch line 1-3 and then trunk route 3-11.

The part behind the coach line network is the “time-space” grid, the time axis at the bottom includes 29 time points from 6:00 to 20:00 within one day, the lines and time points are connected by the grids. The ball means there is a coach dispatched. For example, the top row represents the coach line from Node 1 to Node 3 is a branch line, and the corresponding departure times are 7:30, 9:00, 11:00, 12:00, 14:30 and 18:00.

Fig. 2: The “Time-Space” Network of the Coach Line and Departure Times



3. Fundamental of the Model

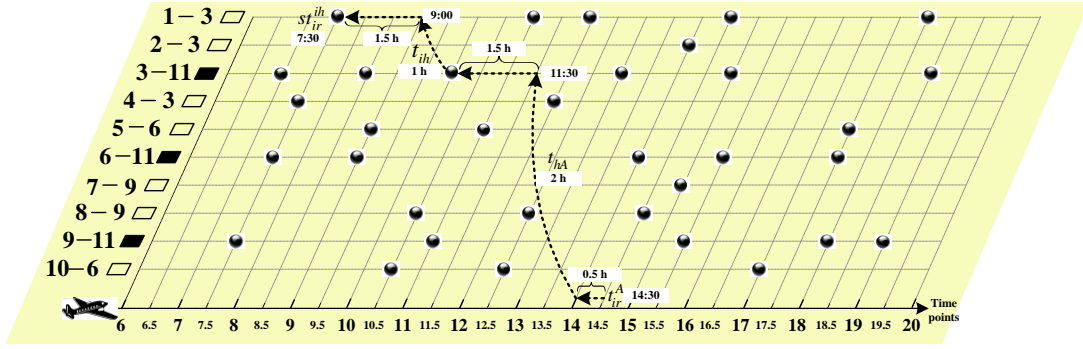
Here we take passengers at the end nodes as example to analyze their trip chains, and then study the impacts of the airport coach timetable on passenger volume and operating cost respectively.

3.1 The Formation of Passengers' Trip Chain

When the line travel time and coach network are fixed, the passengers' trip chain is highly related to coach departure time. Rational passengers will determine the best time to departure for the airport based on the flight schedule and the coach lines to form the trip chain. By analyzing the passengers' expected departure times, we can get to know the passenger demand on the coach departure times. Therefore, we present the relationship between the trip chains and coach timetable on the time-space network to provide a platform for designing the timetable.

To simplify the analysis, the flight schedules are grouped with 30 minutes interval and the passengers are divided into several teams correspondingly. The trip chain from an end node to the airport is shown in Fig. 3. The dash arc represents the travel process from node to node, while the dash line represents the transfer process or the lounge waiting process. The combination of them represents the process of passengers in end nodes to determine the departure time. It includes two steps: the first is to decide the departure time at hub nodes; and the second is to decide the departure time at the end node. More detailed description appears in the following section.

Fig. 3: Determination of the Departure Time and Trip Chain Formation

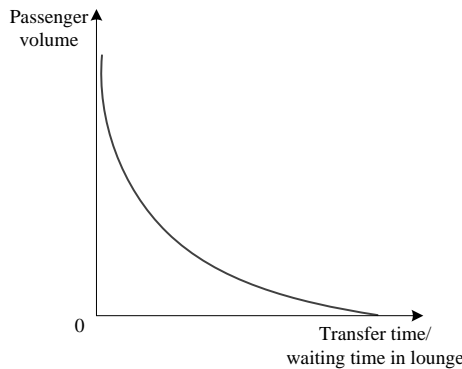


If the flight schedule of the passenger in group r in end node i is t_{ir}^A , then the latest arrival time to the airport (A) should be $(t_{ir}^A - 0.5)$, because the passenger must arrive at the airport 30 minutes in advance at least. Due to the transfer at the hub and the coach travel time from Node 3 to the airport is 3 hours, the latest departure time at hub should be $(t_{ir}^A - 0.5 - t_{hA})$. In order to board on time as well as wait for the shortest period in the lounge, the passengers should take the last bus to the airport which is earlier than the latest departure time we mentioned above. Therefore, passengers' departure time at the hub should be st_{ir}^{hA} , similarly, the departure time at the end nodes should be st_{ir}^{ih} , in conclusion, passenger's waiting time in the lounge is wt_{ir}^D , while the waiting time at the hub is wt_{ir}^h .

3.2 Passenger Volume

Because the transfer time and the lounge waiting time are determined by the time-headway, the relationship between the passenger volume and the timetable can be seen as the relationship between the passenger volume and the transfer time and lounge waiting time. The shorter the time-headway is, the shorter the transfer and waiting times are, and the more passengers will use the coach. Reversely, the longer the time-headway is, the longer the transfer/waiting times and the less the passengers are. This relationship is shown in Fig. 4. The curve in Fig. 4 stands for the change of the volume along with the transfer/waiting times. When the times exceed a threshold, the passenger volume will be 0. When the times are infinitely short, the coach passengers will be near the total flight passengers in the surrounding cities.

Fig. 4: Relationship between the Passenger Volume and the Transfer/Waiting Times

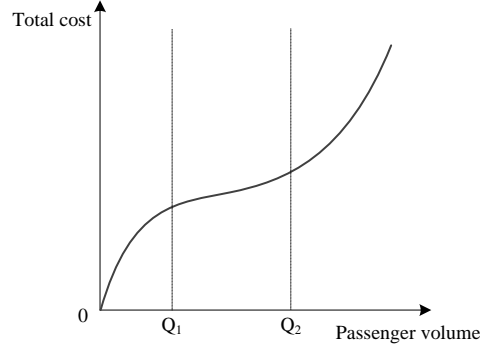


3.3 The Operation Cost

The relationship mentioned in above indicates that passengers hope the shortest time headway. However, for timetable design, in addition to the passenger demand, we must also take the operation cost into account. Based on the relationship between the passenger volume and the time-headway, the relationship between the

operation cost and the passenger volume can be described as: the shorter the time-headway is, the more the passenger volume and the more the operation cost are; (Tsamboula, 2008). Fig. 5 describes this relationship, where horizontal axis represents the passenger volume, and the vertical axis represents the total operation cost. When the passenger volume is in the range from 0 to Q_1 or exceeds Q_2 , the marginal cost is very high for a unit increment of the passengers. However, if the passenger volume is in the range from Q_1 to Q_2 , the marginal cost will be relatively low.

Fig. 5: Relationship between Total Operating Cost and Passenger Volume

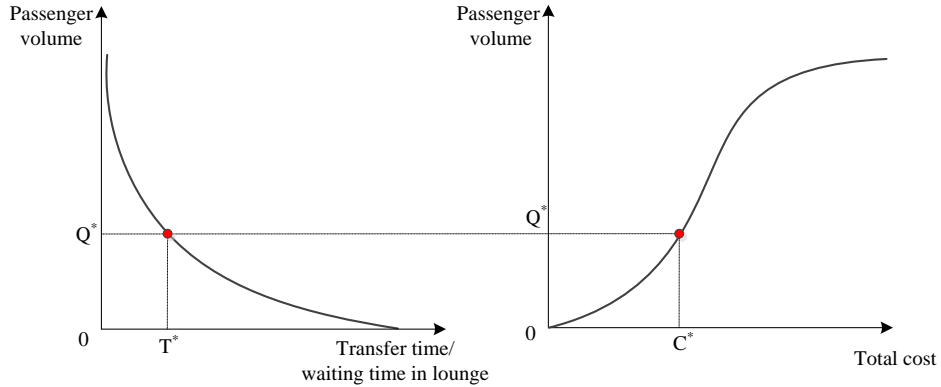


3.4 The Relationship among the Cost, Passenger Volume and the Waiting Time

Fig. 6 shows the relationship between the passenger volume, the transfer/waiting time and the operating cost. When the time increases, the passenger volume and then the operation cost decrease.

Because the marginal cost changes along with the passenger volume, we should firstly find the range of the passenger volume in which the marginal cost is smaller, and then determine the transfer time and the lounge waiting time according to the relationship mentioned in section 2.2. thus design the timetable.

Fig. 6: Relationships among the Times, Cost and the Passenger Volume



4. Timetable Design Model

We design the timetable for the airport access coach rather than the egress one based on the formation of the access trip chain, relationships among the coach timetable, passenger volume and operation cost.

4.1 Objective Function

The model is to minimize the daily cost of the coach system. The objective function is as follows:

$$\text{Min} : C = \sum_i \sum_h \sum_t k_t^{ih} c_{ih} d_{ih} x_t^{ih} + \sum_h \sum_t k_t^{hA} c_{hA} d_{hA} x_t^{hA} \quad (1)$$

Where, C = total operation cost, the first part is the cost of the branch lines, the second part is the cost of the trunk lines. i = end node, h = hub node, A = airport; d_{ih} = length of the branch line, d_{hA} = length of the trunk line; t = time point, c_{ih} = unit cost of branch coach, c_{hA} = unit cost of trunk coach. x_t^{ih} and x_t^{ih} are 0-1 variables, they are as follows:

$$x_t^{ih} = \begin{cases} 1 & \text{a coach departs on branch line } (i-h) \text{ at time } t \\ 0 & \text{otherwise} \end{cases} \quad (2)$$

$$x_t^{hA} = \begin{cases} 1 & \text{a coach departs on trunk line } (h-A) \text{ at time } t \\ 0 & \text{otherwise} \end{cases} \quad (3)$$

k_t^{ih} = needed dispatched coaches on $(i-h)$ at time t , which can be calculated by Eq. (4). Where, N_s = capacity of a branch coach vehicle, n_t^{ih} = passenger volumes on branch $(i-h)$ at time t , and $\lceil \cdot \rceil$ means rounding up to the closest integer.

$$k_t^{ih} = \lceil n_t^{ih} / N_s \rceil \quad (4)$$

n_t^{ih} is calculated by Eq. (5), where $q_{ir} = Q(w_i)$ is passengers in group r at node i . $Q(w_i)$ = the passenger volume, which describes the change of passenger volume in end node i . The form of $Q(w_i)$ may be obtained by fitting the surveyed data.

$$n_t^{ih} = \sum_r q_{ir} \cdot y_{iht}^{ir} \quad (5)$$

y_{iht}^{ir} is a 0-1 variable, which shows whether the dispatched coaches on branch line $(i-h)$ at time t are chosen by the r th group. Its value is as follows:

$$y_{iht}^{ir} = \begin{cases} 1 & st_{ir}^{ih} = t \\ 0 & st_{ir}^{ih} \neq t \end{cases} \quad (6)$$

Eq. (7) can be used to calculate k_t^{hA} . However, passenger volume on trunk line $(h-A)$ at time t equals the sum of $q_{ir} \cdot y_{hAt}^{ir}$ and $q_{hr} \cdot y_{hAt}^{hr}$, which stands for passengers from branch line $(i-h)$ to the airport at time t and the local passengers respectively (Eq.(8)). In addition, y_{iht}^{hr} and y_{hAt}^{ir} are shown in Eq.(9) and Eq.(10) respectively. q_{hr} is determined by the trip demand function $Q(w_h)$ of hub.

$$k_t^{hA} = \lceil n_t^{hA} / N_h \rceil \quad (7)$$

$$n_t^{hA} = \sum_r q_{ir} \cdot y_{hAt}^{ir} + q_{hr} \cdot y_{hAt}^{hr} \quad (8)$$

$$y_{hAt}^{ir} = \begin{cases} 1 & st_{ir}^{hA} = t \\ 0 & st_{ir}^{hA} \neq t \end{cases} \quad (9)$$

$$y_{hAr}^{hr} = \begin{cases} 1 & st_{hr}^{hA} = t \\ 0 & st_{hr}^{hA} \neq t \end{cases} \quad (10)$$

4.2 Constraints

➤ Constraints for waiting time and transfer time

$$0 < (t_{ir}^A - 0.5 - t_{hA} - t) \cdot x_t^{hA} \leq T \quad (11)$$

$$0 < (t_{hr}^A - 0.5 - t_{hA} - t) \cdot x_t^{hA} \leq T \quad (12)$$

$$0 < (st_{ir}^{hA} - t_{ih} - t) \cdot x_t^{ih} \leq T' \\ T' \geq 0.5, T \geq 0.5 \quad (13)$$

Eq. (11) is the constraint of the waiting time spent by group r from node i . The lower limit “0” means there is at least one coach available for the passenger being able to board punctually. The upper limit “ T ” ensures that the waiting time will not exceed a threshold, and then to avoid sending the passengers to the airport too early. Accordingly, Eq. (12) can be explained. The constraint of passengers’ transfer time in the hub is Eq. (13).

➤ Time constraints on passenger boarding the coach

Eq. (14) regulates that the passengers of group r of branch line $(i-h)$ choose the trunk coach that satisfies Eq. (11), which makes they have the least waiting time at airport. Eq. (15) and Eq. (16) are the constraints on passenger boarding time at the hub.

$$st_{ir}^{hA} = K, \quad K \geq t \cdot x_t^{hA} > 0 \quad (14)$$

$$st_{ir}^{ih} = K', \quad K' \geq t \cdot x_t^{ih} > 0 \quad (15)$$

$$st_{hr}^{hA} = K'', \quad K'' \geq t \cdot x_t^{hA} > 0 \quad (16)$$

➤ Constraints for no empty coaches

Eq. (17) shows that on branch line $(i-h)$, the passenger volume on any dispatched coach can not be 0. Eq. (18) is similar to Eq. (17) but for the trunk lines.

$$(n_t^{ih} - 0.5) \cdot (x_t^{ih} - 0.5) > 0 \quad (17)$$

$$(n_t^{hA} - 0.5) \cdot (x_t^{hA} - 0.5) > 0 \quad (18)$$

5. Case Study

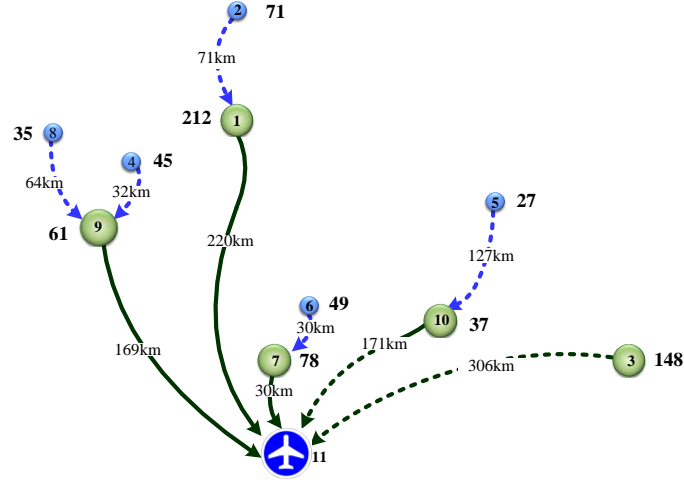
We take Dalian airport as an example to design the timetable of the airport coach.

5.1 The Data

According to the hinterland and air travel demand, the “hub-and-spoke” network shown in Fig. 7 has been adopted by Dalian airport. The number in the node is the city code (1-10 are the city codes, 11 is airport code). The number beside the node is the daily air travel volume in the city. The solid line represents the trunk coach line and the dash line means the branch coach line. The number on the line is its distance. The vehicle capacity of the trunk coach is 50 persons and unit cost is 1.84 Yuan/km. The vehicle capacity of the branch coach is 30

persons and unit cost is 1.3 Yuan/km. In addition, to collect the passengers' flight schedules, we implemented the questionnaire survey in the airport.

Fig. 7: Coach Network Structure of Dalian Airport



5.2 Passenger Volume

The questionnaires are distributed to the passengers who come from the surrounding cities. The ratios of the passengers who expect or accept different time alternatives are shown in Fig. 8 ((a), (b)). And the cumulated ratios are displayed in Fig. 9((a), (b)).

Fig. 8: Ratios of Passengers Waiting/Transfer Time Selection

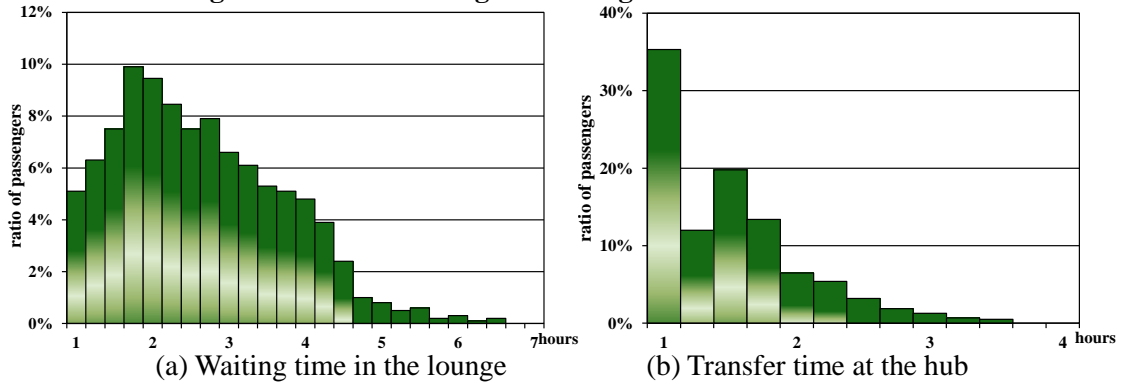
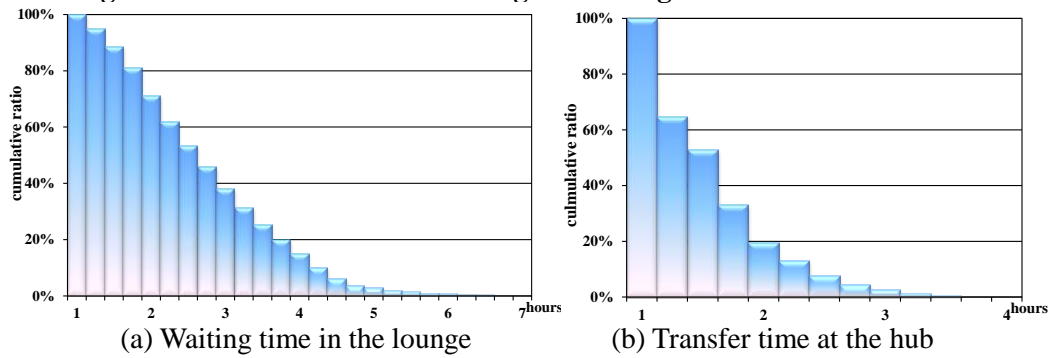


Fig. 9: Cumulated Ratios of Passengers Waiting/Transfer Time Selection



6. Results

According to the relationship between the passenger volume and the waiting/transfer times, we design the coach timetable for Dalian airport in the case that the coach system serves 42% of the total flight passengers from the surrounding cities. In this case, the upper limits of T' and T both equal 2. The calculated results are shown in Table 2 and the operation cost is 2.18 million Yuan.

Because the flight schedule is considered, the departure times of the coaches mainly concentrate in periods of 6:00 ~9:00 and 11:00~14:00, which are corresponding to the peak periods of the flights.

Table 1: The Timetable of Dalian Airport Coach ($T = 2$, $T' = 2$)

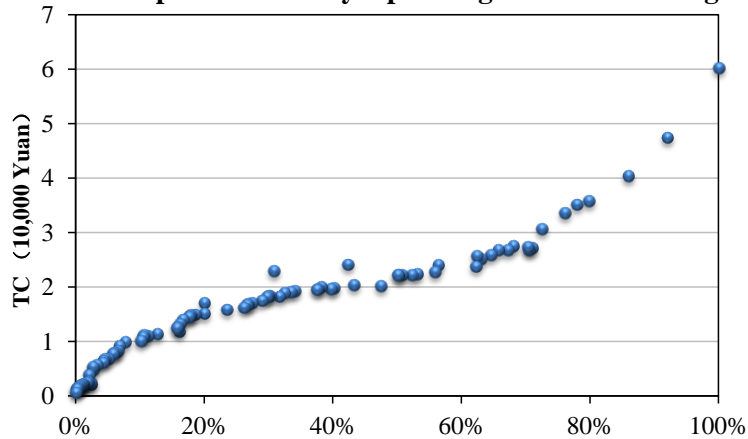
Route	Departure Time (number of the coach)								
1-11	5:00	6:00 (2)	8:00	11:00	13:00	16:00	18:00	20:00	-
2-1	2:00	4:00	5:00	8:00	11:00	13:00	15:00	17:00	-
3-11	3:00	7:00	10:00	14:00	18:00	-	-	-	-
4-9	4:00	5:00	7:00	9:00	11:00	15:00	16:00	18:00	20:00
5-10	3:00	6:00	9:00	7:00	11:00	14:00	-	-	-
6-7	3:00	5:00	7:00	9:00	11:00	14:00	17:00	17:00	-
7-11	5:00	7:00	9:00	10:00	12:00	13:00	16:00	19:00	-
8-9	3:00	5:00	8:00	10:00	12:00	14:00	16:00	19:00	-
9-11	5:00	7:00	9:00	11:00	13:00	16:00	18:00	20:00	21:00
10-11	3:00	6:00	7:00	10:00	13:00	15:00	18:00	-	-

7. Sensitivity Analysis

The coach-carried passengers change with the variation of the departure times, and the daily operating cost changes correspondingly. To find the most appropriate coach timetable for Dalian airport, here we further analyze the change of the operation cost along with the changes of the transfer time and the waiting/transfer time.

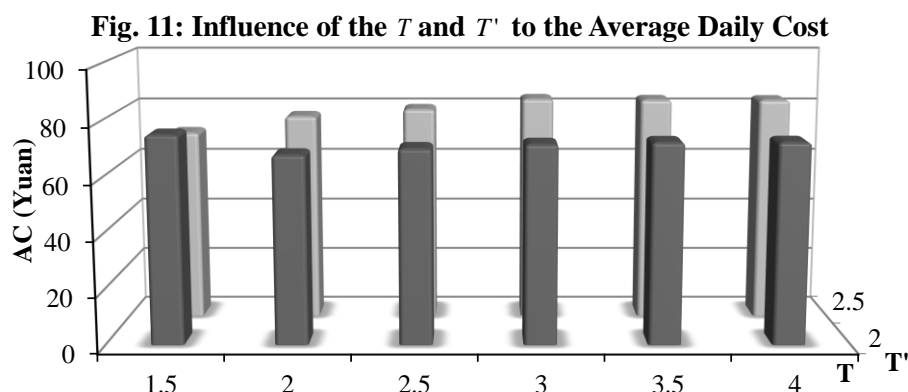
The relationship between the operating cost and the passenger volume is shown in Fig. 10, where the horizontal axis stands for the passenger volume of the coach, and the vertical axis represents the daily cost of the coach. It can be seen that when the ratio of the coach passengers rises from 30% to 55%, the marginal cost is low. However, if the ratio surpasses 55%, the increment of daily operating cost is relatively high.

Fig. 10: Relationship between Daily Operating Cost and Passenger Volume



When the ratio of passengers of the coach rises from 30% to 55%, the daily operating cost will increase 124 Yuan per 1% increment. When the ratio rises from 55% to 100%, the daily operating cost will increase 215 Yuan per 1% increment. Therefore, the ratio of passengers served by the coach should be set as 30%-55%. And passenger volume being served by the coach should be 191 persons to 350 persons. The daily operating cost will be between 0.86 million to 2.21 million Yuan.

From Fig. 9, we found that for 30% passenger volume, $T = 4$, $T' = 2.5$; while for 55% passenger volume, $T = 1$, $T' = 2$. For different combination of T' and T , the change of the daily operating cost is shown in Fig. 11.



It is obvious that the daily operating cost per passenger is smallest when $T = 2$, $T' = 2$. Thus, we think rationally that under this situation the designed timetable is the most reasonable one. With this timetable, the being served passengers are 42% of all the total demands and the daily operating cost is 2.18 million Yuan.

8. Conclusions

Based on the time and space network, the formation of the passenger trip chain from the origin to the airport is analyzed. The relationship among the timetable, passenger volume and operation cost is analyzed and an optimization model is established to design the timetable. Dalian airport is taken as an example for the case study. By solving the model and sensitivity analyses, it is known that when both the upper limit of passengers' waiting time and the transfer time are 2 hours, the designed timetable is most reasonable. The designing method in this paper takes passengers' trip demand and operating cost into account simultaneously, it provides great support for the operation of the airport coach.

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Multiple Comparison of Green Express Aviation Network Path Optimization Research

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Abstract

This thesis make Courier industry aviation network path as the research object, the aviation network path optimization as analysis aspect. With multiple iterative Dijkstra algorithm for research tools, set up to aviation carbon emissions, transportation distance for many factors such as dimensions of green express aviation network path optimization model. Through the calculation of the optimal model, to reduce the flight time, shorten the transportation distance, eventually to reduce carbon emissions and green express aviation network path optimization purposes. Finally, use an example to proof the feasibility and advantages of the method.

Keywords: Aviation network; Green express; Carbon emissions; Multiple iterative

1. Introduction

With global warming issue getting serious, control carbon emissions became the key topic of atmospheric protection, according to related results of global research indicated, that air emissions occupy 2%-3% in total global greenhouse gas emissions, into the atmosphere every year about 700 million tons of carbon dioxide emissions, and by 2025, the number will achieve 1.488 billion tons ^[1]. Not long ago, a global climate conference was held in Copenhagen, the four largest aviation company called on to international airline emissions of carbon dioxide into the new agreement issues. And express industry in air transport application of rapid development, more increased was is heavy air energy consumption burden. In order to reduce the aviation carbon emissions, the fight against global warming, at November 19, 2008, the European Union decided to take the international air field into to EU emissions trading system (ETS)'s account, and at January 1, 2012 implementation, This measure will make aviation participants to pay expensive. According to the EU's plan, carbon emissions in 2013 will down to 2% based on last year's, it will put forward higher request for aviation carbon emissions.

According to research from other countries, the international air transport association said, the airlines and companies involve air transport business; have four strategies to solve the problem of aviation emissions: (1) improved technology; (2) the efficient operation; (3) the infrastructure; (4) positive economic measures. A report by Tyndall center in Manchester University about aviation low carbon shows, by the end of 2011, the

aviation industry will be in the range of carbon emissions to 355 MtCO₂ between 284 MtCO₂. Researches in our country about aviation low carbon is in the initial stage of exploration, the general research aspect for the macroscopic level of research. Lei Xia and Peng Yu (2011)^[2] consider that the development of the aviation industry in the macroscopic level with low carbon economy, and that the relevant macro conclusion, puts forward a low carbon economy in the airline industry development countermeasure; Hui Gong^[3] in the low carbon transport industry development of research, this paper use a new technology application, management changes, actively participate in the new regulations measures. To the airlines and companies involve air transport business, reduce air carbon emissions is an inevitable trend, but in the macroscopic level of the environmental background, at present, the research about the airline network path optimization is not much, and the express profession low carbon green aviation research is less.

From the above aviation carbon emissions present situation and the existing related research found, at present the aviation carbon emissions problem has become the global carbon emissions problem to be solved, but research from the network path optimization aspect is not much, research about express aviation carbon emissions less. This paper take express industry air transport as the research object, consider from aviation network optimization path analysis, from transportation carbon emissions, transportation distance, establish green express aviation network path optimization model, with multiple iterative Dijkstra algorithm for the research tool, research problems of express industry green aviation network path optimization, and reduce the plane running time, so as to reduce carbon emissions. To express aviation network of low carbon green and high timely effect, eventually reduce air transport carbon emissions burden, to reduce carbon emissions. The last make a Courier enterprise of air transport as an example, this paper proved that this method and the model of the feasibility and advantages.

2. Model Illustration

2.1 Basic Assumptions and Symbols

In order to describe the model clearly, now introduce the definition of each symbol and its meaning as follows:

N: Represents the number of air terminals, namely analysis object has N aviation hubs currently, need to transport the goods to N numbers of air terminals.

X_{ij} : Represents the demand amounts of each air aviation hub to other aviation hub i and j represents the Numbers of each aviation hub.

T_{ij} : Represents the flight time of each aviation hub to other aviation hubs, the subscript i and j represents the Numbers of each aviation hub.

F_{ij} : Represents the carbon emissions of each aviation hub to other aviation hubs, the subscript i and j represents the Numbers of each aviation hub.

L_{ij} : Represents the distance between the each aviation hub to other aviation hub, the subscript i and j represents the Numbers of each aviation hub.

S: The speed of aircraft, is a fixed value constants.

H: The usage amount of the plane fuel.

Q: The plane's unit fuel consumption of the constant speed (Unit: L/KM).

According to the variable condition known:

$$L_{ij} = T_{ij} * S \dots \dots \dots (1)$$

S for fixed value, greater than zero, so L_{ij} is a positive correlation function about T_{ij} , namely flying the longer distance, the flight time is long;

According to Carbon emissions coefficient the Intergovernmental Panel on Climate Change (IPCC)¹ made, exist:

$$\text{CO2 emissions} = \text{Suggest emission coefficient} * \text{Intensity activity of emissions sources} \dots (2)$$

Among them, the intensity activity of emission source is to point to fuel usage H,

$$\text{namely: CO2 emissions} = \text{Suggest emission coefficient} * H \dots (3)$$

$$\text{and } H = Q * L_{ij} \dots (4)$$

will (4) generation into (3),so

$$\text{CO2 emissions} = \text{Suggest emission coefficient} * Q * L_{ij} \dots (5)$$

will (1) generation into (5),so

$$\text{CO2 emissions} = \text{Suggest emission coefficient} * Q * T_{ij} * S \dots (6)$$

According to Carbon emissions coefficient the Intergovernmental Panel on Climate Change (IPCC) made, the suggestion emission of coefficient aviation fuel is 2.39,make this data into (6),so

$$\text{CO2 emissions} = 2.39 * Q * T_{ij} * S = F_{ij} \dots (7)$$

According to the known conditions, Q and S for a fixed value, greater than zero, so F_{ij} is a positive correlation function about T_{ij} , namely flying time to grow more, produce of carbon emissions is bigger. In other words, reduce flight distance can reduce flight time, then can reduce the aircraft in flight produce of carbon emissions.

The transport aircraft that have the same hardware conditions (fuel consumption, fuel combustion rate and flight speed the same), flight distance and flight time is proportional to the aviation hub of flight time between different. The plane flying time is shorter, the fuel consumption is less, the cost of the smaller, produce of carbon emissions is smaller. According to the reality, the amount of demand from each aviation hub come and back is different, the back and forth demand between every two hub of demand is different.

2.2 Algorithm Model Analysis

Dijkstra algorithm make by the Dutch computer scientists Dijkstra in 1959 and from a peak to the rest of the vertex shortest path algorithm, is the solution about the shortest path problem. Air transport network is a directed graph, in the first iteration of the supply demand conditions need to calculate a hub to the rest of the hub of the shortest path, which is used for the shortest path Dijkstra algorithm to calculate meets the requirement. So choose Dijkstra algorithm model establishment. This paper on the basis of Dijkstra algorithm, meet the needs of the business case considering flight time, flight carbon emissions factors such as multiple iterative, more deeply than a simple Dijkstra algorithm.

To ensure transport efficiency, the algorithm model regard demand as its first variables, every optimal route will go through the route that meet the maximum demand. Dijkstra algorithm is a method to calculate to calculate the optimal value. Before the calculation, we need to flip the data of demand as Dijkstra is a method to calculate the shortest path algorithm.

¹ Data sources from: Data from Intergovernmental Panel on Climate Change (IPCC)¹2006

Dijkstra algorithm is used in every airline, when it go through the line add a points to the line, the same route go once is one more points. This makes the route and the relative difference between route, finally the conclusion shows the difference between each route, then obtain the final results.

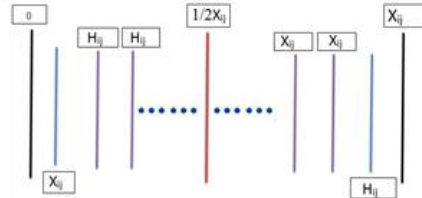
In this algorithm model use the flight time between aviation hub as its second variables, between each aviation hub have different flight time, According to (7),the shorter flight time the lower of the cost. Will all aviation hub of flight time between Dijkstra algorithms with the final line again iteration. After the multiple iterative, choose the multiple supply demand and relatively low cost, then the algorithm is end. At this time, through the “meet demand--relative to save time and to optimize the path for the line-reduce carbon emissions” three steps, get the ultimate goal of green express aviation network path optimization.

3. Algorithm Design

1. Will the aviation hub for business demand (in and out into sum) from big to small sorting, establish processing a number line. Regard a 0 as the starting point of a number line. Select the largest business demand for data X_{ij} as the end of a number line. And will end one half of data ($1/2 X_{ij}$) as the middle of a number line a number line.

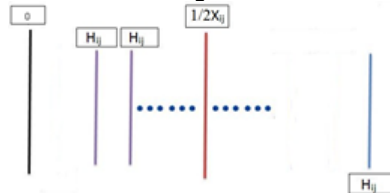
2. Will more than a number line $1/2X_{ij}$ among the digital row among the right to a number line, among the number of less than a number line was a number line on the left. Use a number line between $1/2X_{ij}$ to the right of the X_{ij} demand respectively between minus a number line, get a number X'_{ij} . Use a number line among the digital minus, as $1/2X_{ij}-X'_{ij}$, set to H_{ij} , this digital inevitable among less than a number line. Will this number are among the left to turn a number line; Use a number line between minus among the left side of the business model respectively demand(X_{ij}), get X'_{ij} , use a number line with the Numbers. It means $1/2X_{ij}+X'_{ij}$, set to H_{ij} . This digital inevitable among more than a number line $1/2X_{ij}$, will this number to align to flip a number line. Among the right, as shown in figure 1 show:

Figure 1: First Deal with a Number Line



Will deal with the demand of a number line data and turn data apart, as shown in figure 2 shows:

Figure 2: Final Disposal of a Number Line



Through the data processing, will be big demand for smaller Numbers, conversion of convenient operation after.

3. According to step 2 data processing results Dijkstra algorithm, use for the shortest route. No to figure $G=(V,E)$, the length of the side $E[i]$ that each for $w[i]$, find the vertex V_0 to the others each point of the shortest path.

Dijkstra algorithm is described below:

About identification, Such as node identification for [20, 4]: The first figure said from the beginning node to the node number from the second distance, said the node node to start on the path of please a node in the

Numbers.

Step 1: give node1 identification [0, S]. 0 mark node 1 to the distance to 0 is 0, S said node is the starting point.

Step 2: visit from node to node of the directly to 1, and gives a temporary logo.

Step 3: mark node determine from temporary with minimum distance node, and mark the node is the permanent marks. If all nodes are all permanent identifier, turn to step 5.

Step 4: the new permanent marker, the new logo marking began to examine the permanent logo cannot be directly to permanent marking node.

If the investigation for temporary mark node, node the new logo of permanent marking node and the new logo distance value of permanent mark that point directly to the distance from the node value adding together. If its and less than the distance between temporarily logo point, is to determine the minimum distance value is the closest to the distance value.

If the node is the investigation of the node, not mark the new logo of permanent marking node with new mark distance value of permanent mark that point directly to the distance from the node value adding together. And as a contingent logo to the point. Return to step 3.

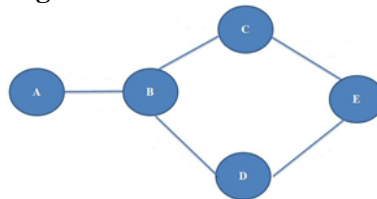
Step 5: The permanent logo is determined from node to node 1 each of the shortest, also identified the shortest route. The shortest route is determination by the pushing down theory.

Table 1: The Shortest Path between any Two Points

	V1	V2	v3	v4	v5	v6	The max number
v1	0	X ₁₂	X ₁₃	X ₁₄	X ₁₅	X ₁₆	
v2		0	X ₂₃	X ₂₄	X ₂₅	X ₂₆	
v3			0	X ₃₄	X ₃₅	X ₃₆	
v4				0	X ₄₅	X ₄₆	
v5					0	X ₄₆	
v6						0	

4. According to the calculated step 3 of the shortest path route, multiple weighted processing.

Figure 3: Shortest Path Chart

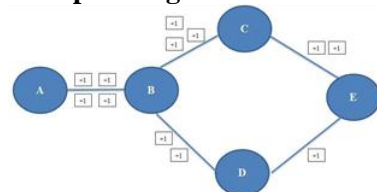


If the current business needs lines for:

(1) A→B(2)A→B→C→E(3)E→D→B→A(4)C→B→A(5)B→D(6)E→C→B

Every course be after once, plus one weights, multiple weighted. According to the above needs of the business lines, the results of multiple weighting as shown in figure 4:

Figure 4: Multiple Weighted the Path after Picture



5. Will the route that the weight value according to the final, from big to small order. In step 4 of the model as an example, the result is as follow:

(1) A—B(2)B—C(3)B—D C—E(4)D—E.....

6. Each aviation hub of flight time between the algorithms as the second variable model, all aviation hub flight between the times required for the list, as shown in chart 2:

Table 2: Aviation Hub Schedule

	A	B	C	D	E	F	G	H	I
A									
B	T_{AB}								
C	T_{AC}	T_{BC}							
D	T_{AD}	T_{BD}	T_{CD}						
E	T_{AE}	T_{BE}	T_{CE}	T_{DE}					
F	T_{AF}	T_{BF}	T_{CF}	T_{DF}	T_{EF}				
G	T_{AG}	T_{BG}	T_{CG}	T_{DG}	T_{EG}	T_{FG}			
H	T_{AH}	T_{BH}	T_{CH}	T_{DH}	T_{EH}	T_{FH}	T_{GH}		
I	T_{AI}	T_{BI}	T_{CI}	T_{DI}	T_{EI}	T_{FI}	T_{GI}	T_{HI}	
.....

7. Will the time factor to consider in iterative Dijkstra algorithm after from the shortest path in the iterative again. If present the same path weights, get smaller time T_{ij} , the lines will once again sort, if $T_{BD} > T_{CE}$, The sort order for again after:

(1) A—B(2)B—C(3)C—E(4)D—E.....

8. Sort of the map, after according to sort results mark. To the data of the results for example in part 7, first of all in the map mark "A- B", then mark "B—C", mark "C—E", finally mark "D—E", until the mark all aviation hub, the algorithm so far end.

9. Through the Dijkstra algorithm for the shortest path, using line through The Times as weights, the first iterative of the shortest path, to select the optimal path; use the length of time as a second variables, the second iteration based on the results of the first iteration, select the optimal path of the optimal path.

Through multiple iterative in the shortest path, a selection of optimal solution, then the optimal solution in a selection of the shortest path in time, reduce T_{ij} , because $F_{ij} = 2.39 * Q * T_{ij} * S$, so to reduce carbon emissions F_{ij} , get the ultimate goal of green express aviation network path optimization, to save fuel costs, and at the same time to save cost objectives.

The final total carbon emissions for:

$$\sum_{ij} F_{ij} = 2.39 \sum_{ij} T_{ij} Q S$$

4. Data Simulation

1. According to a Express delivery enterprise, according to the results of the investigation, This express enterprise current aviation hub in Beijing, Shanghai, Chongqing, Shenyang, Chengdu, Wuxi, Weifang,

Hangzhou, Shenzhen, Hong Kong ten cities. The amount of demand about each city is in the aviation, such as shown in table 3.

Table 3: Each Aviation Hub between the Needs of the Business

	010 Beijing	021 Shanghai	023 Chongqing	024 Shenyang	028 Chengdu	510 Wuxi	536 Weifang	571 Hangzhou	755 Shenzhen	852 Hong Kong
010 Beijing		13585	2339	9219	4825	11433	11911	11978	21460	1799
021 Shanghai	20425		1974	6909	3810		8803		21265	5780
023 Chongqing	750	589		338		459	273	598	1766	53
024 Shenyang	6190	3073	519		839	2070	2207	2997	4188	735
028 Chengdu	3036	1059		604		1281	1057	1416	3628	157
510 Wuxi	16331		1697	5880	4807		8247		33784	8294
536 Weifang	9092	6419	784	2533	1699	5006		5672	12446	2829
571 Hangzhou	23857		4524	9332	9145		13788		58370	18852
755 Shenzhen	53138	44075	6925	14984	13746	48691	24409	63753		
852 Hong Kong	2309	6347	142	858	210	6422	2125	9601		

Note: the above longitudinal for illnesses code (after dialling code for the three), transverse for destination code (after dialling code for the three)

2. Data processing

According to the 1, all aviation hub of the demand for business data processing, purpose is the large number of conversion for small amounts, convenient calculation of the algorithm. Process as follows.

Will the aviation hub of the demand for business (in&out) the amount and quantity from big to small sorting, establish processing a number line. Regard a number 0 as the starting point of a number line. Select the maximum data demand for business, as the end of a number line, and will end one half of the data as a number line among the number line.

In the aviation hub, portfolio in the rankings finishing such as table 4:

Table 4: Aviation Hub in Business

START.....END	Quantity
Shenzhen.....Hangzhou	63753
HangzhouShenzhen	58370
Shenzhen.....Beijing	53138
.....
Chongqing.....Hong Kong	53

(1) According to the table 4 ranking results, will more than a number line number row among the middle right, less than a number line among the number of a number line into the drain on the left a number line. That is $63753/2 = 31877$ (take integer), 31877 as the middle of a number line.

(2) Use a number line on the right side of the middle demand among minus a middle number line, get a number, garnish with a number line minus the number. This digital inevitable among less than a number line, will this number are among the left to turn a number line; use a number line between minus among the left side of the business model respectively demand, garnish with a number line with the same number, this number will among more than a number line, will this number to align to flip a number line right.

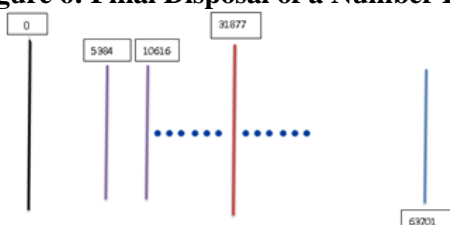
For example: $31877 - (59370 - 31877) = 5384$, $31877 - (53138 - 31877) = 10616$, $(31877 - 53) + 31877 = 63701$, the last of the data processing a number line as shown in figure 5 shows:

Figure 5: Prime Number Lines



Will deal with the demand of a number line data and turn data apart,

Figure 6: Final Disposal of a Number Line



Through the data processing, will be big demand for smaller Numbers, conversion of convenient operation after.

3. Time to handle

We base on the time, subject to all aviation hub of flight time for processing Table 5 for an Express delivery enterprise at present aviation hub of the flight schedule:

Table 5: Business Needs Flight Schedule for the City

Units: minutes

	Beijing	Shanghai	Chongqing	Shenyang	Chengdu	Wu xi	Weifang	Hangzhou	Shenzhen	Hong Kong
010 Beijing										
021 Shanghai	110									
023 Chongqing	150	150								
024 Shenyang	60	135	190							
028 Chengdu	150	150		190						
510 Wuxi	120		140	120	135					
536 Weifang	60	80	80	80	170	90				
571	120		145	130	150		135			

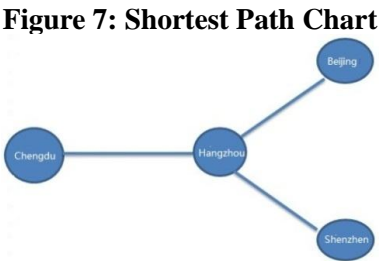
Hangzhou										
755 Shenzhen	190	130	130	310	120	135	180	110		
852 Hong Kong	225	140	135	220	145	130	190	120		

4. For the shortest path

According to the data processing results step 2 and 3 of the time step deal, and use Dijkstra algorithm for the shortest route.

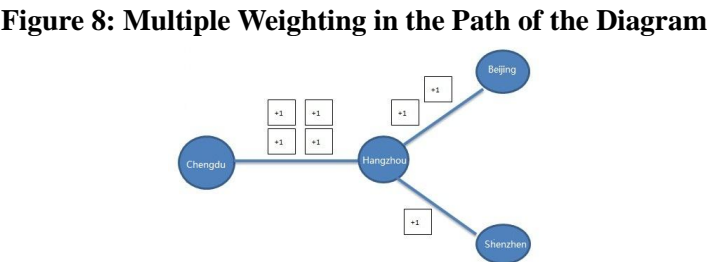
5. Multiple iterative weighted

According to step 4 calculated, the shortest path route multiple weighted processing.
For example: Through calculation of the assumption that after the shortest path as shown in figure 7 shows.



The current business needs lines for:
(1) the Chengdu- Beijing -Hangzhou
(2) the Chengdu-Hangzhou
(3) the Chengdu-Hangzhou-Shenzhen
(4) Beijing-Hangzhou-Chengdu

Every course be go through, plus 1, on the multiple weighted. According to the above needs of the business lines, the result of the multiple weighting on after as shown in figure 8:



6. Ordering and mark

Will the route that the weight value according to the final, from big to small order. After sorting results for:

(1) Chengdu-Hangzhou(2)Beijing-Hangzhou(3) Hangzhou-Shenzhen
After sorting, in the map to sort results according to mark. First of all in the map out "Chengdu--Hangzhou ", and then mark the "Hangzhou-Beijing ", to mark out" Hangzhou-Shenzhen "..... Until finish mark all aviation hubs.

So far, through the “aviation hub sure—the shortest path sure—multiple iterative—make line”, can assure an Express delivery company aviation network than the efficiency of the present situation, So that carbon emissions less than present situation, to achieve the goal of green express aviation network, and the cost less

than the status quo.

Through calculation, the algorithm and the accuracy of practical application other related algorithm is more effective and more close to reality. This algorithm is easy to make the treatment efficiency, through the computer programming calculation relative to other related algorithm is more quickly.

5. Epilogue

Aviation carbon emissions is one of the major reasons for global warming, and express industry in air transport industry is more and more important, construction of the green express aviation network has certain forward-looking. Build the green express industry aviation network, not a single factors, but by many factors, various, multi-level network composed of express.

Before the related studies, most research mainly aims about the civil aviation industry or carbon emissions strategy problem in microscopically on, did not in on microscopic express profession construction of low carbon green the particularity of the aviation network to consider.

From the author's point of view, this paper combining multiple iterative and a Dijkstra algorithm to aviation network planning, research aviation network optimal path, to get the goals about express aviation network of low carbon green, low cost and high efficiency. At the same time, the model is close to reality, has strong applicability.

Along with the raise of consciousness of environmental protection and low carbon green , the aviation industry participants to aviation network resources optimization and configuration also pay more and more attention to, this paper research the express profession green aviation network planning, can provide references about the aviation industry of express to build green aviation network planning, to some extent, reduce the express industry air transport carbon emissions, promotion, and optimization of the aviation network efficiency and reduce the cost. Of course the more draws close to the reality that makes the more complex algorithm, in $\sum_{ij} F_{ij} = 2.39 \sum_{ij} T_{ij} QS$ ($i>0, j>0$), the algorithm considering the situation is Q and S

fixed, carbon emissions only related to flight time, the reality of the Q and S may not fixed, because $T_{ij}S = L_{ij}$, and the distance between the two hub L_{ij} for setting value, this time the aviation carbon emissions only about fuel consumption Q, the greater the Q carbon emissions is high, the smaller the Q carbon emissions is less, the visible through the update technology reduce fuel consumption of the Q, is effective to reduce carbon emissions measures.

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Delivery Schedule Reliability in the International Container Liner Shipping Service: Implications for Research

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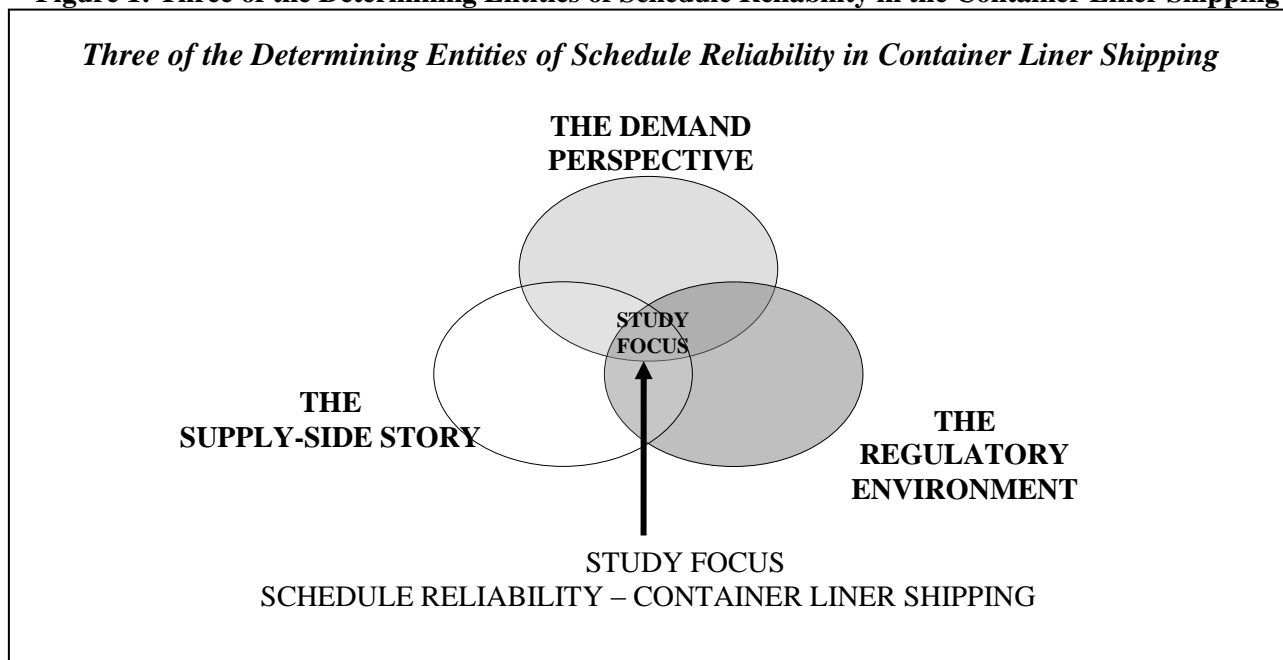
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1. Introduction

Schedule reliability has become an area of topical interest following various initiatives by liner shipping companies recently, notably the new “Daily Maersk” policy by Maersk Line, which focuses on guaranteed punctual departures and arrivals. Shippers have demanded schedule reliability for some time in attempts to reduce uncertainties from their international supply chains. This call has seemingly reached a new level as some powers have apparently shifted to the customers of containerized services as volumes have reduced following the global economic problems seen in recent years. In addition, there have been developments in the Rotterdam Rules legal framework covering liner shipping companies operations in connection with schedule integrity (UNCITRAL, 2008) and beyond this in terms of the anti-trust rules on competition introduced on trading to European Union ports from October 2008 (Marlow and Nair, 2008). The paper will assess the principal developments in the container liner shipping sector in relation to schedule integrity, with the purpose of clearly defining what service reliability currently means and establishing the implications and topics for future research in the field.

Figure 1: Three of the Determining Entities of Schedule Reliability in the Container Liner Shipping



To undertake this study, after a literature review which attempts to clearly define what schedule reliability means in the context of container liner shipping, a structured methodology to system enquiry will be followed (Kettinger, et. al. 1997). This identifies three of the determining entities identified by Mason and Nair (2012) comprising of demand, supply and regulation in the sector (Figure 1). In this paper, a particular focus has been

applied to the main arterial trade routes of inter-regional international container shipping.

2. Background

Container Liner Shipping – A Vital Cog in Modern Global Commerce

Today, commerce is defined by its international spread and nations have become inter-twined in a global network of trade. An important facilitator of this is international seaborne transport which currently provides more than 80 per cent of world trade by volume (UNCTAD, 2011). Within this context container shipping accounts for about 60 percent of the goods by value moved internationally by sea each year (UNCTAD, 2011).

Until recent times the container liner shipping sector has been a strong industry to be involved in, with the demand for global seaborne container transport rising annually on average at around +9% since its inception as a significant mode of international cargo movement commenced over the 40 years until 2007 (Mason and Nair, 2012). This is well above world GDP growth rates for virtually every year over that period. However, there are substantial risks involved in providing shipping services, especially because the size of investments in the sector are invariably highly capital intensive. In recent years, following the banking crisis in 2008 and its prolonged impact on the global economy, notably in the west, the landscape has become more turbulent for container liner shipping operators.

The Scheduled Nature of Container Liner Shipping

One of the key characterising aspects of the container liner shipping sector is the scheduled basis of their operations (Gardner et al., 2002, Stopford, 2009). For bulk shipping vessels, operators have the choice not to embark on a journey until they have a pay-load to meet the costs involved. However, in container liner shipping, because of the scheduled nature of operations, this is quite different. As a result, the majority of total costs for a service are borne irrespective of how full the vessel is. In this sense there is a substantial disconnect between the costs incurred and the price vessel operators actually can levy, which is in reality a function of the demand and supply situation in the marketplace at any one time (Mason and Nair, 2012). Globally, there are approximately 400 scheduled container liner services, most sailing weekly (Containerisation International, 2012) with the dense routes being the transpacific, the Europe Far East and the transatlantic routes.

Defining Schedule Reliability

Principally, the quality of service in container liner shipping largely depends on the reliability of the schedule, the focus of this paper, and the frequency of the service (Marx, 1953 and Mason and Nair, 2012). Notteboom (2006) defines container liner schedule network reliability as, “the probability that one or more of its links does not fail to function, according to a standard set of operating variables”. This is a useful definition as it provides flexibility in terms of how reliability is precisely delineated and suggests through the term “probability”, that it is not just concerned with what has happened in the past, but also about the confidence that can be given by relevant actors to reliability rates for specific carriers in different trade lanes and networks in the future.

To support this broader theoretical definition, numerous monitoring benchmarking surveys are produced by trade information bodies and consultants on schedule reliability: for example Drewry Shipping Consultant’s “Schedule Reliability Insight Report” and SeaIntel’s “Port-Port Schedule Reliability Fact Sheet”. Here, definitions are more exacting and are principally based around a simple delivery on time metric. However, this metric can be determined in different ways: should delivery on time be measured in terms of delivery by a set hour, or a longer period such as a half day or whole day. Similarly, should it be just a measure of being on time or not, however that is specified, or should it include how late a particular vessel was: surely a vessel arriving three days late into port is worse than a vessel being a few hours late. A sign that there is currently the heightened interest in schedule reliability suggested in this paper is the fact that both SeaIntel and Drewry have both launched or re-launched their benchmarking reliability monitor schemes in the past nine months (SeaIntel in July 2011 and Drewry in April 2012). The reports that are produced are used across the industry.

The Low Reliability Record of the Liner Shipping Sector

These trade analyst reports, along with a range of academic studies suggest that the container liner shipping sector has become characterized by poor rates of schedule reliability. For instance, the Drewry survey (Drewry Shipping Consultants, 2007) reported low reliability levels on worldwide liner services, with a percentage of on-time vessel calls of about 52%. Vernimmen, et al. (2007) reported on a large survey which revealed that “over 40% of the vessels deployed on worldwide liner services arrived one or more days behind schedule”. And more recently, according to a report from SeaIntel Maritime Analysis, the global schedule reliability is noted as being still fairly low. It decreased from 63% in November to 59% in December 2011, which means it remains the case that over 40% of the vessels on global liner services arrive behind schedule.

The recently commenced SeaIntel schedule reliability database also provides a useful insight into more of the detail of schedule reliability. It comprises of more than 35,000 arrivals, 44 carriers and 16 trade-lanes. Reliability is measured as arrival on the same calendar day or the day before. In late 2011 it showed that Maersk was the most reliable player with 74% of its vessels arriving on time, followed by Hamburg Sud with 70% and MOL with 67%. The schedule reliability on trade-lanes between North and South America and from Asia to the Mediterranean improved. The east-west trades saw deterioration, caused by ships being withdrawn for the winter season, including dry docking and lay-up. A more exacting measure of schedule reliability is also compiled by SeaIntel who separately measure those carriers that record schedules by the hour, of which there are seven: Maersk Line, Hamburg Sud, NYK, Yangming, OOCL, Wan Hai and Hanjin.

Thus, it can be seen that schedule reliability in the container liner shipping has been an on-going concern for practitioners and a key of area of interest for academics studying the sector.

Identifying the Research Gap

In particular, two papers stand out in making significant contributions in this specific subject area. First Notteboom (2006) assessed the “time factor” in contemporary container liner shipping. He noted that schedule adherence was highly desirable from the shippers’ perspectives but confirmed that in reality reliability rates were low. He explored the reasons for this, identifying port congestion as the principal causing factor, which will be explored in the supply-side story below. Although he suggested that many factors were outside the direct control of carriers he identified that carriers had markedly different approaches to schedule reliability and thus this could become a major source of differentiation in future markets. He concluded by suggesting a range of mitigating tools and applications which if taken could help carriers achieve better reliability rates. He ended by warning that, “as liner service networks have become more complex, the possible impact of service disruptions in one segment of the network on the network as a whole increases and could substantially lower the attractiveness of some types of liner service design”.

The second significant paper of note looked specifically at the subject of “schedule unreliability in liner shipping” (Vernimmen et al, 2007). It reaffirmed the issue of schedule unreliability was a characterizing feature of container liner shipping, but also noted a wide-spread variation between different trade lanes and different carriers. The paper focused on the impact unreliability had on shippers, and through a case study illustrated that significant extra safety stocks were required where the probability of unreliability was high.

Since these two papers however, the operating scenario faced by the sector has changed significantly across all three of the determining entities of demand, supply and regulation which will each be examined in this paper. Thus this paper fulfills an important role in beginning to bring up to date much of the analysis undertaken in previous research in the area so that more contemporary influences that are now coming to bear can be analysed.

3. An Exploration of Three Determining Entities in the Container Liner Shipping in relation to Schedule Integrity

The following section sets out to generate an understanding of the surrounding issues which currently impact on schedule reliability in container liner shipping. As explained at the outset of the paper this is conceived

through the lens of three determining entities which have a profound impact on the container liner system: the demand perspective of the shippers, the supply-side story from the providers and the ever-changing regulatory backdrop pertinent in the regions of the globe liner services operate within.

The Demand Perspective – Why Improved Schedule Reliability is Craved by Shippers?

The global marketplace for goods and services has become increasingly competitive and has become characterized by organizations frequently switching sources of supply and their location of manufacture to lower-wage economies, sometimes at a considerable distance away from the marketplace. This transition has been made partly possible due to the dramatic decreases in transportation costs brought about by the developments of the container liner shipping sector over recent decades. As a result, general cargo shipped in containers can be moved faster, cheaper, safer and in a much more controlled manner than in the days before the container system was invented and established.

Commensurate with this there have been considerable developments in information systems which facilitate advanced communications capabilities to play a crucial role in supporting these extended supply chains. And, there have also been considerable advances in terms of knowledge around how to manage supply chains to achieve optimum results. The management of uncertainty and the ability to control the supply chain have become significant factors for those organizations attempting to compete through supply chain management prowess.

However, although shippers have craved certainty from their international supply chains (Christopher et al., 2006) this generally has not been forth-coming due to the many factors which cause time and cost deviations in “trans-ocean” supply chains. Clearly, these extended supply chains are highly complex and should be viewed holistically from end-end. However, the principal leg of any land-sea-land route involving multi-modal transport connections is the ocean leg and it is here, as has been noted above, that historically reliability of schedule adherence has been very weak.

Why does this matter? In summary Frankel (1997) sums up the issue: “deviations in supply chain times add substantially greater costs than these associated with inter-modal buffer and transport delivery costs.....lack of effective schedule and operational control is estimated to add more than 60% to the cost of inter-modal transport and to more than double the real cost of the total supply chain for simple supply chains, while the costs penalties in more complex or less technologically advanced supply chains will be much higher”.

Thus there is a real need from the demand perspective to transform the schedule reliability of the container liner shipping sector which is at the heart of the global commerce system which has developed today. If this can be achieved there are significant opportunities for the breakthroughs that can be achieved through supply chain management excellence to be applied to extended international supply chains. This clearly would be of huge benefit to shippers and their customers, but also to providers of container liner shipping too. To explore this, the supply side story is now set out.

The Supply Side Story – Why is Schedule Reliability so Poor?

Clearly, schedule unreliability has been an on-going issue for the container liner shipping sector. There are a number of broader supply issues that have contributed to this reputation being developed, some of which are within the control of carriers, whilst others are outside this direct scope of control.

Notteboom (2006) examined the main causes of schedule unreliability. Examining the East Asia – Europe route for 2004 (Table 1) he found that the principal cause cited for schedule unreliability was to do with performance levels at ports, which accounted for a combined sum of 93.8% of the total source explanations for schedule unreliability. Although the survey was carried out in a peak period in 2004 at a time when many ports were particularly lagging behind the compound growth of container shipping volumes in terms of their own capability investments, port connected issues were clearly the dominant factor in causing instability in the container shipping system. Clearly it follows that ports beyond the first call on a loop were more

susceptible to schedule unreliability, as the more ports called on prior to docking the greater the chance of a delay.

Table 1: Sources of Schedule Unreliability on the East Asia – Europe Route – Fourth Quarter 2004 (Notteboom, 2006)

Source of schedule unreliability	Percentage	Port Related Source
Port/Terminal Congestion – unexpected waiting times before berthing or before starting/loading or discharging	65.5%	Yes
Port/Terminal Productivity Below Expectations (loading/discharging)	20.6%	Yes
Unexpected Waiting Times – due to weather or on route mechanical problems.	5.3%	No
Unexpected Waiting Times - in Port Channel Access (pilotage, towage)	4.7%	Yes
Unexpected Waiting Times - in Port Channel Access (tidal windows)	2.8%	Yes
Suez Convoy Missed	0.9%	No
Unexpected Waiting Times – at bunkering site /port	0.2%	Yes

Thus, it would appear that as container liner operators are part of a wider system that they are not in control of their own schedule integrity. Vernimmen et al. (2007) confirmed this pointing out that poor schedule reliability “can be explained by a number of factors, many of which are beyond shipping lines’ control. A major contributing factor to decreasing schedule integrity in recent years is the mismatch between the demand for container services and the supply of container handling capacity; this is especially felt during peak periods”.

This vulnerability of the container liner service to outside sources of problems is also an important issue. Notteboom (2006) cited Taylor and D’Este (2003) in suggesting that reliability and vulnerability are two inter-related concepts. He notes that vulnerability refers to “a network’s weaknesses and the economic and social consequences of a network failure”. Thus, to understand how reliable a network such as the supply of container liner services could be, an assessment of how vulnerable a network is should also be explored.

A further connected point is the ease to which carriers can catch up time if they run behind schedule – their mitigating options. Notteboom (2006) provided a list of six tactics which could be employed by carriers to revert to schedule:

- to reshuffle the order of ports;
- to skip a port completely;
- to employ cut and run tactics;
- to deploy other vessels to take over in combination with a delivery to a hub;
- to look to speed up future port turnaround times, or,
- to increase vessel speed between ports, especially on inter-continental legs.

What can be quickly seen from this list is that no option is totally a harmless one. Each one will either impact severely on service levels for some customers or result in substantial extra costs for the carrier itself. So when a vessel slips behind schedule, for whatever reason, it can be a considerable challenge to make up this time loss in as painless a way as possible.

A key issue here is the degree of buffering that is employed to protect or bolster schedules. Clearly, a buffering policy has costs and penalties inherent in it. Indeed the strategies of different carriers to either build in buffers or show determination to make up schedule slippage range widely and should form an area for future research.

The Regulatory Environment – How can Legislators Ensure a Fair Deal for Providers and Shippers?

As has been discussed the container liner shipping industry is characterised by the provision of scheduled services. Left unregulated the scheduled nature of any maritime sector could threaten the ability to provide a sustainable industry and this has been recognised throughout the history of the maritime sector since the mid-19th century. Therefore, unlike many other industries, operators have been generally permitted since the 1800's to enter into horizontal collaboration in the form of price fixing and supply regulation agreements with competing carriers. These agreements, which have become the norm in the scheduled shipping industry, first appeared in the UK/Calcutta trade in 1875 with the setting of the price conference agreement to serve the tea trade between UK and India (Marlow and Nair, 2008). Subsequently, the industry has seen the proliferation of such agreements all over the world seaborne trade.

In the container liner shipping sector this regulating mentality has been applied. Although these price fixing and conference agreements were regarded as being potentially in breach of the antitrust regulations initially of the USA, they were seen as meeting a latent demand for shipping services of small ship lot cargo and thus assuring stability of trade for shippers and traders globally. The literature suggests that largely as a result of this perception, the agreements were allowed to operate under a system of exemptions from antitrust rules such as firstly the US Shipping Act of 1916 which was then repealed and replaced by the US Shipping Act of 1984, currently still in operation today (FMC, 1989; Nair, 2009). Secondly, this form of horizontal collaboration was also granted immunity from the rules on competition contained in Articles 81 and 82 of the EU Treaty (subsequently renumbered as Articles 101 and 102 of the Treaty on Functioning of the European Union, under the Treaty of Lisbon signed in 2007).

International Legal Rules and Instruments on Reliability

Schedule reliability is conceived within the regulatory framework as a key constituent of what needs to be monitored to ensure a fair deal for both carriers and shippers. Thus a legal burden is placed on maritime transport including container shipping by relevant international transport rules to provide a minimum level of commitment to schedule reliability. This ensures that relevant provisions in carriage contracts such as the bill of lading for container sea transport include liability on carriers to perform their service without delay. It also permits an antitrust rule framework which enables carriers and shippers to work on a short term basis with mutual obligations and commitments.

The route for ensuring compliance of shipping lines to time reliability is through transport contract agreements which are then contained in documents with the most used one being the bill of lading. This document has been regulated by a number of international conventions with the popular one being the Hague Visby Rules (HV Rules) adopted in 1968. This Convention which is currently in force in a number of jurisdictions worldwide including under English law does not contain any provision for delay. The liability of the carrier under the HV Rules concern the loss or damage to cargo that is carried and provides for the rules to determine the damages that would be payable to claimant in the event that such losses or damages occur to the cargo carried under the Rules.

The Hamburg Rules of 1978 on the other hand (United Nations Convention on the Carriage of Goods by Sea, Hamburg, 1978), provides specifically in Article 5, that:

“The carrier is liable for loss resulting from the loss of or damage to the goods, as well as from delay in delivery, if the occurrence which caused the loss, damage or delay took place while the goods were in his charge as defined in Article 4, unless the carrier proves that he, his servants or agents took all measures that could reasonably be required to avoid the occurrence and its consequences”

The concept of delay in paragraph 2 of this article is measured “...within the time expressly agreed upon...or within the time which ...reasonable to require of a diligent carrier....”.

The liability for delay is provided in Article 6 paragraph 1, sub para (b), as “...equivalent to two and a half times the freight payable under the contract of carriage by sea.”

More recently, the United Nations adopted the text of the UN Convention on Contracts for the International Carriage of Goods Wholly or Partly by Sea on 11 December 2008. The Resolution that was adopted with this Convention also recommended that the rules be called the “Rotterdam Rules” (Carr, 2010). The Rules provide that the carrier is liable for the loss or damage to the goods or delay in delivery. In addition, the Rules provide for the right to claim for economic loss due to delay in delivery, with a specific provision on the limits established for these claims in Article 60. Finally, there is the provision that the limits under this claim would be removed where the carrier actions are attributable to a personal act or omission of the person claiming a right to limit with intent to cause such loss or recklessly and with knowledge that such loss would probably result, and this is defined to include delay. This most recent international legal regime, which could have wide international application has already moved similarly to the provisions in the Hamburg rules and have incorporated the need to consider delay as an element of the transport operations.

Over the above specific provisions in legal instruments, there is another legal provision which is the instrument of service contracts (Marlow and Nair, 2008). These service contracts are available within the body of rules contained in antitrust laws of both the United States and the European Union. These contracts allow container shipping companies to enter into direct transport contract arrangement with exporters. These contracts are defined in their scope in terms of service frequency and coverage; this would also include provisions on the commitments to reliability by both cargo owners as well as shipping companies. The principal reason to enter into these service contracts is to reduce potential uncertainties of cargo volumes and thus ensure more consistent deployment of ships in a particular trade route to be served by container shipping companies. These service contracts provide a wider net of the legal framework for structuring the relationship between carriers and shippers in their cargo contracts and it would be useful to determine whether these provisions are within the consideration of carriers in their commitment to service quality for scheduled services.

The bill of lading is the document that is regarded in law as the evidence of the contract although it would also be referred to for the contract of carriage in its entirety depending upon the party that is the holder of the document. It contains the terms of the carriage that will be relied upon to establish the obligation of the carrier and the shipper depending upon the circumstances. It should be noted that in the case of the FIATA bill of lading for multimodal transport there is a provision for liability of the freight forwarder not only for loss or damage, but also for delay. In view of this provision in the bill of lading there is a contractual commitment to perform to an agreed time frame when the transport contract is entered into between the parties concerned.

4. Developing an Agenda for Future Research in Container Shipping Schedule Reliability

This study’s objective is to determine an agenda for future research in the concept of schedule reliability. A key output of this is to suggest that future research in this area should be conceived of from the three determining entities set out above: the demand perspective, the supply side story and the regulatory environment. In the following section specific themes emerging from each of these entities, which have emerged through the review above, are presented (Table 2). This can act as an agenda for future research in this topic area by, in essence, breaking down the research and asking two fundamental questions:

1. What are the factors driving the need for enhanced container liner schedule reliability?
2. What are the factors decreasing the vulnerability of container liner schedule disruption?

Table 2: Potential Causes of a Change of Emphasis on Liner Shipping Schedule Reliability – An Agenda for Future Research

	What are the factors driving the need for enhanced container liner schedule reliability?	What are the factors decreasing the vulnerability of container liner schedule disruption?
The Demand Perspective (from shippers and other supply chain)	<ul style="list-style-type: none"> - Is there an increasing focus from shippers on schedule reliability as a key performance attribute? - Does a trade off for schedule reliability exist from shippers in 	<ul style="list-style-type: none"> - Does a cooling off of demand volumes on routes such as the Asia – Europe leg since 2008 reduced the pressure on port systems? For example:

actors: e.g. port operators)	<p>demanding an exchange for slow-steaming (if it is going to take longer at least to make sure consignments arrive are on time!)?</p> <ul style="list-style-type: none"> - Is a trade off for greater schedule reliability demanded for against higher prices being levied (again – if it is going to cost more to move goods – make sure the service reliability is improved)? 	<p>Allowed investments in port handling capacity time to catch up with demand levels (e.g. in Chinese and in north west European ports)</p> <p>Facilitated an increase in inter-port competition sharpening the focus on reducing loading/unloading delays</p>
The Supply Side Story	<ul style="list-style-type: none"> - Has vertical integration through ownership of the supply side of container shipping been developed in recent years – e.g. how many of the leading vessel operators now also own/run ports or berths within ports? - Is there a more integrated network emerging in support of large arterial carriers on Asia – Europe routes (spin-off implications of poor schedule reliability have increased)? - Is there a more integrated ownership of assets emerging in international maritime logistics among the principal liner shipping operators which may be impacting on the desire they have for better reliability? (operators suffer in other aspects of their business if reliability levels remain poor)? - Is there an increased strategic focus given to liner shipping reliability in recent years by leading operators (the need to differentiate through service increasing as other differentiating options become exhausted)? 	<ul style="list-style-type: none"> - Do buffering tactics have to become more prominent to support liner operators strategies around schedule reliability? For example: <ul style="list-style-type: none"> • Does slow-steaming provide a greater transit time buffer? • Do investments in capacity ahead of realized demand levels mean more back up vessels are available? • Do the increasing dominance of larger vessels mean that hub-hub routes are becoming simpler (with generally fewer port calls)? • Have ownership of ports become more integrated with vessel operations for the main carriers?
The Regulatory Environment	<ul style="list-style-type: none"> - Do the changing anti-trust rules create a more competitive environment especially since 2008 in Europe following the removal of immunities from article 101 TFEU? - Do the new Rotterdam rules mean that the focus on schedule reliability has become more of a transparent imperative as an industry legal standard to be complied with? 	<ul style="list-style-type: none"> - Have the new Rotterdam rules meant that stricter penalties are enforceable for delays in delivery of shipments?

5. Conclusion

This paper is conceived through the lens of three determining entities which have a profound impact on delivery schedule reliability: the demand perspective of the shippers, the supply-side story from the providers and the ever-changing regulatory backdrop pertinent in the regions of the globe liner services operate within. The broad picture for each determining entity has been developed with more contemporary issues in relation to each entity being identified as potential avenues for exploration and for future research.

The financial market has changed drastically since 2008, which has had a severe impact on demand and

supply for shipping services. The 2008 financial crisis saw the shipping industry responding by adjusting supply through slow-steaming, laying-up and engaging in chartering as ways to adjust to the changing demand (Drewry Shipping Consultants, 2009, Mason and Nair, 2012). There was a brief recovery through 2009 after the 2008 financial crisis and several liner companies regained the confidence in building larger ships (for example: Maersk Line and Evergreen). However, in 2010 and 2011 the Euro zone crisis hit the financial market and the shipping market suffered again. Following the two shocks the shipping industry has faced, it appears that the shipping companies could have miscalculated and to be running out of strategies to save themselves from substantial losses on their container liner businesses. More recently, shipping companies appear to be exploring service quality as a means to regain profit, which raises the potential for more severe competition among different shipping companies. To complicate this situation a shift appears to be developing in the strategies of liner shipping companies from collaborative action to a more independent unilateral stance. This appears to be partly driven by recent changes in the anti-trust rules on competition introduced on trading to EU ports since October 2008, which is important to research in any study on schedule reliability. The findings of future research in this area will be of interest to practitioners connected with the international liner shipping sector as well as academics interested in the industry and the wider notion of the viability of international supply chain management.

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Knowledge-Sharing within Strategic Alliance Networks and its Impact on Firm Performance in the Liner Shipping Industry

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Abstract

Following the proliferation of globalization and the knowledge-based economy, there is widespread consensus amongst researchers in the field of strategy that knowledge – an invaluable resource – enhances the competitiveness of firms. Strategic alliances between firms – a pervasive phenomenon in the field of business today – are increasingly employed as instruments for knowledge-sharing, whilst the consequent formation of alliance networks is progressively becoming rampant and prominent. In recent years, the effect of alliance networks on individual firm performance has become a vital subject of study for both industry practitioners and scholars. While there has been increased growth in literature on the knowledge-based view, strategic alliance and alliance networks in recent years, research in these areas within the maritime industry has been limited. Nevertheless, as strategic alliances are common phenomena in the maritime industry, especially in liner shipping, it is important to examine the knowledge dynamics within alliance networks in the context of the liner shipping industry. Utilizing a qualitative research approach based on in-depth face-to-face interviews with high level executives from liner shipping firms embedded in alliance networks, this study sheds light on the mechanisms of knowledge-sharing within alliance networks, illustrates how knowledge-sharing amongst strategic alliance partners leads to improved firm performance, as well as depicts the limited positive moderating effects of the co-location of alliance firms within clusters on the former relationship. The results of this study provide significant practical insights to senior executives of liner shipping firms in their strategic decision-making process pertaining to the management of knowledge and relations within ‘co-petitive’ strategic alliances, as well as the consequent implications on firm performance. In addition, this study also contributes academically by illustrating how knowledge management theory applies in the context of the maritime industry.

Keywords: strategic alliance networks, knowledge-sharing, cluster theory, liner shipping

1. Introduction

Strategic alliances, undoubtedly a pervasive phenomenon in the field of business today, are generally defined as voluntary cooperative arrangements between firms which encompass the exchange, sharing, or co-development of capital, technology or firm-specific resources (Parkhe, 1993; Gulati, 1998). It is extensively acknowledged that strategic alliances provide significant means to firms for customer value creation and competitive advantage augmentation, such as access to new markets and technologies, enhanced product development, and economies of scale and scope (Mariti and Smiley, 1983; Hagedoorn, 1993), whilst the consequent formation of alliance networks is progressively becoming rampant and prominent. Following the proliferation of globalization and the knowledge-based economy, there is widespread consensus amongst researchers in the field of strategy that knowledge, viewed as an invaluable resource, is instrumental for the success and competitiveness of firms (Grant, 1996; Boisot, 1998). Consequently, it is unsurprising that

strategic alliances are increasingly employed by firms as instruments for knowledge access and acquisition, while research interest in the area of knowledge sharing amongst strategic alliances has also grown tremendously (Simonin, 2004; Grant and Baden-Fuller, 2005).

In recent years, the effect of alliance networks on individual firm performance has become a popular subject of study for both industry practitioners and scholars (Dyer and Singh, 1998; Gulati et al., 2000; Koka and Prescott, 2002). It has been suggested that the performance and conduct of firms can be more meaningfully comprehended by studying the network of relationships within which they are embedded (Gulati et al., 2000; Molina-Morales and Martinez-Fernandez, 2010). While there has been burgeoning literature on knowledge sharing within strategic alliance networks in recent years, studies which empirically examine the specific mechanisms of knowledge sharing in horizontal alliances and assessing their resulting impact of knowledge sharing on the performance of firms embedded within alliance networks are limited. Furthermore, research in the aforementioned areas within the maritime industry is also relatively scant despite strategic alliances and alliance networks being pervasive phenomena, especially in liner shipping. Hence, it is meaningful both in terms of academic and practical implications to study and explore these concepts in the context of the liner shipping industry.

In essence, this study seeks to identify the relevant knowledge sharing mechanisms and their impact on firm performance within strategic alliance networks. The moderating effects of the co-location of alliance partners within an industrial cluster in the context of the liner shipping industry would also be examined. This paper consists of five main sections, with the next section comprising of a discussion of the general theories related to the topic examined, namely the knowledge-based view, cluster theory, as well as strategic alliances in the liner shipping industry. The third section then follows by introducing the proposed conceptual framework and research methodology. The fourth section consists of research findings, discussion of the implications of this study and the opportunities for future research, while the final section concludes this paper.

2. Related Theories and Strategic Alliances in the Liner Shipping Industry

2.1. What is Knowledge?

Morone and Taylor (2010) have classified and summarized several knowledge types as follows: 1) 'know-what'; 2) 'know-why'; 3) 'know-how'; and 4) 'know-who'. 'Know-what' encompasses knowledge pertaining to facts and is strongly linked to the concept of information, while 'know-why' comprises of 'the scientific knowledge of principles and laws of motion in nature, in the human mind, and in society' (Lundvall and Foray, 1998). 'Know-how', on the other hand, refers to the skills and capability to accomplish something, which usually reside in individuals and firms. Finally, 'know-who' involves information regarding 'who knows what and who knows how to do what' (Lundvall and Foray, 1998). With reference to above classification, knowledge and information are evidently inter-related concepts, but are nevertheless distinctly different. As proposed by various scholars, information consists of the structured arrangement of data which makes its conveyance through physical channels relatively easy, while knowledge is derived via cognitive processes and procedures through which an array of information are intermixed and expressed (Davenport and Prusak, 1998; David and Foray, 2002). Thus, as Howells (2002) aptly defines, knowledge is '*a dynamic framework or structure from which information can be stored, processed and understood*'. Conclusively, knowledge functions as a critical means to comprehend and utilize information, which would be ineffective and futile for any kind of economic application in the absence of the necessary prior knowledge.

In addition, knowledge was broadly also differentiated into two main epistemological dimensions namely, explicit (or codified) knowledge and tacit knowledge (Polanyi, 1967; Nonaka and Takeuchi, 1995). Explicit or codified knowledge is basically recorded and formalized in a specific language which can be transferred and communicated in the form of manuals, instruction booklets and etc. On the other hand, tacit knowledge is characterized to be abstract, informal, internalized and experiential, and is mainly acquired through direct experience and vigorous participation in the learning process (Polanyi, 1967; Nonaka and Takeuchi, 1995). Explicit knowledge fundamentally forms the basic building blocks in the learning mechanism, while tacit knowledge involves the cognitive connection and integration. Moreover, while explicit knowledge is entrenched within standardized routines and procedures, tacit knowledge is normally transferred and

established within context-specific non-standardized regimes (Martin and Salomon, 2003). While tacit knowledge is widely debated to be of more value, explicit knowledge can be obtained and utilized more straightforwardly and promptly in comparison (Polanyi, 1967). By and large, knowledge in the form of quantifiable and recorded procedures, routines and technologies are considered to be explicit and relatively easier to transfer. In contrast, managerial, organizational and marketing expertises, which are intrinsically complex and difficult to codify in handbooks or formulas, are deemed to be more tacit as compared to technological knowledge (Shenkar and Li, 1999).

Following the studies of Polanyi (1967), the two-prong dimensions of explicit and tacit knowledge have actively been acknowledged and applied in research for various fields, including strategic management, knowledge management, organizational management and etc. Inevitably, these distinct concepts of explicit and tacit knowledge have profound implications on the mechanisms and dynamics of knowledge sharing.

2.2. *The Knowledge-based View of Collaboration*

The knowledge-based view of the firm, derived from resource-based theory (Barney, 1991), emphasizes knowledge as a critical resource necessary for sustained competitive advantage and highlights the importance of the ability of firms to access, create and assimilate knowledge (Grant, 1996; Grant and Baden-Fuller, 2004). Similarly, the knowledge-based view of collaboration, which entails the acquisition and access of knowledge as a resource via strategic alliances, stems also from the resource-based view (Barney, 1991) and resource-dependence theory (Pfeffer and Salancik, 1978). This is evident in the increasing number of strategic alliance studies which have uncovered knowledge sharing, which entails the transfer of know-how, organizational capabilities, technology and etc, as a primary intent for collaboration (Khanna et al., 1998; Dyer and Nobeoka, 2000; Simonin, 2004). As economies become more globalized and knowledge-based, knowledge creation and learning are increasingly becoming more crucial for firm competitiveness and performance. In order to innovate and remain competitive, firms generally go through learning processes involving the utilization of existing knowledge, as well as acquisition and creation of new knowledge. Many scholars have also identified that inter-organizational learning, through collaboration with other firms coupled with the subsequent monitoring and imitating of their practices, is crucial for firm competitiveness (Levinson and Asahi, 1996; Powell et al., 1996). Often, innovation also entails the exchange of mutually beneficial learned knowledge, which implies that knowledge sharing is inherently a socially-driven process (Berger and Luckmann, 1966) that plays a critical role in the mechanism of learning.

Grant and Baden-Fuller (2004) argue that alliances possess a fundamental advantage of knowledge access as compared to other firms, and have revealed in their study that alliances enhance efficiency in knowledge utilization and integration of applicable knowledge into complex product and service offerings. Collaboration networks within strategic alliances are thus essentially effective conduits which can be exploited for knowledge access and exchange for mutual benefit by alliance partners. These conduits for knowledge flows can take the form of legal contracts governing the collaboration, as well as social relations between alliance partners. While legal contracts specify the obligations and confines of alliance partners, social relations go further by helping to foster trust and shared identities, which encourage the free flow and exchange of knowledge as well as decrease transaction costs (Dyer and Nobeoka, 2000). Generally, trust provides confidence and security that the knowledge shared will not be abused and subject to opportunism, while shared identities facilitate learning and overcome obstacles. When appropriate knowledge is shared amongst alliance partners and effectively utilized to enhance the efficiency, flexibility, as well as service quality and offering of the respective strategic alliance, the individual firm performance is expected to improve.

2.3. *Cluster Theory*

Nevertheless, the relationship between knowledge sharing and firm performance is expected to be significantly enhanced by a firm's co-location with alliance partners within an industrial cluster. This is because the incidence and tendency of knowledge sharing is generally acknowledged to be augmented by clusters, which are defined as 'geographic concentrations of inter-connected companies and institutions in a particular field' (Porter, 1998). Subsequently, presuming that the relationship between knowledge sharing and

firm performance is positively linear, an increased level of knowledge sharing would essentially lead to a proportionate increase in firm performance.

Clusters typically embody the notion of geographical proximity, which encourages the formation of strong local networks (Saxenian, 1994; Maillat et al., 1997; Porter, 2000) amongst alliance partners in the event of co-location. These strong local networks forged amongst co-located alliance partners in turn facilitates dynamic social interactions (Henry and Pinch, 2002), thereby generating ‘untraded interdependencies’ (Storper, 1995) – informal exchanges and arrangements – that can function as effective conduits for knowledge or information flows. Furthermore, knowledge sharing is believed to be enhanced by relations established on reciprocity and trust, which stem from being a part of communities of practice (Brown and Duguid, 2001) or epistemic communities where actors share similar education and skill-sets (Wilson and Spoehr, 2010). Moreover, geographical clustering is widely proposed to enrich the exchange of spatially ‘sticky’ and difficult to articulate tacit knowledge between the proximate firms (Gertler and Wolfe, 2005), as opposed to remote firms. Therefore, the co-location of alliance partners in a cluster fosters the stimulation of dynamic knowledge flows – both tacit and explicit – within the alliance network via the effects of the cluster’s ‘local buzz’ (Bathelt et al., 2004) or ‘industrial atmosphere’ (Marshall, 1927). According to Storper and Venables (2003), ‘buzz’ is generated through parties being physically co-located and refers to the wide-ranging settings conducive for both purposed and accidental face-to-face meetings that give rise to myriad forms of knowledge exchanges.

2.4. *Strategic Alliances in the Liner Shipping Industry*

Following the illustrations of relevant theories in the previous sections, this section discusses whether the respective theories are applicable in the context of the liner shipping industry. As most liner shipping routes are dedicated to the shipment of containers, the strategic alliances and networks discussed in this study shall be confined to the containerized liner shipping sector. Horizontal in nature, strategic alliances amongst liner shipping firms are operationally-driven and revolve mainly around collaborative agreements with competitors encompassing vessel pooling, space purchase and space exchange. While it is widely accepted and understood that strategic alliances in the liner shipping sector are essentially forged for the purposes of risk-sharing, cost minimization, attainment of economies of scale, plugging resource-based gaps, service network integration and market penetration (Slack et al., 2002), the persistent challenges posed by the current volatile and uncertain business climate, coupled with the perennial low profitability of liner shipping firms calls for a shift in paradigm towards a knowledge-based view for collaboration. The knowledge-based approach for collaboration involves alliance firms establishing an effective knowledge sharing network within the strategic alliance, whereby relevant knowledge vital for alliance competitiveness and sustainability flow freely for the benefit of the alliance network as a whole. With the increase in accessibility of knowledge, coupled with its subsequent appropriate application and integration, the liner shipping firms’ performance is expected to improve.

Liner shipping firms operate in an extremely volatile and uncertain environment, with demand and supply being highly dependent on the state of the global economy and trade. Demand for shipping is fundamentally driven by the world economy and seaborne commodity trades, and is primarily recognized as ‘derived demand’. Shipping demand in turn influences freight rates, which would consequently impact the supply of ships in the shipping market (Stopford 2009). In addition, the shipping cycle, which is depicted by relatively short peaks and extended troughs, characterizes the vulnerability of liner shipping demand and supply, especially during periods of economic uncertainty or random economic shocks. This can be illustrated by the fact that freight rates for Asia – Europe routings plunged to zero and even negative freight for certain routings when the global financial crisis struck in 2008, whereby global trade drastically slowed to a crawl. During this period, the liner shipping firms participated in massive price wars and slashing of freight rates in a bid to retain their market share, which unfortunately led to massive industry-wide financial losses and bankruptcies. The liner shipping industry was thereafter plagued with a high level of overcapacity, which led to massive vessel lay-ups and scrapping.

Nevertheless, the issue of overcapacity and financial woes of liner shipping firms appear to be perpetual problems up till today. Most liner shipping firms are still deeply entrenched within a quagmire of hefty

financial losses, seemingly mindless pursuit for market share at the expense of bottom-lines, and the extensive ordering of mega-size ships – more than 18,000 TEUs in capacity – in the relentless race to attain economies of scale. The apparent mismanagement of capacity and unsustainable rate levels offered by liner shipping firms indicates a blatant disconnect with the oversupply situation afflicting the industry. Hence, it is undeniably critical and beneficial for liner shipping firms within alliance networks to share relevant market-specific and firm-specific knowledge and/or information necessary to achieve a more balanced alignment of collective capacity within an alliance with that industry demand levels. Appropriate knowledge and information, when integrated and applied to the relevant strategic alliance would aid alliance partners in making more sound decisions, on the strategic and pricing basis, both collectively as an alliance and individually. This would also enable the strategic alliance to function operationally in a more nimble manner, maintain its schedule integrity, adapt its service standards and capacity readily to changes in demand and supply levels, as well as seize relevant business opportunities like breaking into new markets and service routes when they arise. As proven empirically by Lee (2010) in a case study targeting Korean maritime firms, knowledge, namely market-specific and firm-specific, is vital in mitigating environmental uncertainty and aiding firms' flexibility in adapting to environmental challenges. Therefore, as liner shipping firms within alliance networks collectively engage in learning and knowledge-sharing, the individual firm performance, in terms of capacity management, operational efficiency, service quality and overall profitability is expected to improve.

With prolonged commitment and engagement in knowledge sharing amongst alliance partners, 'social capital' in the form of trust and reciprocity accumulates within the strategic alliance, which would further reinforce the former relationship. In addition, based on findings reported in cluster literature as discussed previously, the incidence of knowledge sharing is likely to increase and be facilitated by geographical proximity and social ties when firms are co-located within an industrial cluster (Henry and Pinch, 2002). Hence, liner shipping firms belonging to alliance networks embedded in industrial clusters are expected to share knowledge and information more frequently and intensely, through the fostering of closer relationships and dynamic interactions, with their spatially proximate partners. This increased knowledge sharing consequently leads to a better understanding of and response to the market situation and operational environment, hence boosting firm performance.

In general, there is a dearth of empirical literature on knowledge sharing within horizontal alliance networks and its impact on firm performance especially in the context of liner shipping despite the increasing prominence of the knowledge economy, as well as the pervasiveness of horizontal alliances in the industry. Hence, in an attempt to fill above literature gap coupled with the preceding theoretical discussions, this research paper seeks to answer the following research questions (RQs):

- RQ1: What are the mechanisms of knowledge sharing amongst liner shipping firms within an alliance network?
- RQ2: What is the impact of knowledge-sharing within alliance networks on a liner shipping firm's performance?
- RQ3: Does the co-location of alliance partner firms within an industrial cluster moderate the relationship between knowledge-sharing within alliance networks and a liner shipping firm's performance?

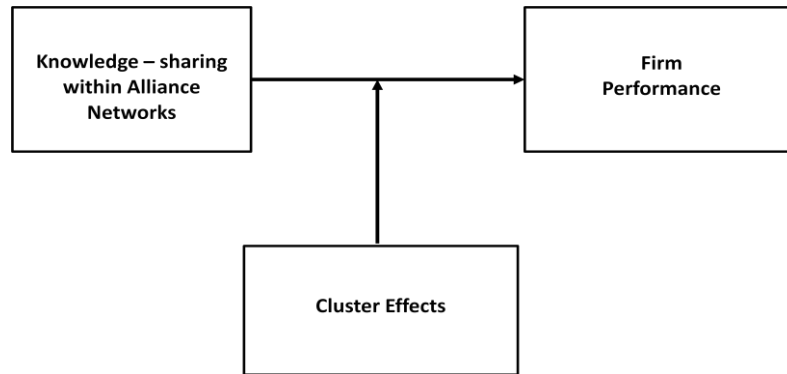
3. Methodology

3.1. The Conceptual Framework

The conceptual framework of this research revolves mainly around three areas, namely 1) knowledge sharing within liner shipping alliance networks, 2) the impact of knowledge sharing on firm performance, and 3) cluster effects derived from alliance partners' co-location within an industrial cluster. In order to develop this framework, a broad review on literature was conducted to a) identify the categories and dimensions of knowledge, the relevant knowledge sharing dynamics amongst strategic alliance partners, the relevant

indicators of firm performance; b) determine the relationship between knowledge sharing and firm performance, and c) the effects of co-location within an industrial cluster. Figure 2 provides an illustration of abovementioned conceptual framework.

Figure 1: The Conceptual Framework



Source: The Authors

First and foremost, to operationalize the above conceptual framework for this study, the two-pronged categorization of maritime logistics knowledge as specified by Lee (2010), namely i) market-specific knowledge and ii) firm-specific knowledge, is utilized and adapted in the context of the liner shipping industry. This is because Lee (2010) is one of the few maritime-related studies for which the knowledge-related indicators are available and deemed suitable by the authors. Lee (2010) described market-specific knowledge as valuable know-how and information of the maritime industry and market, and firm-specific knowledge as operational and technological, which comprises of organizational capabilities as well as employee experience and know-how. The details of these two knowledge categories are found in Table 1. With the knowledge indicators clearly identified, the relevant knowledge sharing mechanisms can then be empirically examined in line with the first research question.

Table 1: Categories of Knowledge for Liner Shipping

Market-specific knowledge	Firm-specific knowledge
<ul style="list-style-type: none"> General information about the liner shipping industry, e.g. shipping trends, market practice, governmental regulations, etc. Customer-related information. Competitors' strategy and behaviour. 	<ul style="list-style-type: none"> Operational know-how and expertise, e.g. knowledge of regulations of fuel type and engine failures, vessel and schedule management, etc. Internal expertise to manage employees and the organization. Internal firm management and IT systems, e.g. data systems, stowage planning, etc.

Source: Adapted from Lee (2010)

After the knowledge sharing mechanisms are determined, the relationship between knowledge sharing and firm performance would be explored. Pertaining to firm performance, it has been widely recognized by scholars that the selection of firm performance measures is often complicated and subjective (Venkatraman and Ramanujam, 1986), while strategic management scholars have conceptualized firm performance to broadly encompass financial and operational (non-financial) performance measures. However, appropriate financial data, which are confidential and sensitive, are often not accessible especially with privately-held firms or are inevitably intertwined with corporation-wide data with business conglomerates. This has consequently led scholars to utilize perceptual measures of firm performance, which are based on the perceptions and opinions of participants, when objective financial data is absent (Dollinger and Golden, 1992; Rhodes et al., 2008). Although perceptual measures may be criticized for possible bias and inaccuracy, there is robust empirical evidence supporting and demonstrating that a strong correlation exists between perceptual and objective performance measures at the firm level (Dess and Robinson, 1984; Venkatraman and

Ramanujam, 1987). Furthermore, it is also held in literature that operational performance, which is deemed a different construct from financial performance, mediates the relationship between organizational conduct and financial performance (Venkatraman and Ramanujam, 1986; Combs et al., 2005; Molina-Azorín et al., 2009). Hence, it can be deduced that operational performance indicators affect and plausibly improve financial performance. Considering that liner shipping firms engaged in strategic alliances are generally large conglomerates for which obtaining valid financial data is a difficult and complex process, this study thus focuses on perceptual non-financial performance measures comprising of market and operational performance. The relevant performance indicators obtained from reviewed literature are summarized in Table 2.

Table 2: Categories of Firm Performance Indicators

Firm Performance Measures	Performance Indicators	Sources
Market performance	Market share & growth Sales volume & growth Market development Reputation & image Customer satisfaction	Venkatraman and Ramanujam (1986), Cleveland et al. (1989), Raju and Lonial (2001), Combs et al. (2005), Green et al. (2008), González-Benito (2010)
Operational performance	Service quality Responsiveness Flexibility Cost reduction Dependability Technological efficiency	Venkatraman and Ramanujam (1986), Cleveland et al. (1989), Brewer and Speh (2000), Raju and Lonial (2001), Combs et al. (2005), Green et al. (2008)

Source: The authors, adapted from various sources

Finally, with regard to cluster effects – the proposed moderator between knowledge sharing and firm performance – the relevant indicators encompasses geographical proximity, trusting relationships, frequent interactions, trust and reciprocity, as well as common values, identity, practices and cultures, and these have been discussed in section 2.3 accordingly.

3.2. Method of Data Collection and Sampling

As this research is a preliminary exploratory study for a future research scheme of a larger scale, the authors adopted face-to-face in-depth interviews as the primary method of data collection with the purpose of acquiring in-depth and thorough insights of the research questions discussed. The sample of this study consists of two senior executives and an ex-senior executive from prominent liner shipping firms, located in Singapore, which are deeply entrenched in strategic alliances. The respective participants were shortlisted based on their immense wealth of experience in the liner shipping industry and their active involvement in liner shipping strategic alliances.

In preparation for abovementioned in-depth interviews, a questionnaire comprising of questions tailored to answer the three research questions was designed for verbal administration to the relevant research participants. The questionnaire was also fine-tuned successively at the discretion of the authors after each interview to enhance the effectiveness and efficiency of the data collection process.

3.3. Administration of Research Tools

The face-to-face interviews were arranged and conducted at the respective offices of participants by the authors, during which, questions from the designed questionnaire were rigorously discussed. Audio recordings of interviews conducted were also made with the approval of the participants. Upon the completion of the interviews, the audio recordings were transcribed and reviewed by the authors for the extraction of relevant and valid data.

4. Findings and Discussion

4.1. Mechanisms of Knowledge Sharing

All interviewees were asked if knowledge or information sharing exists within the strategic alliances that their respective companies were engaged in, and if so, to elaborate on the mechanisms through which the sharing takes place. According to preliminary findings gathered through the interviews, the levels of interaction and sharing varies with the types of alliances or consortia companies are engaged in, which range from contractual slot-swaps for which interaction is minimal to integrated alliances which requires closer cooperation and coordination, and these arrangements differ in accordance to specific trades and loops. Thus, for the purpose of this research, focus is placed on integrated strategic alliances in which interaction and knowledge sharing are more evident and meaningful.

Based on research findings and concurring responses obtained from virtually all interviewees, it was confirmed that market-specific knowledge and information, encompassing freight rates, customer-related information and other commercial issues, are considered taboo in the liner shipping industry due to strict anti-competition laws and regulations and can potentially lead to heavy penalties if discussed or exchanged. This unique situation is blatantly depicted in below excerpt quoted by an interviewee as follows:

“You can’t share information amongst the lines, that’s taboo now. They can talk about operational stuff, but when it comes to anything else on marketing information, even in terms of talking about how many TEUs you (an individual shipping line) are carrying in this market, you can’t share....You can’t talk about rates or customer-related information....You can’t even talk over the phone or over coffee....The moment they’re found discussing all these, there are hefty fines....Lines are getting worried, they can’t talk about anything, and they’re worried that the moment they talk, they might leak out something and be seen as sharing information.”

On the other hand, it was generally conceded by interviewees that knowledge and information sharing from an operational perspective, which is in line with firm-specific knowledge indicators as shown in Table 1, is a necessity to ensure smooth running of day-to-day operations. As ships assigned for specific loops are generally operated by an individual firm but with space onboard shared by the entire strategic alliance, close coordination and sharing of operational information and knowledge amongst alliance partners such as stowage plans, vessel assignment and scheduling, as well as problem-solving expertise in events of engine failures are vital to ensure operational safety and service integrity, as quoted by one of the interviewees as follows:

“When it comes to them (firms embedded in a specific strategic alliance) as a grouping versus another alliance, of course they will want to share certain things in terms of port coverage, loops, scheduling because they are all together. Their vessels are operating in loops and each one contributes certain vessels. They want to try to maintain schedule integrity and vessel safety, and do share information where they can ensure on-time vessel calling and port efficiency.”

Thus, there is generally close cooperation amongst operations personnel within strategic alliances, and common issues such as regulations of fuel types, new building plans, environmental issues, operational efficiencies and engine failures, consisting of a mix of both explicit and tacit knowledge (Michael Polanyi, 1967), are openly discussed.

Within integrated liner shipping strategic alliances or consortia, one of the main mechanisms through which operational-based knowledge sharing occurs is through formal structural set-ups of committees of various levels, such as principle committees, steering committees, regional operational committees and a series of other support committees. The principle, steering and regional operational committees meet face-to-face via official meetings that take place half yearly and/or quarterly, subject to operational requirements. The support committees however, where necessary, interact on a daily basis via video conferences, electronic mails and telephone calls. These committees effectively form the knowledge network within which operational knowledge flows within the alliance network. In addition, joint operational centres or offices are also set up for major alliances for which closer and more complex coordination is vital.

4.2. Impact of Knowledge Sharing on Firm Performance

Following the revelations pertaining to the regulatory restrictions and mechanisms of knowledge sharing within liner shipping strategic alliances, the benefits of operational knowledge sharing are hence apparent only on the operational basis. Based on interview findings, the sharing of operational knowledge within strategic alliances or consortia indeed improves a liner shipping firm's operational performance, which includes improved operational efficiency and innovation, as well as enhanced service quality (vessel and cargo safety) and reliability (schedule integrity) for the alliance as a whole. This result reinforces the study by Grant and Baden-Fuller (2004), which illustrates the advantage of alliances in enhancing efficiency in knowledge utilization and integration of applicable knowledge into complex product and service offerings. Nonetheless, apart from common benefits, private benefits (Khanna et al., 1998), which includes the fine-tuning of internal systems, are inevitably conferred to liner shipping firms through learning and knowledge spillovers from partner firms. This is supported by an example provided by one of the interviewees, whereby liner shipping firms learn from partners and upgrade their internal IT systems from that which requires manual data inputs to that of XML (extensive markup language) and EDI (electronic data interchange) formats, which in turn improves internal firm efficiency. This supports the notion of inter-organizational learning through collaboration, whereby monitoring and imitating of partners' practices leads to firm competitiveness (Levinson and Asahi, 1996; Powell et al., 1996).

In addition, when interviewees were asked if knowledge or information sharing would improve firm performance, the responses gathered were generally positive and consensual. Moreover, apart from confirming the relationship between the former constructs, one of the responses received strongly implied that the prohibition of information sharing has dire consequences on firm performance and subsequently the entire liner shipping market, as follows:

"Yes, it will impact the whole industry. That will be very helpful. If they can really share information, they can improve their performance. Lines can then plan their capacities, better moves in terms of inter-modalism and whatever....Things now are different from the early days of the conferences when they were able to free discuss these things. Personally I felt that back then, they were able to better plan by sharing information, like this is the total trade, this is the total capacity, where are we in terms of disparity. Then can we now do something, like reduce supply or bring up some rates or where we can reduce rates to get more market share? And that helped to balance; it wasn't as bad as what's happening now. Now they're in the dark, this guy does something and doesn't know what is happening at the other side. All are just bringing in capacity and the whole market is just collapsing, I've never seen anything like this before..."

Although strict anti-competition laws presently restrict the sharing of market-related information or knowledge, which nullifies any possible assessment of the impact of market-related knowledge sharing on firm performance for this research, it was however evident in the days when liner conferences were legal that there was generally greater stability and cooperation in terms of vessel capacity and freight rates as compared to the volatility currently observed in the industry. This strongly implies that the market performance of a liner shipping firm would in fact improve if market-related knowledge sharing is legally permitted.

4.3. Moderating Effects of Co-Location within a Cluster

Regarding the moderating effects of co-location of alliance firms within an industrial cluster, it was by and large established through the interviews conducted that physical co-location of liner shipping alliance partners is not a necessity. This can be attributed to the fact that the liner shipping industry is by-and-large global in nature, with firms possessing vast international networks of branch offices or agencies which can plausibly be utilized as conduits of knowledge sharing and operational implementation. Furthermore, with the proliferation of technological advancement in electronic and virtual communications, interaction can take place via virtual platforms with relevant information and knowledge codified and disseminated via the networks of branch offices and agencies. Nonetheless, the interviewees did comment that co-location within a cluster, though not imperative, does help in terms of reduced travelling time and distance when circumstances call for face-to-face meetings where tacit information and knowledge is usually shared. Furthermore, the existence of physically co-located joint operational centres for prominent consortia involved in dominant trades

substantiates the benefits of the geographical proximity conferred by co-location within a cluster. These are summarized in a quote made by an interviewee as follows:

“There is no necessity to actually be physically located next to each other. It probably helps if there is some geographical clustering going on because it makes the travel easier..... I think the need to cluster is not an essential ingredient, it is a helping ingredient but it's not essential. But I would say one point in the case of the most consortia-heavy type of alliance, they may in that situation make a decision to have a joint operations centre.”

When alliance partners are physically co-located, knowledge sharing and interaction takes place at higher frequency with reduced delays, which leads to more efficient and nimble decision-making and problem-solving when the relevant need arises. Hence, it can be suggested that co-location within a cluster indeed moderates the relationship between knowledge sharing and a firm's operational performance but nevertheless to a limited extent.

This is because there is a common consensus derived from the interviews conducted that there is an apparent lack of common identity and culture, as well as limited common values within strategic alliances in the liner shipping industry. According to one of the interviewees, consortia arrangements are deemed to be operational and transactional partnerships of convenience, as opposed to concepts of untraded dependencies (Storper, 1995), communities of practices (Brown and Duguid, 2001) or epistemic communities (Wilson and Spoehr, 2010) found in cluster literature. Hence, it can be deduced that dynamic interactions, facilitated by geographical co-location, amongst firms embedded in clusters (Henry and Pinch, 2002) is not applicable in the context of strategic alliances in the liner shipping industry.

4.4. Discussion and Opportunities for Future Research

This research has revealed that knowledge sharing within strategic alliances within the liner shipping industry revolves mainly only around firm-specific or operational knowledge or information. The exchange of market-related knowledge or information is presently prohibited by anti-competition regulations, which imposes extremely heavy penalties if breached, causing personnel in the liner shipping industry to be exceptionally cautious and guarded to the extent of completely avoid even the remotest hint of market-related discussions. Through the interviews conducted, it was discovered that the mechanisms of operational knowledge sharing revolves primarily around the setting up of formal structured committees and/or joint operational centres comprising of all relevant alliance members. Within these formal structures and arrangements, interactions which facilitate knowledge sharing within the alliance networks takes place via face-to-face meetings and virtual forms of communication. Nevertheless, through examining only the sharing of firm-specific or operational knowledge, the results of this study suggest that a positive relationship indeed exists between knowledge sharing within strategic alliances and firm performance. In the case of the liner shipping industry, firms have reaped improved operational firm performance in terms of enhanced efficiency, innovation, service quality and reliability. Pertaining to co-location within a cluster as a moderating effect between the former relationship, it is found that physical co-location within a cluster brings about convenience but is nonetheless not considered essential. This implies a positive moderating effect on the former relationship but albeit to a limited extent, since there is an apparent dearth of dynamic interactions which are necessary conduits for knowledge flows.

Consequently, the results of this study provide significant insights to senior executives of liner shipping firms in their strategic decision-making process pertaining to the management of knowledge and relations within 'co-petitive' strategic alliances, as well as the consequent implications on firm performance. This paper also contributes to the field of cooperative strategy and maritime research with regard to non-equity based alliances governed by contracts and agreements from a knowledge-based perspective within the liner shipping industry. Moreover, research on the maritime industry from strategic management and knowledge management perspectives is limited, and this study contributes academically by illustrating how knowledge management theory applies in the context of the maritime industry.

Nevertheless, the authors acknowledge that there are methodological limitations in this study involving the sample size and data collection method. Considering that only three in-depth face-to-face interviews were

conducted, the results of this study are insignificant with regard to generalizability and reliability. Hence, future research should encompass a larger sample size and quantitative surveys to address generalizability and reliability concerns. Furthermore, while this study explores the knowledge sharing mechanisms amongst liner shipping alliance partners, it does not take into account the dilemmas and opportunism within the 'co-petitive' arrangement. It would hence be meaningful to examine the dynamics of competition and cooperation between the alliance partners for future research, and explore the tensions which arise when the respective alliance partners juggle between reaping private and common benefits (Khanna et al. 1998). In addition, while strategic alliances in the liner shipping industry provide a good example of non-equity based alliances, there is an issue on generalizability across other industries as the liner shipping strategic alliance phenomenon is rather unique to this industry. Hence, future research could seek to explore the significance of knowledge sharing on firm performance in non-equity strategic alliances in other non-shipping industries or other shipping sectors, like shipping pools in bulk shipping industry.

5. Conclusion

In conclusion, this study establishes that knowledge sharing positively impacts firm performance, while co-location within a cluster moderates the former relationship within the liner shipping industry, despite unique industry-specific regulatory constraints. The results of this study provide significant practical insights to senior executives of liner shipping firms in their strategic decision-making process pertaining to the management of knowledge and relations within 'co-petitive' strategic alliances, as well as the consequent implications on firm performance. In addition, this study also contributes academically by illustrating how knowledge management theory applies in the context of the maritime industry.

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Appendix

<<Interview Questionnaire>>

Mechanisms of knowledge sharing:

- 1) What are the means of communication between your firm and alliance partners? (Email, phone calls, face-to-face meetings, conference calls?)
- 2) Could you please describe the nature of the relationship between your firm and that or alliance partners? (Tie strength – weak or strong, Frequency of face-to-face communication, level of informal communication, level of trust, spontaneity in knowledge sharing)
- 3) What kind of information/data/knowledge do your firm and alliance partners share with each other (market-specific, firm-specific, explicit, tacit)? How are above shared and exchanged?
- 4) Is there any motivation to share knowledge/data/knowledge amongst alliance partners? If yes/no, why?
- 5) Could you please advise what types of information/data/knowledge are deemed to be confidential and what are for public sharing amongst partners?

Impact of knowledge-sharing on firm performance:

- 1) Do you think that the sharing of information/data/knowledge with alliance partners is beneficial for your firm? Does it impact the performance of your firm? If yes/no, how and why? If yes, what types of information/data/knowledge contribute more to benefit your firm and in what way?
- 2) Does the sharing of information/data/knowledge with alliance partners improve the ability of the firm and alliance as a whole to adapt to the volatile environment? If yes, what types of information/data/knowledge and how?
- 3) Does the sharing of information/data/knowledge with alliance partners improve your firm's market access and market share? If yes, what types of information/data/knowledge and how?
- 4) Does the sharing of information/data/knowledge with alliance partners bring about improvements in your firm's organizational procedures, routine, culture, environment apart from the alliance arrangements? Are the knowledge gained internalized and assimilated into your firm? If yes, what types of information/data/knowledge and how?

Moderating effects of co-location within industrial cluster:

- 1) In your opinion, is being closely located to your alliance partners beneficial for knowledge sharing and does it facilitate communication? How?
- 2) Does being closely located with your alliance partners increase the frequency of face-to-face meetings and the fostering of friendships beyond that of work?
- 3) Do frequent meetings and stronger ties bring about a greater level of trust?
- 4) Do the members of the strategic alliance to which you belong share a common identity/camaraderie/culture? If yes, does it improve the quality of knowledge sharing? If yes, how? Does the improved quality of knowledge sharing improve firm performance?
- 5) Beyond that of work, do employees from different firms within the alliance network spend time networking with each other?
- 6) Does the management of your firm encourage employees to socialize with employees of alliance partners? Why or why not?

Food Supply Chain of a Liner Shipping Company: A Case Study

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Abstract

Liner shipping companies (LSCs) have been coping with the demand for high quality and wider range of food for seafarers over the last decade. Food is important for LSCs to attract seafarers, especially when the industry is suffering from a global shortage of seafarers. The food supply chain starts from sourcing various kinds of food from different suppliers to deliver the appropriate amount of food to seafarers on board. Food issues are basically addressed by the ILO Food and Catering (Ships' Crews) Convention 1946 (No. 68), amended 2006. Failures of food supplies appear in LSCs because (1) the inventory level in ships is low due to limited space for food storage on board; and (2) the turnaround time of ships in port is reduced but the voyage time is increased due to low streaming. Food issues are accorded greater attention and the food supply chain becomes a dynamic and difficult task.

In order to find out an optimal solution for the food supply for ships, this paper aims to illustrate how to facilitate the food supply for ship lines and to further evaluate the associated supply chain. This paper presents a case study on a LSC's food supply chain, which is related to the proposed framework for performing flexible but punctual, responsive but rapid food supply at the operational, tactical and strategic levels. The measurement of the performance of the entire food supply chain is an important issue, and the choice of appropriate performance indicators is rather complicated due to the nature of food supply. The paper will help LSCs better enhance food provisions for seafarers.

Keywords: Food supply chain; Liner shipping; Supply chain performance indicators; ILO Convention

1. Introduction

Liner shipping companies (LSCs) have been coping with the demand for high quality and wider range of food for seafarers over the last decade. Food is important for LSCs to attract seafarers, especially when the industry is suffering from a global shortage of seafarers. Nevertheless, food is a basic necessity of human beings. It is important for the food industry to provide harmless, fresh and nutritious food to support the daily life and fulfil the demand for seafarers (McWilliams, 2008). Any toxic or problem substances that appear in food will significantly influence the health of seafarers (Robert et al., 1998). Therefore, different food management is proposed in order to maintain the food quality and safety (Andre and Hans, 2006; Jacques and Peter, 2007; Keiser et al., 2008).

Ocean-going seafarers live on board vessels within a confined environment for a long period of time. Seafarers encounter various changes in the human body under such a special environment. Recent studies have discussed different aspects of maritime health issues. Ocean voyages could influence the human immune system and thus various illnesses arise (Protasov et al., 1996; Myznikov et al., 2000; Lu et al., 2010). Abnormal electromagnetic radiation, great temperature changes and poor diet structure lead to the

appearance of subtle changes in physiological and psychological functions of seafarers (Lu et al., 2010). Indeed, diet and lack of physical exercise are regarded as the two significant factors leading to ischemic heart disease (IHD).

In the maritime industry over the last decade attention has been paid to monitoring food and catering for seafarers. The food issues are basically addressed by the ILO Food and Catering (Ships' Crews) Convention 1946 (No. 68), amended 2006. It was convened in Seattle by the Governing Body of the International Labour Office. The Convention replaces 68 existing international maritime labour instruments and is divided into two parts - the mandatory provisions of Part A and Part B recommendations. The UK government has taken account of Part B as part of the ratification process, but will not make its provisions compulsory under UK law. The Maritime Labour Convention (MLC) will not come into force until it has been ratified by at least 30 countries, representing 33 per cent share of gross tonnage of ships. These include the terms of employment, accommodation, food and healthcare protection.

MLC has decided upon the adoption of certain proposals with regard to protect 1.2 million seafarers across the world by ensuring minimum and consistent living and working conditions (Milde, 2011). ILO (1999, page 4) introduced a new enforcement mechanism that ensures that the seafarers' living and working conditions meet the ILO-requirements of "*decent work (...) in condition of freedom, equity, security and human dignity*". ILO (1999) was applied to all ships ordinarily engaged in commercial operations. Seafarers at sea work in tough environmental conditions which require a good amount of physical strength. The principle of ILO Food and Catering (Ships' Crews) Convention is to ensure seafarers have the best quality with all the necessary ingredients required to support their healthy body and well-being. ILO has maintained laws or regulations to monitor the practices of shipping companies. ILO adopted 21 Articles to implement different actions in the key main areas:

- Deal with food quality, drinking water and catering standards, including the training requirements for ships' cooks;
- Ensure that ships adhere to these standards including equipment of catering department and training of catering staff;
- Propose crew of less than 10, no need for qualified cook but person trained in food and personal hygiene and handling and storage of food;
- Propose master to carry out inspections of food and drink and catering facilities;
- Promote a proper standard of food supply and catering service for the crews of its sea-going vessels, whether publicly or privately owned;
- Cooperate between the competent authority and the organisations of ship-owners and seafarers on questions of food and health;
- Recruit a permanent staff of qualified persons, including inspectors and catering department;
- Provide proper meals relative to the size of the crew and the duration and nature of the voyage in respect of quantity, nutritional value, quality and variety;
- Provide a system of inspection by the competent authority of (a) supplies of food and water; (b) all spaces and equipment used for the storage and handling of food and water; (c) galley and other equipment for the preparation and service of meals;
- Organise training courses for employment in the catering department of sea-going ships so as to bring the seafarers knowledge and skill up to date; and
- Collect up-to-date information on nutrition and methods of purchasing, storing, preserving, cooking and serving food, with special reference to the requirements of catering on board ships.

In LSCs, the food supply chain refers to activities from sourcing various kinds of food from different suppliers to deliver the appropriate amount of food to seafarers on board. Literature review on liner shipping indicates a lack of discussion on the food supply chain to ships.

One of the major functions of the purchasing department of the LSCs is to procure food from all over the world for fleet vessels so as to sustain the smooth operations on board. The food supply chain has become a dynamic, extensive and ever-changing entity and attempting to cover such a broad subject is a difficult task.

Failures of food supplies repeatedly appear in LSCs due to (1) the inventory level in ships is low because there is limited space for food storage on board; and (2) the turnaround time of ships in port is reduced but the voyage time is increased due to low streaming. In order to find out an optimal solution for the above problems, the food supply to ships must be flexible but punctual, responsive but rapid to formulate and implement different sourcing strategies.

The paper is divided into five sections. Section 1 is the introduction. Section 2 presents related literature review on food supply chain to ships and uses of value chain in food supply chain. In Section 3 value chain analysis about food supply chain to ships is explained, while in Section 4, a case study is conducted and discussed so as to evaluate the food supply chain performance. A conclusion is drawn in Section 5.

2. Literature Review

2.1 Food Supply Chain

A supply chain contains all the parties involved, directly or indirectly, in coping with a customer request (Chopra and Meindl, 2007). Christopher (1992, page 12) defined a supply chain as “*a network of organisations that are involved, through upstream and downstream linkages, in different processes and activities that produce value in the form of products and services in the hands of ultimate customer*”. In order to maximise the overall value generated in the supply chain, recent literatures have stressed the need for Supply Chain Management. Jones and Riley (1985) discussed that Supply Chain Management should recognise end-customer service level requirements, identify where to position inventories along the supply chain and how much to stock at each point, and it should develop appropriate policies and procedures for managing a supply chain as a single entity. Cooper et al. (1997) stated that Supply Chain Management is the integration of business processes from end-user through original suppliers so as to provide services, products and information that added value to customers. Simchi-Levi et al. (2003, page 1) defined Supply Chain Management as “*a set of approaches utilised to efficiently integrate suppliers, manufacturers, warehouses, and stores, so that merchandise is produced and distributed in the right quantities, to the right locations, and at the right time, in order to minimise system wide costs while satisfying service level requirements*”.

Food chain refers to the total supply process from agricultural production, harvest or slaughter, through primary production and/or manufacturing, to storage and distribution, to retail sale or use in catering and by consumers (Stringer et al., 2007). Food supply chain is a process of planning, implementing and controlling efficient and effective flow and storage of perishable goods, related services and information from one or more points of origin to the points of production, distribution and consumption in order to meet customers' requirements on a worldwide scale (Bogataj et al., 2005). The food supply chain processes impose several characteristics including shelf life constraints for raw materials and perishability of products, long production throughput time, seasonality in production, necessity of conditioned transportation and storage, safety concerns (Kuo and Chen, 2010). From the perspective of the food industry, the generic overview of food supply chains are fragile due to the geographic, socioeconomic and legislative spread of participating entities and any materialisation of risk quickly permeates across its different entities (Iijima et al., 1996; van der Vorst and Beulens, 1999; Dani and Deep, 2010; Kuo and Chen, 2010). The food supply chains are constantly changing due to the dynamic business environment. Any changes in distance, time or temperature in the chain could significantly increase the costs or create the net present value of the activities and their added value in the supply chain to be perturbed (Verbic, 2006). Roth et al. (2008) discussed three main trends affecting food supply chains in contemporary business environments, pertaining to commoditisation, consolidation and globalisation. Commoditisation defines the distinction between foods products as either commodities or value added. Consolidation refers to food supply chain members combine as many food categories as well as levels of the supply chain in pursuit of higher margins. Globalisation leads to not only global sourcing of raw materials, but also all the post-production activities such as storage, transport, distribution and retail of final food products, their export and import (Kuo and Chen, 2010). The global nature of the food supply chains are vividly depicted as the ingredients are sourced from different countries.

Based on the WHO website (<http://www.who.int/food-safety/en/>), food and waterborne diarrhoeal diseases has killed around 1.8 million people per year. Thus, the food supply chains aim to distributing nutritious, fresh

and harmless food to satisfy the end-consumers (Jacques et al., 2007; Eyles et al., 2008). Indeed, the food life cycle is short as well as the rate of degradation of food is easily affected by biological factors and environmental conditions (Poon et al., 2012). In order to protect the integrity of food and reduce the growth rate of spoilage microorganisms, it is important to design flexible but punctual, responsive but rapid food supply chains by removing unnecessary activities, creating information transparency in the supply chain and increasing coordination of existing operations (Kurt Salmon Associates, 1993; Rodrigue and Craig, 2009; Kuo and Chen, 2010).

2.2 Value Chain in Food Supply Chain

Broadly speaking, intrinsic and extrinsic factors determine the food degradation rate (Robert et al., 1998). Intrinsic factors are defined as the properties and product nature of food pertaining to sugar content, salt content and pH, along with extrinsic factors related to environmental factors such as humidity, presence of gases and temperature (Robert et al., 1998; Bryan and Brian, 1999; Mohsen, 2005). It is essential to handle the above two factors efficiently and effectively in order to slow down the degradation rate. In order to lengthen the shelf life of food, pickling and salting of food are the common approaches to control the intrinsic factors (Robert et al., 1998). However, those methods are not the optimal solutions to tackle the problem of food degradation and short shelf life due to permanent change of the structure or the taste of food. Thus, this research paper pays attention to managing the extrinsic factors so as to control the quality of food while keeping the structure and taste of the food. Indeed, the value chain is adopted in food supply chain.

The concept of value chain arising from business management was first developed by Michael Porter in his book *“Competitive Advantage: Creating and Sustaining Superior Performance”* (Porter, 1985). It has been widely adopted by research articles over the last two decades. The activities of the firms can be broken down into a sequence of activities called the value chain (Campbell et al., 2002). The value chain framework of Porter (1990, page 41) is *“an interdependent system or network of activities, connected by linkages”*. When the system is managed carefully, the linkage can be a vital source of competitive advantage (Pathania-Jian, 2001). According to Lynch (2003), the value chain analysis is divided into the linkage of two areas. The first part discusses the value chain that links the value of the organisations’ activities within key functional parts. The second part assesses the contribution of each part in the overall added value of the business. In value chain analysis, the firm is mainly divided into primary and support activities. On one hand, primary activities are related to the production. On the other hand, support activities are concerned with the background necessary for the efficiency and effectiveness of the firm.

3. Value Chain Analysis of Food Supply Chain to Ships

In this paper, we illustrate the value chain in our food supply chains (Table 1). We conduct value chain analysis as a fundamental theoretical framework to evaluate the importance of the food supply chain to ships. Value chain analysis is a powerful analysis tool for managers to identify the key activities and design the strategic planning within the firm. We discuss in detail the use of value chain analysis in our food supply chains with respect to competitive strategies and value to the customer. The competitive strategies of firms demonstrate the ability to perform crucial activities along the food supply chains better than its competitors. The food supply chains emphasise maximising value creation while minimising costs (Porter, 1985).

After review of primary activities and support activities in the value chain, we find that most of the elements determine the performance of food supply chains. In primary activities, inbound logistics, operations and outbound logistics enhance food supply chain operations. In inbound logistics, the activities are concerned with receiving the food or materials from suppliers, storing these externally sourced food or materials, and handling them within the firms. In operations, the food supply chain can be split into more departments within the firms such as the activities related to the production or value added products and services. In outbound logistics, the activities concerned with distributing the food to the final customer. In service, the firms regularly monitor the conformance of food supply chain operations and remedial action is taken in the event of non-conformance. In marketing and sales, the activities preserve the required quantity and quality of the food in the available market so as to maintain the stability in cold chains (Verbic, 2006)

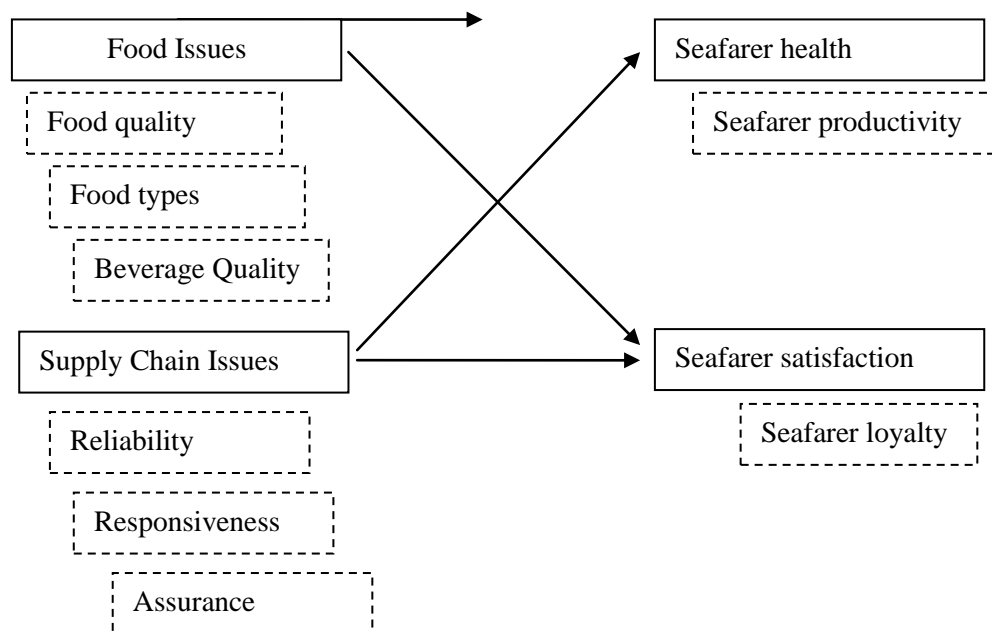
In support activities, procurement, technology development and firm infrastructure facilitate the operations of food supply chains. In procurement, this function is related to the purchase of food or materials necessary for the food supply chains' operations. An efficient procurement department is capable of obtaining the highest quality food or materials at the lowest prices. In technology development, this area is concerned with the technological innovation, training and knowledge that is crucial for food supply chains to upgrade their capacities. In firm infrastructure, the firms implement corporate strategy to support the entire food supply chain operations. Human resource management concerns with recruiting qualified person to manage the cool chain process. The food can be produced, stored and distributed under the most hygienic and controlled conditions possible. The ultimate objectives are to provide customer assurance and confidence.

Table 1: Value Chain Analysis of Cool Chain Logistics

	Cool Chain	Logistics
Support activities		
Firm infrastructure	The Board Executive Committee implements strategic planning, adopts information systems and provides guidance throughout food supply chain operations	Planning, finance, information systems and management. Strategic planning and management provides guidance throughout the logistics operations. Information systems support logistics operations. Finance provides budgets and capital expenditure for the forecast logistics activity.
Human resources	Recruit qualified person to manage the cool chain process. The food can be produced, stored and distributed under the most hygienic and controlled conditions possible.	Recruitment, selection, training, reward and motivation of staff. The right people manage the flow of logistics so as to ensure the products and/ or service is delivered in efficient and effective.
Technology development	Development of technology enhances cool chain systems. The operational processes meet and exceed safe and hygienic benchmarks of an international standard.	Technology maintains the product quality, controls the logistics process and upgrades the resource deployment.
Procurement	Streamlined and efficient procurement procedures ensure that cool chain obtains the best quality raw materials and other production requirements in the timeliest manner.	Purchasing of resources. This is related to the upstream of supply chain management.
Primary activities		
Inbound logistics	Keep bacterial contamination to minimum levels and maintain appropriate temperature of food. For instance, hot food (above 60 °C constantly), fresh food (18 °C constantly), cold food (0°C to + 7 °C), chilled food (-2°C to + 2 °C), frozen food (below -18 °C) and deeply frozen food (below -30 °C) (Giulia and Francesco, 2010; Kuo and Chen, 2010).	Receipt and storage of input materials. Stock control and distribution of inputs.
Operations	Convert the available supply of raw food into the products required by the customer on a daily basis. All final products are subjected to physico-chemical and microbiological examinations, in addition to monitoring of aseptic points and temperature. Products records are created and maintained throughout the whole process, enabling total traceability on all	Transformation of inputs into final products.

	products manufactured.	
Outbound logistics	Improvement in transportation efficiency to distribute the food products freshly and safely, and on time to the final customer (Kuo and Chen, 2010). Delivering final food products to meet food safety regulations such as, tracking of air and product temperature in refrigerated vehicles, production workcells and loading-reloading points, and verified standardised equipment (Bogataj et al., 2005).	Storage and distribution of finished goods. This is related to the downstream of supply chain management.
Marketing and sales	Visibility is required so as to maintain the quantity and quality of the food at the end of cool chain (Verbic, 2006).	Ensuring products are delivered at the right time in the available market.
Service	The firms regularly monitor that retailers conform to the requirements of the cool chain by checking and inspecting the temperatures of the cold storage and remedial actions is taken in the event of non-conformance.	Provide after sales support. Firms should establish the capabilities of reverse logistics to take remedial action in the event of non-conformance.

Figure 1: Category of Issues of Food Supply Chain to Ships



In Figure 1, food issues and supply chain issues are the two main categories of issues of food supply chain to ships. On one hand, food quality, food types and beverage quality are the key elements of food issues. On the other hand, reliability, responsiveness and assurance are the main evaluation items of supply chain issues. The issues are discussed as follows:

- (1) Food quality: intrinsic food quality such as menu, taste and freshness; extrinsic forms of food pertaining to sanitation, presentation and temperature (An and Noh, 2009). The totality of features and characteristics of a product or service that bear on its ability to satisfy stated or implied needs (ISO 8402).
- (2) Food types: certain kinds of food that a shipping line entertains to seafarers. In general, the food can be divided into bond and provision. On the one hand, the bond includes cigarette, alcohol, chocolate and snack. On the other hand, provisions such as biscuit, rice and flour.

- (3) Beverage quality: the degree to which seafarers become satisfied with beverages provided on board such as alcohol, water, tea and juice.
- (4) Reliability: ability to conduct promised food accurately and credibly.
- (5) Responsiveness: intention to provide food promptly to seafarers.
- (6) Assurance: temperament or quality of employees to inspire reliability, belief, courtesy and knowledge (An and Noh, 2009).

The conditions of health are mainly determined by food issues and supply chain issues. Seafarer health imposes direct impact to seafarer productivity. Accordingly, an excellent quality of seafarer meal and a capable agri-food supply chain should be maintained so as to provide better health of ocean going seamen.

Seafarer satisfaction is based on seafarers' perception about the food quality and performance, which is an emotional response. Seafarer loyalty means the desire to provide the service of a shipping line, which includes the willingness to work and to recommend the shipping line to others. Thus, meal service should be planned carefully to satisfy the seafarer's expectations from the selection of menu to efficient and reliable service.

In this paper, we would like to conduct an analysis of interactions of value chains between food suppliers and LSCs (see Figure 2), developed from syntheses with previous work on value chains (Porter, 1985). We have conducted value chain analysis as a fundamental theoretical framework to offer the possibility of linkages between food suppliers and LSCs. The framework has strong theoretical underpinnings and has shown food suppliers and LSCs are closely interrelated.

Figure 2 presents the different elements in which value creation takes place in the food suppliers and LSCs. The performance of their value chain operations is influenced by a range of primary activities (i.e. Inbound Logistics, Operations, Outbound Logistics, Marketing & Sales, Service) and support activities (i.e. Firm Infrastructure, Human Resource Management, Technology, Procurement). In food suppliers, primary activities and support activities have a direct impact on the performance of the LSCs value chain operations. In LSCs, primary activities have imposed influence on the performance of food suppliers' value chain operations. The ultimate objectives are to maximise value creation while minimising costs in their food supply chains.

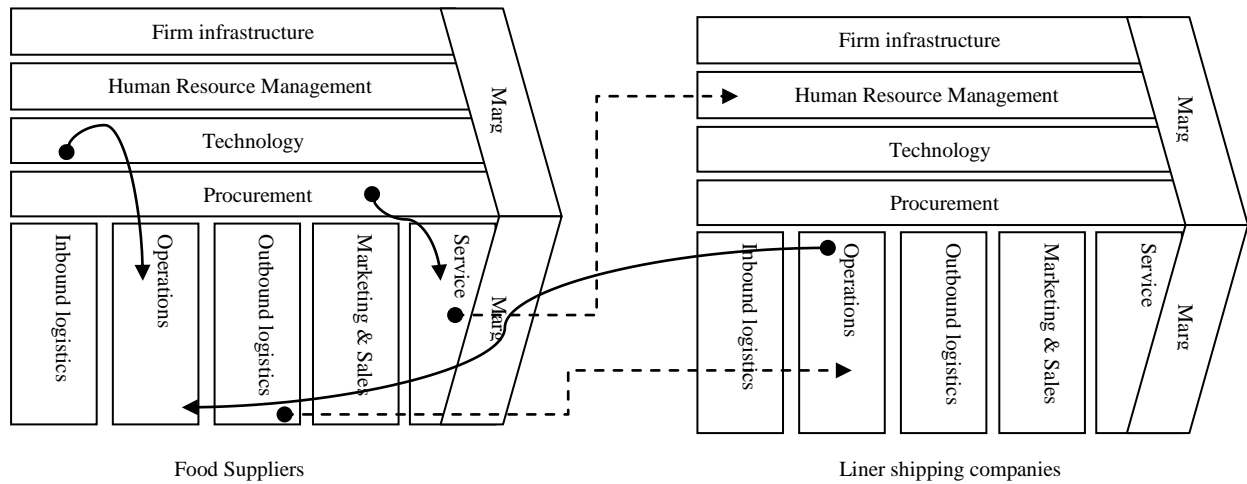
From food suppliers to liner shipping companies (dotted lines):

1. Outbound logistics is critical to the operations (i.e. ship schedule). Development of technology enhances food chain systems. The operational processes meet and exceed safe and hygienic benchmarks of an international standard. Food suppliers need to distribute the food products not only freshly and safely, but also be on time to meet liner shipping companies' schedule or the turnaround time of ships in port. Otherwise, the whole voyage time will be delayed and the customer service level of liner shipping companies will be significantly affected.
2. Streamlined and efficient procurement procedures ensure that the food chain obtains the best quality raw materials and other production requirements in a timely manner. Good service of food suppliers is critical to the satisfaction of seafarers, which is a critical issue of human resource management. Human resource department recruits the qualified personnel to operate the food supply chain. At the same time, human resource personnel designs and delivers comprehensive training courses to staff in order to increase their knowledge on food quality and safety. The food quality and performance can maintain conformance level. Seafarers' satisfaction level can be increased.

From liner shipping companies to food suppliers (solid lines):

The operations (i.e. ship schedule) post constraints on food suppliers' operations. The inventory level in ships is low because there is limited space for food storage on board; and the turnaround time of ships in port is reduced but the voyage time is increased due to low streaming. As a result, food suppliers repeatedly fail to catch up with ship schedule and request.

Figure 2: Interactions of Value Chains



4. Case Study

In practice, LSCs source the variety of food from different suppliers. It is difficult for LSCs to manage the procurement operations and build up the relations with suppliers. Indeed, external environmental factors pertaining to port of calls, nature of commodities and climate affects the quality and reliability of food supplies. Based on that, we design our food supply chains to ships in Figure 3. Food suppliers have multiple suppliers based on the nature of commodities. However, LSCs usually appoint only one single supplier to provide food to seafarers. This single supplier consolidates different food and then distributes it to different ships. Lau and Yip (2010) stated the key advantages of single sourcing.

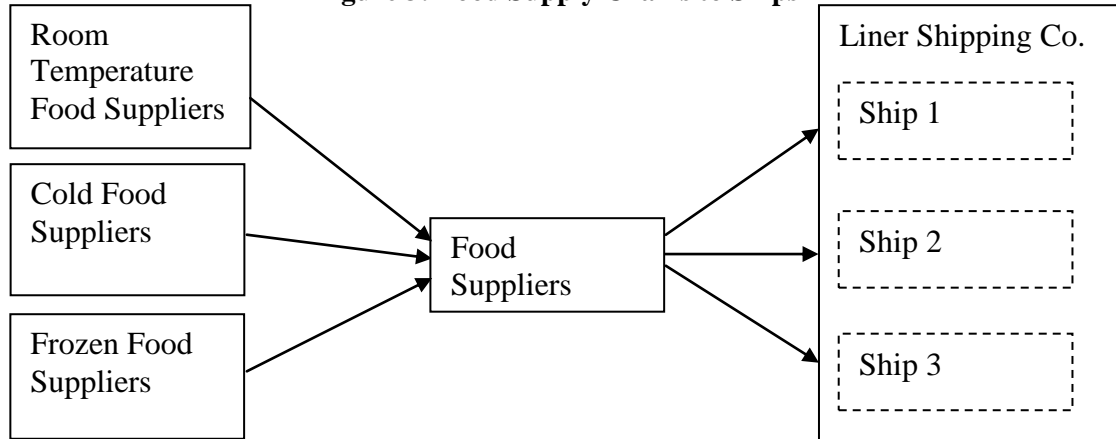
- Develop a long-term relationship between LSCs and supplier;
- Allow both parties to work together more closely;
- Have stronger commitment of the supplier pertaining to invest in the facilities or information technology and share the real-time information;
- Get suppliers involved early in the product development stage and thus control the upstream supply chain as soon as possible;
- Enhance resource allocation in the core business;
- Acquire a lower purchase cost resulted from a much higher volume from one single supplier; and
- Easier vendor management.

From LSCs perspective, there are three major categories according to the temperature control and monitoring of the food supply chain in LSCs. They include room temperature food, cold food, and frozen food. Each type of food has different requirements in the food supply chain. Room temperature food includes water, biscuit, rice and flour; the temperature must be maintained at 18 °C constantly, which may include a slow response to temperature changes. Cold food includes vegetable and fruit; the temperature must be maintained at 0 °C to + 7 °C, which may encompass items highly responsive to temperature changes. Frozen food includes meat and fish; the temperature must be maintained at -18 °C, which may include a slow response to temperature changes. In the transportation of frozen food, the fresh air ventilators must always be closed and the humidity indicator should be in the OFF position. Temperatures can be regarded as an important parameter in food safety and quality (Montanari, 2008; Ovca and Jevsnik, 2009). During logistics process, any change in time-distance or temperature creates even spoilage or loss of flavour. Thus, temperature needs to be continuously and carefully controlled and monitored in each stage of the food supply chain with adequate control systems, correct placement of temperature sensors and efficient insulation. All perishable products are required to be delivered via a refrigerated loading dock so as to minimise the rise of product temperature during loading and unloading and to avoid the entrance of moist, warm and ambient air.

Within the food supplier (Figure 2), (1) cold technologies are critical to the cool chain operations; and (2) procurement of cold facilities is critical to the service to liner shipping companies. Currently, food suppliers

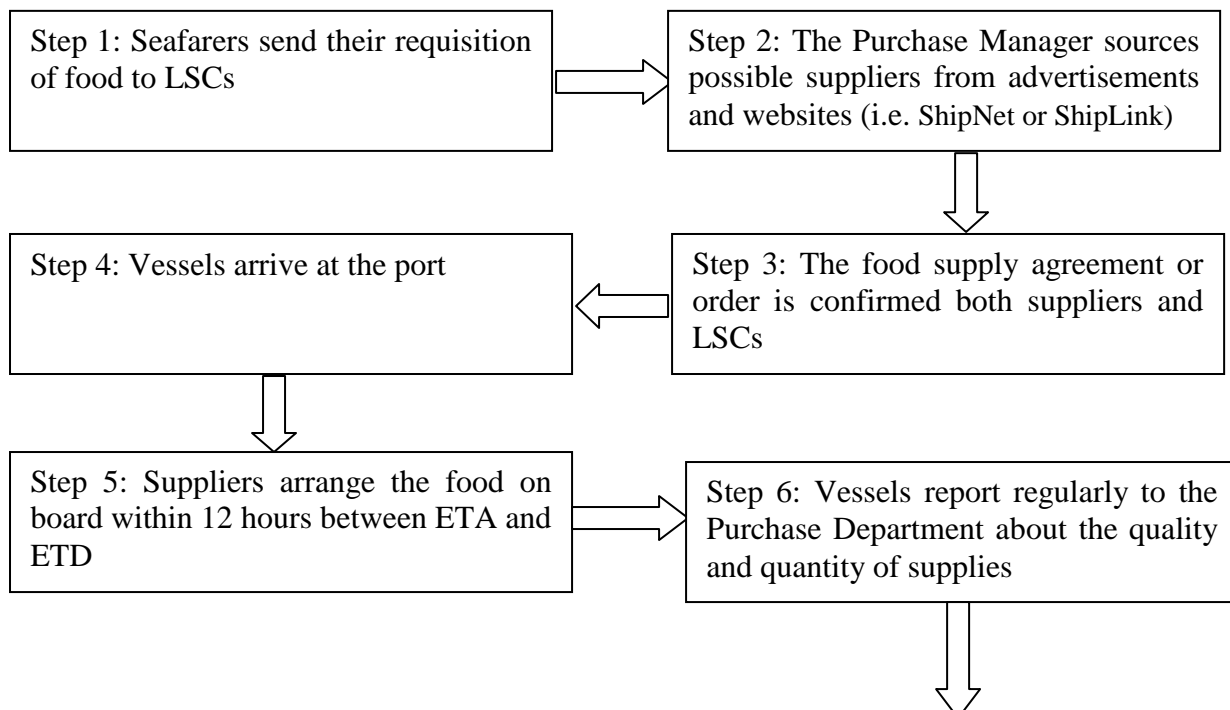
incorporate multi-temperature measuring devices (e.g. melting point, thermal expansion, emissivity, diffusion, solidification temperature), and viscoelastic properties or chemical reactions (e.g. electrochemical corrosion, enzymatic reactions, and polymerisation), as well as mobile technology to ensure food quality and safety in the cold chain. The emergence of radio frequency identification (RFID) is a common type of mobile technology. RFID can be used for tracking, identification and recall in the food supply chain. RFID includes various functions including real-time information, real-time tracing, order tracing, temperature monitoring and so on (Kuo and Chen, 2010). It can ensure that all kinds of perishable products with different temperature requirements can be kept in the best quality condition, from the point of supply to the point of consumption, throughout the processes of storage and distribution along the food supply chains (Kuo and Chen, 2010). Seafarers ensure that the products they order can be received freshly, safely and on time.

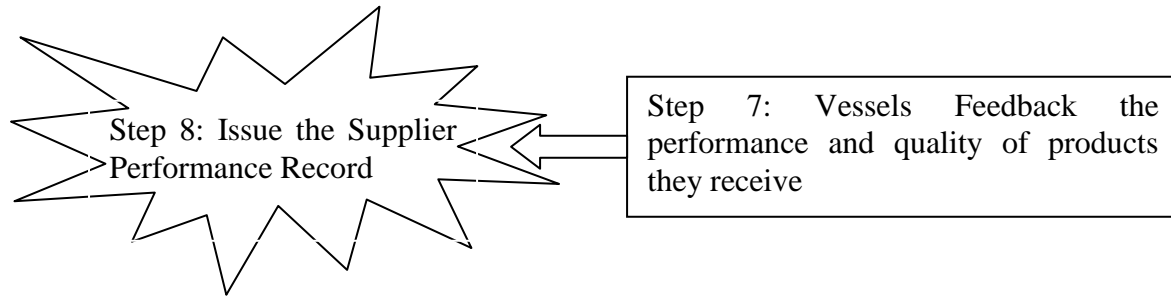
Figure 3: Food Supply Chains to Ships



Broadly speaking, seafarers send their requisition or order to LSCs so as to obtain the required amount of food. The Purchase Manager and the Assistant Purchase Manager usually search advertisements and websites (ShipNet or ShipLink) for possible supplies. When vessels arrive at the port, suppliers need to arrange the food on board within 12 hours between Estimated Time of Arrival (ETA) and Estimated Time of Departure (ETD). Vessels report regularly to the Purchase Department about the quality and quantity of supplies. Vessels further feedback the performance and quality of products they received. Such information goes into the Supplier Performance Record. The above procedures are a critical process which covers the entire food supply to seafarers.

Figure 4: Flow Chart of Food Supply to Ships





5. Conclusion

Our study has two-fold implications. From a theoretical perspective, this study presents the proposed framework for performing flexible but punctual, responsive but rapid food supply at the operational, tactical and strategic levels. This study aims to illustrate how to facilitate the food supply for LSCs and to further evaluate the associated supply chain. We conduct value chain analysis as a fundamental theoretical framework to evaluate the importance of the food supply chain to ships. From a managerial perspective, this study explores the current food supplies situation of the liner shipping industry. This provides a useful reference for the LSCs to evaluate their food supply chains so as to help LSCs improve food provisions for seafarers.

This study is one of the few studies to discuss the food supply chain of LSCs. However, we should take account of some limitations and pitfalls in this study. This research is a descriptive paper and there is a lack of data to support our proposed framework. In future research, we shall conduct a questionnaire to assess the data in order to verify our findings. A detailed study should focus more on the LSCs formulate strategies on the food supply chains.

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The Impact of EU to Repeal the Block Exemption for Liner Shipping Conference

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Abstract

The first well known liner shipping conference was created for the UK/Calcutta trade in 1875. In 1986, European Union (EU) Council Regulation 4056/86 allowed liner shipping operators to have an exemption from EU competition rules to organize themselves into conferences with the aim of fixing prices and coordination capacity for the transport of containerized cargo. In September 2006, the council of EU decided to abolish that exemption from EU competition rules, with effect from 18 October 2008. This paper investigates the reasons why the EU to repeal the block exemption for liner conference after its operation more than 130 years. The major issues studied are as the following: (1) the development and influence of the liner conference and strategic alliance on the shipping industry; (2) the important regulations governing the operation of liner conference promulgated by EU and Taiwan government; (3) responses of carriers to the EU action to nullify the shipping conference; (4) what action the stakeholders may take in response to the annihilation of shipping conference from the EU-related trades.

Keywords: European Union (EU), Liner Shipping Conference, Block Exemption

1. Introduction

Coalition operation strategies have been common in liner shipping industry. Many types of mechanism have been employed by ocean transport industry to do business cooperatively or to limit competition. The traditional organization is liner conference. The others are consortium which encompasses many different arrangements and stabilization agreement (Chiu, 1996). Sturme (1962) defined conference as “*an association of competing liner owners engaged in a particular trade who have agreed to limit the competition existing among themselves. As a minimum, they will have agreed to charge freight rates or passenger fares for each class of traffic according to an agreed schedule of charges and to show no discrimination between shippers. To the agreement forswearing all forms of price competition may be, and usually is, added an agreement to regulate sailings according to a predetermined pattern and to recognise the berth rights of other members. A further step may be to add a full pooling agreement under which profits and losses on the trade covered by the conference are shared between the member lines.*” It is well known that the first successful shipping conference was the “Calcutta Conference” which was created for the U.K./Calcutta trade in 1875 (Blanco, 2007). Consortia can be defined as “specialized joint ventures encompassing many different arrangements”. The organizational structures and the commercial scope of consortia are many and varied. As shown in Table 1, consortia agreements range from joint scheduling to equity joint venture. The consortium originated from the United Kingdom in the mid-1960s and only conference members joined its operation. Latterly, consortia operation took place in both conference and independent camps in the 1990s. At the end of 1980s, a kind of new-cooperative mechanism in liner shipping, stabilization (or discussion) agreement, was born and

mushroomed subsequently.

Table 1: Types of Consortia Agreement

Types of Agreements	Main Characteristics
Joint scheduling	Minimal cooperation
Deck chartering	Container/bulk combination
Slot chartering	Piggy-backing
Vessel sharing	Space sharing
Equipment-/Chassis-sharing	Equipment sharing
Cost pooling	Cost equalization
Joint venture	Single marketing

Source: Chiu (1996)

The reason for creating liner conferences was to restore profitability and control predatory and cut-throat competition in liner shipping. In the latter half of the 1800s, the widespread introduction of steam propulsion greatly increased the effective supply of shipping services; then, fierce competition took place out of excess capacity. Many factors jointly determine how a conference operates, such as: the amount of tonnage on the route and the relative strength of each company, the quantity and type of cargo on the route, the variety of nationalities involved, the length of the route, and government's intervention (Herman, 1983). A consortium is a means to help carriers to raise capital and to operate on a larger scale than before. In other words, through consortia arrangements individual carrier may enjoy increasing service frequency and extending port coverage, while requiring no more investment on ships. Besides, consortia measures can help maximize asset utilization and help spread the risks of having to add/reduce capacity in line with changing market conditions. Regarding stabilization agreements, most of them positioned themselves as a bridge for both conference and non-conference carriers to discuss common issues of liner business environment, and then try to reach some kind of agreement in view of overcoming liner services operation difficulties.

The existence of shipping conferences has always been a controversial issue. However, there has been no consensus in theory and practice despite a pile of literature discussing on this topic. Table 2 presents those opinions which are for and against the conference system.

Table 2: The Pros and Cons for Liner Conferences

Pros	Cons
<ol style="list-style-type: none"> 1. It provides a stable, regular and coordinated services; 2. It controls capacity efficiently and thus minimize costs; 3. It covers the whole trade, including uneconomic cargoes and locations; 4. It maximises trade potential by cross-subsidization of cargo; 5. It offers stable freight rates which permit shippers to make forward sales with confidence; 6. It offers security to carriers for capital investment. 	<ol style="list-style-type: none"> 1. It artificially raise freight rates by restricting competition and overriding market forces; 2. It induces commercial inertia by protecting the most inefficient members; 3. It is bureaucratic, costly and unresponsive to change.

Source: Drewry Shipping Consultants (1991), pp. 17-18

Due to the European Union (EU) officially repealed the block exemption for liner shipping conference on 18 October 2008, this study intends to investigate what the responses are from the industries. The organization of this paper is as follows. First, a brief review of the shipping conferences is introduced. Then, the shipping conference under EU antitrust law is discussed. Third, we investigate the responses from the industries including those opinions from shippers and carriers. Finally, a conclusion is presented.

2. Shipping Conferences under EU Antitrust Law

Under normal circumstances, liner conference which is a kind of business cartel and should be regulated by anti-trust laws (in the United States) or competition rules (in the European Union). However, liner conferences have been enjoyed the so-called block exemption from competition regulation in considering the special

characteristics of liner shipping services mentioned previously. The block exemption rulings were supported by some large-scale investigations in North America and Europe, respectively. The most often quoted official enquiries are: the 1906 Royal Commission on Shipping Rings of the U.K., the 1912 Alexander Committee of the U.S.A., and the 1967 Committee of Inquiry into Shipping (which is often called “the Rochdale Committee”) of the U.K.

2.1 EU competition rulings for Liner Conferences

Articles 81 and 82 (previous 85 and 86) of the EC Treaty laid down the EU competition rules for all business sectors; Article 81 details the prohibition of agreements to restrict competition and Article 82 is about prohibition of abuse of a dominant position. According to Blanco (2007), maritime policy of European Community started to develop in 1974 and was shaped by three main objectives: (1) the promotion of safety at sea, (2) the protection of Community fleets against unfair practices by shipowners of third countries, and (3) acceptance of the system of shipping conferences in liner trades as a way of organizing the market. As regards Regulation 4056/86, the greatest impetus for reaching an agreement which permitted the application of competition rules to maritime transport came from outside the European Community. The most important event for the adoption of provisions implementing ex Articles 85 and 86 of the EC Treaty in maritime transport was the approval in Geneva, on 6 April 1974, of the United Nations Convention on a Code of Conduct for Liner Conferences (Liner Code). Considering not to infringe upon Member States’ right to ratify Liner Code, EU passed the Council Regulation 4056/86.

Council Regulation (EEC) No 4056/86 (the so-called “Regulation 4056/86”) of 22 December 1986 laid down detailed rules for the application of Articles 85 and 86 (now 81 and 82) of the EEC Treaty to maritime transport. The Regulation 4056/86 provides, under certain conditions and obligations, for a so-called “block exemption” for agreements, decisions and concerted practices of all or part of the members of one or more liner conferences, as defined in Article 1(3)(b) of Regulation 4056/86, that have as their objective the fixing of rates and conditions of carriage, and that, in addition, cover one or more of the following forms of cooperation: (1) the co-ordination of shipping timetables, sailing dates or dates of calls; (2) the determination of the frequency of sailings or calls; (3) the co-ordination or allocation of sailings or calls among members of the conference; (4) the regulation of the carrying capacity offered by each member; and (5) the allocation of cargo or revenue among members (Commission of the EC, 2004).

2.2 EU Decision to Repeal the Block Exemption for Liner Shipping Conferences

The EC competition rules are modelled on the presumption that competition provides the best services to the consumer at the most affordable prices. The block exemptions for liner conferences from EU competition rules had been attacked seriously, especially from the shippers’ group (the European Shippers’ Council) (van der Jagt, 2010). Another decisive factor in the renewed impetus of transport competition policy was the creation in 1987 of the Transport Division of the Directorate General for Competition (DG IV) of the European Commission (Blanco, 2007). In consideration of the liner shipping market has changed since the adoption of Regulation 4056/86 for 18 years, the European Commission started review process in March 2003 on whether “block exemption” for price fixing and capacity regulation by liner conferences was still justified under Article 81 of the EC Treaty. After many years’ consultations and discussions with stakeholders and coupled with many studies done by academics and experts, the EU made decision to pass Regulation 1419/2006.

Regulation (EC) No 1419/2006 repealed Council Regulation (EEC) No 4056/86 of 22 December 1986 on the application of Articles 81 and 82 of the Treaty to maritime transport containing the liner conference block exemption which allowed shipping lines meeting in liner conferences to fix rates and other conditions of carriage, as the conference system no longer fulfils the criteria of Article 81(3) of the Treaty. The repeal of the block exemption takes effect as of 18 October 2008. Thereafter, liner carriers operating services to and/or from one or more ports in the European Union must cease all liner conference activity contrary to Article 81 of the Treaty. This is the case regardless of whether other jurisdictions allow, explicitly or tacitly, rate fixing by liner conferences or discussion agreements. Moreover, conference members should ensure that any agreement taken under the conference system complies with Article 81 as of 18 October 2008 (Commission of the EC, 2008).

3. Responses from the Industries

3.1 Shippers' Opinions

The shippers' responses to the abolition of shipping conference's operation by the EU were quoted from the partial results of shippers' survey conducted by Containerisation International (CI) in 2008 and 2009 respectively.

3.1.1 Before Liner Conference is Abolished

On November 2008, CI published its annual shippers' survey results, where some questions discussing about how shippers' responses to the shipping conferences to be banned by the EU. The first question handles about what things the substitute association of liner shipping conferences will be allowed to do. Facing the EU action to abolish the liner conference, European Liner Affairs Association (ELAA) was set up in 2003 to discuss with the EU's Directorate General for Competition (DG Comp) the replacement of the Liner Conference regime in the EU. ELAA was closed since 1 July 2010 and transferred its responsibilities to the World Shipping Council (WSC). As shown in Table 3, the majority of shippers agreed that shipping trade association can be allowed to: (a) consolidate each members' cargo liftings, (b) consolidate and publish details of each members' historic vessel capacity adjustment in each tradelane, and (c) consolidate members' actual freight rates achieved between the major port pairs and then publish freight indices. Nevertheless, nearly half of shippers (48.5%) still cast some doubts on the publication of freight index by carriers' association. Regarding the operation of carriers' trade association, shippers concerned about the following points: (1) there is no problem to consolidate carriers' operational data such as liftings, vessel capacity, or freight index; however, carriers will not allow to conduct group discussion on these information; (2) carriers' trade association should not be permitted anything in addition to what is possible within a free market environment; and (3) the collected industrial data should be available to both carriers and shippers. If possible, the data are better be compiled by independent bodies, such as UNCTAD (United Nations Conference on Trade and Development) or customs, etc.

The issue of whether or not ocean carrier conferences should be banned elsewhere? The answer is positively confirmed. Over two thirds of bigger shippers agreed that liner conferences should be banned in the rest of the world (Table 4). The small shippers are not so sure about to abolish all liner conferences outside the EU area. Shippers do not like carriers to dominate the market through liner conference system. However, they hope carriers to provide abundant slot for carrying imports/exports. Table 5 presents that over 86.3 % of shippers concurred with EU to allow the improving operation of shipping consortia after conferences were banned on 17 October 2008. Worried about the shipping consortia to strongly control the market, more than half of shippers (52.1%) were against the maximum trade share for consortia in each tradelane to increase from 35% to 50%.

Table 3: Shippers' Opinion on What Things the Carrier's Association can do after Conferences are Banned in the EU on 17 October 2008

<i>Question 1:</i> Ocean carrier conferences are due to be banned in the EU on October 17, 2008. Afterwards, do you believe that their trade association should be allowed to:		
	Yes	No
a) consolidate each members' cargo liftings so that more accurate cargo flow forecasts can be established?	69.7 %	30.3 %
b) consolidate and then publish details of all members' historic vessel capacity adjustments in each tradelane, enabling them to know how full their vessels are likely to be after tacking into account public cargo flow forecasts?	62.7 %	38.6 %
c) consolidate members' actual freight rates achieved between the major port pairs and then publish indices to show overall port-to-port pricing trends?	51.5 %	48.5 %

Source: Beddow (2008)

Table 4: Shippers' Opinion on the Carrier Conferences should be Banned in the Rest of the World

<i>Question 2:</i> Do you think that ocean carrier conferences should be banned in the rest of the world?		
Size of shipper (categorized by import/export per year)	Yes	No
0-500 TEU	54.5 %	45.5 %
501-1000 TEU	42.9 %	57.1 %
1001-5000 TEU	76.9 %	23.1 %
5001-10000 TEU	75.0 %	25.0 %
Over 10000 TEU	88.9 %	11.1 %
Total	74.3 %	25.7 %

Source: Beddow (2008)

Table 5: Shippers' Opinion on can the EU allow the Improving Operation of Shipping Consortia after Conferences are Banned on 17 October 2008, and should the Maximum Trade Share for Consortia in each Tradelane be Increased from 35% to 50%.

<i>Question 3:</i> Once conferences are banned in the EU, ocean carriers want the way that they are allowed to cooperate together in consortia to be improved. Should they be allowed to exchange slots with other consortia in the same tradelane, in order to provide you with a better market coverage?	
Yes	No
86.3 %	13.7 %
<i>Question 4:</i> Should the maximum trade share of 35% automatically allowed by each consortia in each tradelane be increased to above 50% to enable better economies of scale to be achieved?	
Yes	No
47.9 %	52.1 %

Source: Beddow (2008)

3.1.2 After Liner Conference is Abolished

Around one year after the EU formally nullified the liner conferences, CI published its shippers' survey and revealed some investigation on shipping conferences (Dixon, 2009). Two questions dealt with the impact of the ban on liner conferences in EU trades and how this might have changed carrier's behaviour. The enquiry focuses on exploring that opening up market to greater competition might improve customer service functions and pricing responsiveness. Table 6 shows that less than 16 % of shippers indicated that liner carriers were making noticeable change to be more customer focused. In addition, more than 63% of shippers perceived limited change on carriers' practice to be more transparent with their pricing. Regarding the competition between liner carriers after the EU banned the conferences, shippers did perceive more competitive situation occurred in liner market because 68% of them recorded at least some change. There are difficulties to discern shippers remained unimpressed on carriers' behavioural change and more intensive competition was due to the 2008 financial crisis resulting in the massive global economic recession in 2009 or the EU abolishing the conference system on October 2008. Despite the ambiguity surrounding the impact of the EU ban on conferences, 74% of shippers felt that they should be abolished in the rest of the world (Table 7). The results shown in Tables 4 and 7 indicate that shippers are quite consistent with the opinions to call nullifying liner conferences system all over the world.

Table 6: Shippers' Perception on Carrier's Behaviour after Liner Conferences are Officially Banned

<i>Question 1:</i> Liner conferences were banned in the EU in October last year. Since then, have ocean carrier become:	
A. More customer focused?	
No change	42 %
Limited change	21 %
Some change	21 %
Noticeable change	7 %

Significant change	9 %
B. More transparent with their pricing?	
No change	23 %
Limited change	40 %
Some change	25 %
Noticeable change	12 %
Significant change	0 %
C. More competitive?	
No change	13 %
Limited change	19 %
Some change	34 %
Noticeable change	28 %
Significant change	6 %

Source: Dixon (2009)

Table 7: Shippers' Opinion on Liner Conferences should be Banned in the Rest of the World

<i>Question 2:</i>	
Based on this experience, do you think that liner conferences should be banned in the rest of the world?	
Yes	No
74 %	26 %

Source: Dixon (2009)

3.2 Carriers' Opinions

To understand how carriers responding to the EU banned the liner conferences system, this study conducted a questionnaire survey on November 2011 in Taiwan after 3 years the EU invalidated the shipping conferences (Tsai, 2012). Totally 31 carriers respond to the survey. As shown in Table 8, five aspects are discussed including influence on: (A) overall liner conference system, (B) European tradelane, (C) Far East/North American tradelane, (D) shipping services, and (E) Taiwan's ruling system. Carriers' opinions these five aspects will be detailed in the following. First, regarding the influence on liner conference system, over 60% of carriers' agreed that two aspects will be greatly impacted including the global liner conference system and promoting the use of other cooperative agreements (e.g., consortia arrangements). Around 22.6% of them did not think the carrier's monopoly power in the market will receive more restrictive due to the EU banned the liner conferences. Second, owing to the EU abolish the conference system, more than two thirds of carriers agreed that European tradelanes will be influenced on the following points: (1) freight rate fluctuation more frequently, (2) more competition for container carriers, and (3) market share for median to small liner carriers. Third, discussing the influence on Far East/North American trade routes, over 40% of carriers agreed that freight rate will fluctuate more frequently and competition between container carriers will be more intensive. Besides, market share for median and small carriers will receive more impact. Fourth, regarding the impact on shipping services, some important points are as the following: (1) nearly half of carriers (48.4%) disagreed EU to abolish liner conferences would cause negative influence on shipping service reliability; 35.4% of them also disagreed it would cause positive impact; (2) 38.7% of carriers agreed that liner service quality and innovation would be positively influenced; nevertheless, still more than one third (32.3%) of carriers did not agree that it would cause positive influence; (3) majority of carriers (61.4%) indicated that removing liner conferences in the EU would cause disadvantages for median and small carriers. Finally, considering the impact on conference ruling system in Taiwan, majority carriers (70.9 %) agreed that government authorities should not intervene in the operation of liner conferences. Interestingly, more than one third of carriers disagreed Taiwan government following EU's action to abolish the liner conferences system; more than one third of them also disagreed the government to change regulations to govern the conferences or consortia arrangements.

Table 8: Carriers' Opinion on the Influence of EU Abolished the Liner Conferences

Aspects to be influence	Degree of agreement				
A: Influence on liner conference system	Strongly	Disagree	Normal	Agree	Strongly

	disagree				agree
A1. Causing influence on global liner conferences	0 %	16.0 %	22.7 %	41.9 %	19.4 %
A2. Causing influence only on liner conferences in European tradelanes	6.5 %	19.3 %	29 %	29 %	16.2 %
A3. Causing restriction on carrier's monopoly power in market	6.5 %	22.6 %	25.8 %	32.2 %	12.9 %
A4. Promoting the other cooperative agreements to be used	0 %	6.5 %)	32.3 %	41.9 %	19.3 %
A5. Promoting the other countries considering to abolish liner conferences system	3.2 %	12.9 %	38.7 %	32.3 %	12.9 %
B: Influence on European tradelanes	Strongly disagree	Disagree	Normal	Agree	Strongly agree
B1. Causing freight rate fluctuation more frequently in European tradelanes	0 %	6.5 %	6.5 %	45.1 %	41.9 %
B2. Causing freight rate more stabilized in European tradelanes	0 %	9.7 %	19.3 %	45.2%	25.8%
B3. Causing more competition for container transport in European tradelanes	6.5 %	9.7 %	22.5 %	35.5 %	25.8 %
B4. Influence on market share for median to small liner carriers in European tradelanes	0 %	6.5 %	12.9 %	58.1 %	22.5 %
C: Influence on Far East/N. American tradelanes	Strongly disagree	Disagree	Normal	Agree	Strongly agree
C1. Causing freight rate fluctuation more frequently in FE/NA tradelanes	0 %	25.9 %	29 %	29 %	16.1 %
C2. Causing freight rate more stabilized in FE/NA tradelanes	3.2 %	45.2 %	19.3 %	25.8 %	6.5 %
C3. Causing more competition for container transport in FE/NA tradelanes	9.7 %	19.3 %	29 %	38.8 %	3.2 %
C4. Influence on market share for median to small liner carriers in FE/NA tradelanes	3.2 %	25.8 %	19.3 %	38.8 %	12.9 %
D: Influence on shipping services	Strongly disagree	Disagree	Normal	Agree	Strongly agree
D1. Causing positive influence on service reliability (e.g. reliable schedule)	9.7 %	25.7 %	35.5 %	22.6 %	6.5 %
D2. Causing negative influence on service reliability (e.g. reliable schedule)	6.5 %	41.9 %	35.5 %	12.9 %	3.2 %
D3. Causing positive influence on service quality and innovation	9.7 %	22.6 %	29 %	35.5 %	3.2 %
D4. Causing negative influence on service quality and innovation	0 %	29 %	41.9 %	19.4 %	9.7 %
D5. Removing conferences cause disadvantages for median to small shipping carriers	3.2 %	16 %	19.4 %	35.5 %	25.9 %
D6. Removing conferences help carriers get more flexibility in responding to market changes	3.3 %	9.8 %	29 %	41.9 %	16 %
D7. Causing influence on the volume of international imports and exports	16 %	29 %	45.3 %	9.7 %	0 %
E: Influence on Taiwan's system	Strongly disagree	Disagree	Normal	Agree	Strongly agree
E1. Taiwan government should not intervene in the operation of liner conferences	3.2 %	22.7 %	3.2 %	41.9 %	29 %
E2. Taiwan government should follow EU's action to abolish the liner conferences system	16 %	19.3 %	32.3 %	25.9 %	6.5 %
E3. Taiwan government should amend regulations to limit the operation of liner	12.9 %	19.3 %	32.3 %	29 %	6.5 %

conferences					
E4. Taiwan government should amend regulations to regulate carrier's consortium agreements	16 %	16 %	29 %	32.4 %	6.6 %

Source: Tsai (2012)

4. Conclusions

The first well known liner shipping conference was created for the UK/Calcutta trade in 1875. In 1986, European Union (EU) Council Regulation 4056/86 allowed liner shipping operators to have an exemption from EU competition rules to organize themselves into conferences with the aim of fixing prices and coordination capacity for the transport of containerized cargo. In September 2006, the council of EU decided to abolish that exemption from EU competition rules, with effect from 18 October 2008.

Shippers basically expect two things will be improved following the EU to repeal the liner conference system: carrier's being more customer-focused and more transparent on ocean pricing mechanism (Beddow, 2009). Shippers seemingly perceived that these two intentions have not yet realized. Because of the global economic recession in 2009, ocean carriers have been forced to focus on financial survival rather than looking at customer-care. Although liner conferences are no longer exist in European tradelanes, shipping lines are still following the prices set by the big carriers such as Maersk and MSC (Mediterranean Shipping Company).

The empirical study about the carriers' perception on the influence of the EU repealing the block exemption for liner conferences reveals the following important points. First, majority of carriers (over 60%) agreed that obvious impact will be on the global liner conference system and promoting the use of other cooperative agreements (e.g., consortia arrangements). Second, freight rate fluctuation would be more frequently on all tradelanes. Third, the EU to remove conferences system will possibly (1) help carriers get more flexibility in responding to market changes, (2) cause positive influence on service quality and innovation, and (3) cause disadvantages for median to small shipping carriers.

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Optimizing a Containership Stowage Plan Using a Modified Differential Evolution Algorithm

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Abstract

As the core of ship planning, stowage planning has a direct impact on the efficiency of a maritime container terminal. In this paper, we consider the stowage plan of a containership as a combinatorial optimization problem that maximize ship stability and keep no container reshuffles during the ship's unloading process at each port of a multi-port journey, which is the process of assigning available positions within the ship to specific categories of containers considering attributes such as destination, weight, and size type of the container. We describe practical constraints in detail and give a multi-objective integer programming model for the problem with considering the irregular structure of the hold of containership and three most common size types of container. Successively, in order to generate the containership stowage plan effectively and efficiently, we propose a modified Differential Evolution algorithm which employs a new mutation operator in an attempt to balance the exploration and exploitation capabilities of optimization method. The validation of the proposed approach is performed with some real life test cases from a maritime container terminal.

Keywords: Stowage Plan, Combinatorial Optimization, Differential Evolution

1. Introduction

The containerships are cargo ships those carry their entire load in truck-size intermodal containers, in a technique called containerization. They form a common means of commercial intermodal freight transport. Containerization has increased the efficiency of moving traditional break-bulk cargoes significantly, reducing shipping time and costs. As in 2001, more than 90% of world trade in non-bulk goods was transported in ISO containers, and in 2009, almost one quarter of the world's dry cargo was shipped by container, an estimated 125 million TEUs or 1.19 billion metric tons worth of cargo. Containerization not only changed the face of shipping but also revolutionized world trade as well.

The containership stowage planning (CSP), a pivotal link to containers transportation, is to draw up a plan of determining how to stow a set C of containers of different types into a set S of available locations of a containership with the considerations of some structural and operational constraints, related to both the containers and the ships (Ambrosino et al., 2004). In practice, CSP not only affects the economic benefit of shipping line and container terminal from transportation but also has direct relation to the safety of the ships and cargos.

When we draw the plan, some factors must be considered, such as the structure of ship, distribution of goods, port of destination (POD) and so on, with consideration of different objectives including optimal space allocation, maximization of the stability and minimization the berthing time. All these factors are interactive and conflictive with each other which make the CSP problem become a combinatorial optimization problem. The increasing number of containers transported by ships and corresponding increase of containerships size (*Edith Maersk* has 11,000 TEUs capacity) lead to containerships enlarging in principal dimension, which makes it more complicated to draw containership stowage plan.

The CSP problem has been proved to be NP-complete (Avriel et al., 2000). Todd and Sen (1997), firstly attempted to apply genetic algorithm to solve CSP problem, proposed a multi-criteria complete encoding genetic algorithm for solving the stowage problem. In their approach, different sections of the solution vector corresponded to each POD. Each section of the solution contained integer vectors of size P , where P was equal to the total number of container slots in the ship. Each element in such a vector indicated the POD of the container that occupies the corresponding slot at the given port. The major disadvantage of the approach is that the vector of encoding is too long. For example, to encode a ship carrying 1,500 containers and visiting 15 ports, a vector of length 22,500 is needed. Such long vectors would cause the search space too large and reduce the convergence rate of the algorithm. Dubrovsky and Levitin (2002) proposed a compact encoding technique, in which the disadvantages of complete encoding were overcome. The compact encoding method just saved the mutative part after the operation of loading and unloading completed along the route of ship calling, rather than holding the complete layout. Since the ship layout has a relatively small number of changes at each port, the size of solution encoding vectors should be much smaller than complete code. So this method would significantly reduce space of solution and advance efficiency of algorithm.

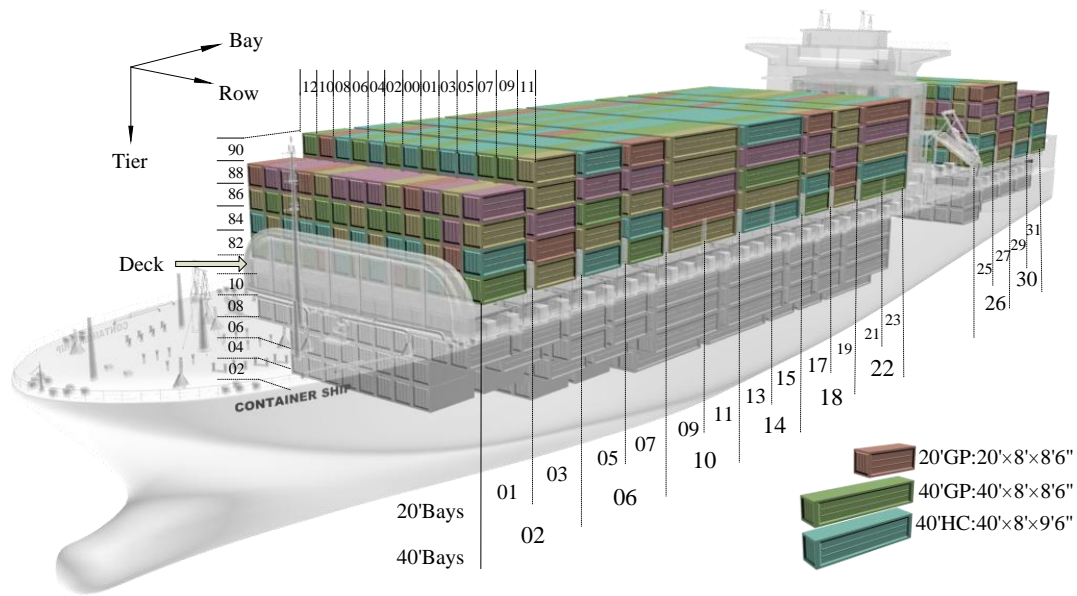
Wilson and Roach (1999) and Wilson et al. (2001) tested the application of local search algorithms and techniques based on combinatorial optimization. In particular, the authors broke the container stowage process into two phases, which are respectively at a strategic and tactical planning level. The computational experiments reported by the authors show the goodness of the sub-optimal solutions obtained in computational time of the order of 90 minutes for instances relative to a 688 TEUs ship. A similar staged approach has been followed by Ambrosino et al. (2006) and Ambrosino et al. (2009) that, in a first phase, split the set of available locations into different partitions with respect to their bay address and the POD of the ship; finally, solve the MBPP model looking successively for the global stability of the ship by performing multi-exchanges and using a tabu search (TS) meta-heuristic approach. However, due to many simplified assumptions, such as neglecting the irregular structure feature of the hold and the High Cube container most commonly used at present terminal and so on, the most of approaches employed in literatures are not suitable for real large scale applications.

In this paper, we solve the CSP problem as a combinatorial optimal problem with maximizing stability of ships and keeping zero reshuffles using a modified DE algorithm employed a new mutation operator, to our knowledge, with the first application of DE to stowage planning. The CSP problem and practical constraints are presented in detail in Section 2. A multi-objective optimal model for the problem and our proposed algorithm are present in Section 3. In Section 4 we give the experimental example and present some computational results aimed at validating the proposed approach. We finish the paper with conclusion in Section 5.

2. CSP Problem

Firstly, to give an idea of how stowage takes place, we consider the basic structure of a ship with its perspective view shown in Figure.1. It consists of a given number of locations to stow the containers that can vary in size depending on the ship. Most commonly, container capacity is often expressed in twenty-foot equivalent units (TEU) which is a unit of capacity equal to one standard 20'×8'×8' (length × width × height) container. Each location is identified by the three indices, each one consisting of two numbers that give its position with respect to the three dimensions. In particular, each position is addressed by the following identifiers: (a) Bay, the position relative to the cross section of the ship, counted from the bow to stern; (b) Row, the position relative to the vertical section of the corresponding bay, counted from the centre to the both sides; (c) Tier, the position relative to the horizontal section of the corresponding bay, counted from the bottom to the top of the ship. Thus a container is located in a given bay, on a given row and on a given tier.

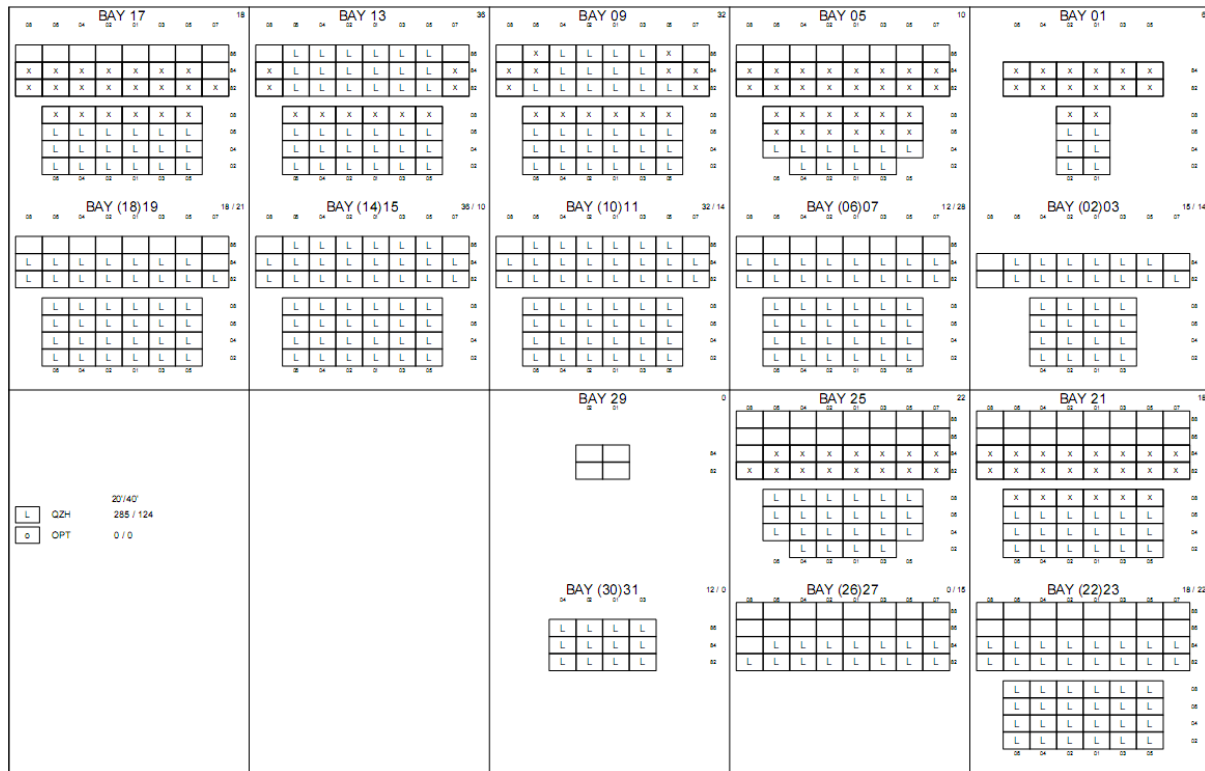
Fig. 1: Perspective Of A Containership



In particular, each 20' bay is coded with an odd number for the stowage of 20' containers, i.e. by 01, 03, 05, etc., while two continuous odd bays conventionally yield one even bay for stowing the 40' containers, i.e. bay 10 = bay 09 + bay 11 (see Figure.1). The second index is the row, ship locations have an even number if they are located on the seaside, i.e. row 02, 04, 06, while an odd number if they are located on the yard side, i.e. row 01, 03, 05, etc. Finally, third index, that is the tier, are numbered from the bottom of the hold to the top with even number, i.e. tier 02, 04, 06, etc., while in the upper deck possible numbers are 82, 84, and 86. It is noticed that, the numbers of rows and tiers within each bay are different, especially at the bow and the stern of the ship, due to the irregular structure of hold (below deck). This irregular feature of the containership, neglected by many authors for reducing the complexity of the problem, is considered in our mathematic model presented in next Section.

Stowage planning is the core of the ship planning. In practice, planning a ship's stowage is a two-step process (Stahlbock et al., 2004). The first step is executed by the shipping line. The shipping line's stowage plan has to be designed for all ports of a vessel's rotation journey. Stowage planning of a shipping line is a stowage instruction as shown in Figure 2, which is usually not according with specific containers identified by numbers, but on categories of containers, such as the size of a container, the POD and the weight or weight-class of containers. According to these features, containers are assigned to specific space within the ship to satisfy the constraints for the stability of the ship. The objectives of optimization from the shipping line's viewpoint are to minimize the number of reshuffles during port operation and to maximize the ship's utilization. The stowage plan of the shipping line is sent to the terminal operator by EDI before the arrival of the corresponding ship. The stowage instruction of the shipping line is filed into the terminal's ERP system and serves as a working instruction or pre-plan for the terminal's ship planner. Here, the container stowage stacks of the entire ship are shown in more detail, in the form of a series of vertical transverse sections, or bays, viewed from aft. Each stowage location is shown as small box. Positions are marked using letters and/or colors to indicate the container's port of destination and the presence of extra-height and extra-width containers.

Fig. 2: Stowage Instruction



Based on this instruction the terminal planer then assigns corresponding containers identified by numbers to the respective slots. Optimization objectives are possibly different, e.g., maximization of cane productivity, cost minimization, or minimization of yard reshuffles. The minimization of the yard reshuffles plays an important role through a practical viewpoint. Reshuffles occur when a container has to be accessed while others on the top of it have to be removed first. Reshuffling consumes time which is an offset to the transportation time between stack and shore reducing the productivity of ship operation, so containers should be arranged optimally to reduce the number of reshuffle as much as possible.

Moreover, both the constraints related to the particular ship under consideration and those of the containers should be taken into account to solve the CSP problem.

a) Size of container. The standard sizes of three types of containers are considered in this paper, namely 20' GP (General Purpose), 40' GP and 40' HC (High Cube). 'GP' indicate a container should be 8' width, 8'6" high and, most commonly, 20' and 40' long. Taller units have been introduced recently (see Figure.1), including high cube units at 9'6" and 10'6" high, are widely used in many countries. As it is always required for security, 20' containers cannot be located above locations where 40' containers are already stowed, and 40'HC cannot be stacked from the bottom to the top tier to prevent to touch the hatch-lids in hold.

b) Weight of container. The standard weight of an empty container ranges from 2 to 3.5 tons, while the maximum weight of a full container to be stowed in a containership ranges from 20 to 30 tons and 30 to 50 tons for 20' and 40' containers respectively.

c) Destination of container. A good general stowage rule suggests to load first (i.e. in the lower tiers) those containers having as destination the final stop of the ship and load last those containers that have to be unloaded first. Containers are loaded by cranes from the bottom of the ship into vertical stacks. If a container destined for one port is positioned below containers destined for a later port, the containers above must be unloaded and reloaded at earlier port, such movements are called reshuffles. Movements of container reshuffle incur additional costs in time and reducing the productivity of ship operation, so containers should be arranged optimally to minimize the time spent in port.

A balanced distribution of the weight in the ship is the basic condition for good stowage. So it is necessary to check the stability of the ship by using some mathematical methods only when ship is loaded. In practice, most of heavy containers are located in the hold, while the others are located in the upper deck. Moreover, to ensure the security, after the loading operation is complete, we have to verify two equilibrium indicators considered as the objectives of mathematical model in our work.

a) Horizontal equilibrium. The weight on the stern of the ship must be equal (or with a difference within a certain tolerance) to the weight on the bow.

b) Cross equilibrium. The weight on the right side of the ship, including the odd rows of the hold and upper deck should be equal (or with a difference within a certain tolerance) to the weight on the left side of the ship, including the even rows of the hold and upper deck.

Therefore, a ship must be loaded in such a way to satisfy the constraints above so that it can be able to travel independently in a variety of the weather conditions and that the stability constraints must also be satisfied during some possible loading/unloading at intermediate destinations.

3. Approach Taken

In this section we present our multi-objective optimization model of the CSP problem and the modified DE algorithm used in this paper as follows.

3.1. Mathematical Model

The objective function is used to evaluate solutions of the problem and the corresponding constraints require a number of definitions to model the underlying structure of the problem, which are shown as follows.

- T : the set of all 20' GP containers;
- FG : the set of all 40' GP containers;
- FH : the set of all 40' HC containers;
- F : the set of all 40' containers, $F = FG \cup FH$;
- C : the set of all containers, $C = T \cup F$;
- c, e : the container indices;
- D : the set of all ports of destination;
- d_c : the port of destination of container c , $d_c \in D$;
- w_c : the weight of container c ;
- I : the set of all bays of the whole containership;
- i : the index of bay, $i = 1, \dots, |I|$;
- E : the set of even bays, $E \subset I$;
- O : the set of odd bays, $O \subset I$ and $I = E \cup O$;
- J : the set of all rows of the whole containership;
- j : the index of row;
- J_i : the set of all rows within the bay i ;
- K : the set of all tiers of the whole containership;
- k : the index of tier;
- K_i : the set of all tiers within the bay i ;
- K_{ij} : the set of all tiers within the bay i and row j ;
- KB_{ij} : the set of all tiers within the bay i and row j below the deck;
- KA_{ij} : the set of all tiers within the bay i and row j above the deck;
- S : the set of all stowage locations;
- l : a stowage location;
- x_{lc} : the decision variable of the problem, with the following specification:

$$x_{lc} = \begin{cases} 1, & \text{if container } c \text{ is allocate to the location } l, \\ 0, & \text{otherwise.} \end{cases}$$

It is noticed that the l^{th} location is actually identified by indices i, j, k representing, respectively, its bay, row and tier address, while c identifies the number of the c^{th} container in set C . It means that, in practice, variable $x_{lc}=x_{ijkc}$, directly giving the location where container c is stowed if it is set to 1. Therefore, at the optimal solution we have the exact position of each container in the ship.

The definition of variables above enables a formulation of the model for the CSP problem, which is reported here as follows.

$$\min Z = W_1 + W_2 \quad (1)$$

where:

$$W_1 = \sum_{i=1}^{|I|} \left| W_i - \overline{W}_i \right| = \sum_{i=1}^{|I|} \left| \sum_{j=1}^{|J_i|} \sum_{k=1}^{|K_{ij}|} \sum_{c \in C} w_c x_{ijkc} - \frac{1}{|I|} \sum_{i=1}^{|I|} \sum_{j=1}^{|J_i|} \sum_{k=1}^{|K_{ij}|} \sum_{c \in C} w_c x_{ijkc} \right| \quad (2)$$

$$W_2 = \sum_{i=1}^{|I|} \sum_{j=1}^{|J_i|} \left| W_{ij} - \overline{W}_{ij} \right| = \sum_{i=1}^{|I|} \sum_{j=1}^{|J_i|} \left| \sum_{k=1}^{|K_{ij}|} \sum_{c \in C} w_c x_{ijkc} - \frac{1}{|J_i|} \sum_{j=1}^{|J_i|} \sum_{k=1}^{|K_{ij}|} \sum_{c \in C} w_c x_{ijkc} \right| \quad (3)$$

s.t.

$$\sum_{l \in S} \sum_{c \in C} x_{lc} = |C| \quad (4)$$

$$\sum_{l \in S} x_{lc} \leq 1 \quad \forall c \in C \quad (5)$$

$$\sum_{c \in C} x_{lc} \leq 1 \quad \forall l \in S \quad (6)$$

$$\sum_{c \in T} x_{ijkc} = 0 \quad \forall i \in E, j \in J_i, k \in K_{ij} \quad (7)$$

$$\sum_{c \in F} x_{ijkc} = 0 \quad \forall i \in O, j \in J_i, k \in K_{ij} \quad (8)$$

$$\sum_{c \in T} x_{i+1,jk+1c} + \sum_{c \in F} x_{ijkc} \leq 1 \quad \forall i \in E, j \in J_i, k = 1, \dots, |K_{ij}| - 1 \quad (9)$$

$$\sum_{c \in T} x_{i-1,jk+1c} + \sum_{c \in F} x_{ijkc} \leq 1 \quad \forall i \in E, j \in J_i, k = 1, \dots, |K_{ij}| - 1 \quad (10)$$

$$\sum_{\substack{c, e \in C \\ c \neq e}} (w_e x_{ijkc} - w_c x_{ijk+1c}) \geq 0 \quad \forall i \in I, j \in J_i, k = 1, \dots, |K_{ij}| - 1 \quad (11)$$

$$\sum_{\substack{c, e \in C \\ c \neq e}} (d_c x_{ijk+1c} - d_e x_{ijkc}) \geq 0 \quad \forall i \in I, j \in J_i, k = 1, \dots, |K_{ij}| - 1 \quad (12)$$

$$\sum_{k=1}^{|K_{ij}|} \sum_{c \in FH} (x_{ijkc} + 1 - |K_{ij}|) \leq 0 \quad \forall i \in E, j \in J_i \quad (13)$$

$$x_{lc} \in \{0, 1\} \quad \forall l \in S, c \in C \quad (14)$$

Expression (1) is the objective function that minimizes the total ship stability difference W , expressed in terms of the sum of W_1 and W_2 denoting the cross equilibrium difference and horizontal equilibrium difference respectively. Expression (2) is the definition expression of W_1 , where W_i and \overline{W}_i denote the weight of

containers stowed in bay i , $\forall i \in I$, and average of the weight of $|I|$ bays in containership respectively. Expression (3) is the definition expression of W_2 , where W_{ij} and $\overline{W_{j_i}}$ denote the weight of containers stowed in Row j , $\forall j \in J_i$, in bay i , $\forall i \in I$, and the average of the weight of $|J_i|$ rows in bay i in ship respectively.

Constraint (4) defines the number of locations to be selected for stowing the given containers. Expression (5) and (6) are the well known assignment constraints forcing each container to be stowed only in one ship location and each location to have at most one container. Constraints (7) and (8) force, respectively, 40' containers to be stowed in even bays and 20' containers to be stowed in odd bays, while (9) and (10) prevent 20' containers being positioned over 40' ones. Constraint (11) forces heavier containers could not to be put above lighter ones. The destination constraint (12) avoids positioning containers which have to be unloaded first below those containers with a later destination port. Particularly, constraint (13) prevents the height of 40' HC containers stack stowed below deck to exceed the capacity of hold. Finally, in Expression (14) the binary decision variables of the problem are defined.

Note that in the formulation of the problem we assume that the ship starts its journey in the port for which we are studying the problem. In particular, zero reshuffle is achieved via satisfying the constraint (12), which is more practical applicability than minimization of the reshuffles when solving the real problem in practice. Moreover, we assume that the number and the weight of containers to be loaded on board are not greater than the number of available locations and the capacity of the ship, respectively.

3.2. The Modified DE

Differential Evolution (DE), proposed by Storn and Price (1997), is an efficient and powerful population-based stochastic search technique for solving optimization problems over continuous space, which has been widely applied in many scientific and engineering fields. However, the success of DE in solving a specific problem crucially depends on choosing evolutionary strategies appropriately and their associated encoding method. To solve the CSP problem efficiently for application in practice, we present a modified DE employing a new evolutionary strategy, which can improve the balance performance of the algorithm between exploitation and exploration during the process of convergence. The basic steps of the approach are shown by illustrating the procedure of DE in this subsection.

A. Initialization. To initialize a population of NP D -dimensional individuals over the optimization search space, we shall symbolize each individual by $\mathbf{x}_g^i = [x_{g,1}^i, x_{g,2}^i, \dots, x_{g,D}^i]$ encoded as the loading sequence of all containers, for $i = 1, \dots, NP$ and $D = |C|$, where g is the current generation. At the same time, all positions on ship are numbering according to their three-dimensional coordinates. Hence, each element of the individual and its value denote a container and the stowing position of it, i.e. the container with the minimum elements will be allocated to the first location on the ship. We can initialize the j^{th} dimension element of the i^{th} individual according to

$$x_{0,j}^i = L_j + rand_j(0,1) \cdot (U_j - L_j) \quad (15)$$

where $rand_j(0,1)$ is a uniformly distributed random number confined in the $[0, 1]$ range; U and L are lower and upper bound values of individual respectively. After initialization, DE enters a loop of evolutionary operations: mutation, crossover, and selection.

B. Mutation Operation. For each target individual \mathbf{x}_g^i of the current population a new individual, called the mutant individual \mathbf{v}_g^i , is derived through the linear combination of base individual \mathbf{x}_g^i and difference individuals $(\mathbf{x}_g^a - \mathbf{x}_g^b)$ randomly selected individuals with a real parameter mutation factor F determined by a normal distribution with mean value 0.5 and standard deviation 0.1, denoted by $N(0.5, 0.1)$. The originally proposed and most frequently used mutation strategies in the literature are:

$$\mathbf{v}_g^i = \mathbf{x}_g^{r1} + F \cdot (\mathbf{x}_g^{r2} - \mathbf{x}_g^{r3}) \quad (16)$$

Because the real number encoding method, which is different from the binary encoding method of the decision variables, is employed in our algorithm, the linear combination in mutation operation such as (2-2) does not influence the feasibility of the individual. For enhancing the robustness of the algorithm, a new difference vector, added in mutation strategy, combines a better individual x_g^b and a random individual x_g^r beyond the current population within the searching space to improve the convergence rate and the diversity of the population respectively. The new mutation strategy is:

$$v_g^i = x_g^{r1} + F \cdot (x_g^{r2} - x_g^{r3}) + F \cdot (x_g^b - x_g^r) \quad (17)$$

C. Crossover Operation. The crossover is performed on each component j ($j=1,2,\dots,|C|$) of the mutant individual v_g^i . In detail, for each component of the mutant vector a random real number r in the interval $[0, 1]$ is drawn and compared with the crossover rate, $CR \sim N(0.5, 0.1)$, which is the second DE control parameter. The procedure can be outlined as:

$$u_{g,j}^i = \begin{cases} v_{g,j}^i, & \text{if } (r_{i,j}(0,1) \leq CR \text{ or } j = j_{\text{rand}}) \\ x_{g,j}^i, & \text{otherwise} \end{cases} \quad (18)$$

D. Selection Operation. Finally, the selection operator is employed to select the most promising individual with less value of objective function, i.e. the better stability of the containership, between target individual and trial individual survives to the next generation and to retain the population size constant over the evolution process. Thus, the selection operator can be defined as

$$x_{g+1}^i = \begin{cases} u_g^i, & \text{if } f(u_g^i) \leq f(x_g^i) \\ x_g^i, & \text{otherwise} \end{cases} \quad (19)$$

where $f(x)$ is the objective function to be minimized. Therefore, the population of the algorithm either gets better (with respect to the minimization of the objective function) or remains the same in fitness status, but never deteriorates. The terminating condition of iteration can be defined by a fixed number of iterations G_{\max} .

4. Evaluation Example

In this section we present some evaluation examples aimed at showing the performance of our approach. In particular, our test problems are related to a containership of 600 TEUs as is shown in Fig. 2 (named Xin HongXiang 57), with 16 bays, 8 max available rows in the upper deck, 6 in the hold, 4 max available tiers in the upper deck and 4 in the hold. Here we test our approach of looking for stowage plan of 10 real instances, which are reported in table 1; such instances differ from each other of the containers number to be loaded, their sizes and weights, and the number of TEUs to load on board, where the range of the containers number is from 274 to 406, the number of ports to be visited is 3, and the number range of TEUs to load on board is from 451 to 570.

All evaluation examples have been performed on a PC with Core 2 Quad CPU 2.83GHz and 3.25GB Memory.

Table 1: The Set of Evaluation Examples

Instance	TEUs	C	Size			Destination		
			20'GP	40'GP	40'HC	1	2	3
1	453	274	95	118	61	98	93	83
2	451	335	219	60	56	120	106	109
3	474	316	158	32	126	119	107	90
4	491	362	233	45	84	78	114	170
5	510	380	250	74	56	95	173	112

6	517	327	137	116	74	67	106	154
7	536	278	20	82	176	102	78	98
8	551	406	261	68	77	65	128	213
9	550	330	110	137	83	47	170	113
10	570	392	214	54	124	193	126	73

Table 2 reports the comparison between the solutions obtained by solving the multi-objective model for CSP problem using CPLEX 11.0, the present modified DE (mDE) algorithm and the Genetic Algorithm (GA). The comparison is based on two main indicators, which is the value of objective function Z (in ton) and the computational time (in hour, minute and second).

Table 2: Comparisons of the Z Function Value and the Computing Time between Cplex, mDE and GA

Instance	Z Function Value (ton)					CPU time (h:mm:ss)				
	Model	mDE		GA		Model	mDE		GA	
		Value	$\Delta\%$	Value	$\Delta\%$		Value	$\Delta\%$	Value	$\Delta\%$
1	217	225	3.69	247	13.82	0:33:18	0:08:36	74.17	0:09:08	72.57
2	270	283	4.81	295	9.26	0:56:42	0:09:11	83.80	0:12:17	78.34
3	256	263	2.73	267	4.30	2:43:06	0:06:56	95.75	0:08:35	94.74
4	273	279	2.20	292	6.96	0:42:25	0:07:35	82.12	0:08:43	79.45
5	212	217	2.36	227	7.08	2:11:43	0:07:12	94.53	0:08:32	93.52
6	289	299	3.46	328	13.49	1:36:48	0:06:12	93.60	0:07:53	91.86
7	201	210	4.48	213	5.97	2:07:23	0:09:54	92.23	0:12:34	90.13
8	277	284	2.53	286	3.25	0:43:11	0:08:16	80.86	0:09:27	78.12
9	186	192	3.23	196	5.38	1:47:23	0:08:31	92.07	0:10:21	90.36
10	265	270	1.89	282	6.42	2:13:34	0:14:17	89.31	0:12:37	90.55
Average	244.6	252.2	3.14	263.30	7.59	1:33:33	0:08:40	87.84	0:10:01	85.96

According to the data of the solutions, we can note the impressive reduction of the CPU time of our approach which is up to 95.75% with the average value 87.84%. Even though GA achieved the reduction of CPU time with 85.96% on average, GA has a poor performance in solutions of Z functions value. The results we got averagely are about 3.14% greater than the optimal values and only 4.81% in the worst case, and the gap value between the results obtained by GA and the optimal are 7.59%. Then we notice that, the consideration of HC containers increases the complexity of the solving CSP problem especially in case 3, 7 and 10 with a large proportion in which superiority of mDE is more significant. In practice, at least half an hour is required to draw up a specific stowage plan. Even though the model can find the optimal value of the objective function, it is time-consuming and inefficient. The sub-optimal solutions obtained by our approach are accord with the actual stability requirement, and more efficient than the model and the manual operation.

5. Conclusion

In this paper we have presented a multi-objective model for the CSP problem with the consideration of the irregular structure of the ship hold and three most commonly size containers, and a modified DE algorithm is proposed for solving the CSP problem. According to the comparison with the application of Cplex and GA in ten large scale real cases, the proposed solution method has very good performance in terms of both solution quality and computational time in large scale cases. Moreover, our approach for solving the CSP has been used in the central control room of a container terminal.

Acknowledgements

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A Column Generation Algorithm for Slab Stack Shuffling Problem

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Abstract

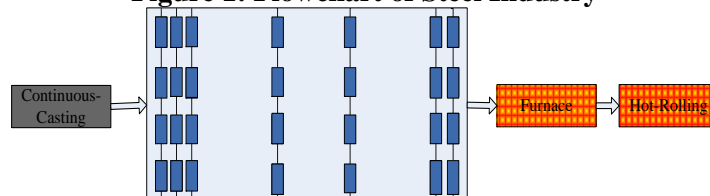
As a kind of warehousing operations management problem, SSS problem plays a key role between continuous casting and hot rolling in steel industry. If a slab in the yard that stacks in a middle tier of the stack is chosen for hot rolling, other slabs above it should be moved away first before the target one can be retrieved, then shuffle occurs. SSS is to choose appropriate slabs for hot-rolling schedule, from their respective candidate slab sets aiming at minimizing the resulting shuffle number. Properly selection of slabs can reduce shuffles during the retrieval process, improve working efficiency of cranes in slab yard and decrease the time spent on feed preparation of hot-rolling and also logistics cost. Since slabs are piled one upon another in a stack, the number of shuffles for retrieving the chosen slabs not only depends on the slabs about to taken out, but also the slabs previously taken out from the stack. SSS is formulated as a nonlinear model. Because of its complexity, several intelligent algorithms have been applied to SSS but few optimization algorithm has been introduced to solve it according to previous literatures. In this paper, the concept of stack-scheme is proposed to synthetically consider the decision situation in a stack. The net shuffle number in a stack is independent with the situation in other stacks and thus the needed shuffle number associated within a stack-scheme can be individually calculated. Based on above, the original problem can be reformulated as a linear master problem and a set of sub-problems by Danzig-Wolf decomposition. Column generation (CG) is then applied to solve it and a branch-and-bound method is proposed to get the optimal solution. The performance of the proposed algorithm is verified by numerical experiments.

Keywords: steel industry, warehousing management, slab stack shuffling, column generation

1. Introduction

SSS problem is abstracted from hot-rolling stage in steel industry. Steel production is a multi-stage process. A slab yard serves as a buffer between continuous casting and steel rolling. Finished products of continuous-casting (steel slabs) are stored in slab yard, waiting to be chosen for hot-rolling stage (Figure 1). In hot rolling production, slabs are rolled turn by turn according to hot-rolling plan. A plan is actually a predefined sequence of rolling items and each item requires a slab of specified size and grade. Since the slabs which are casted from the same batch are of the same steel grade and similar size, there is usually more than one candidate slab in the yard satisfying the requirements of each item. These candidate slabs for the item is called a *slab family*, from which one target slab needs to be selected for an item in hot-rolling plan. If a target slab is not on top of a stack, the slabs above it need to be shuffled aside first, which is called slab stack shuffling. The proper target slab selection can reduce the extra slab-handling due to slab shuffling. This is the slab stack shuffling (SSS) problem.

Figure 1: Flowchart of Steel Industry



Properly selection of slabs can reduce shuffles during the retrieval process, improve production efficiency of slab yard and decrease the time spent on feed preparation of hot-rolling stage. Reduction in shuffles during the retrieval process can also promote the production efficiency of the steel enterprise indirectly. This research can promote the management level of production and logistic in steel making enterprises, and decrease the logistics operation cost.

Some attentions have been paid on SSS problem in previous literatures. Tang *et al.* proposed a two-phase algorithm to solve SSS. An initial feasible solution was generated first and improved using local search. Experimental results show that the proposed algorithm yields significant better solutions than the old algorithm with an average improvement of 15%. Singh et al. proposed a Parallel GA to solve the SSS problem based on Tang's model, and shuffles decrease by 6%. In this paper, a column generation algorithm is proposed so solve SSS problem, which can get an optimal solution.

This paper is organized as follows: Section 2 gives a detailed description of the problem and formulates SSS as an integer programming model. For the nonlinearity of the model, in section 3, a definition of *stack-scheme* is proposed to linearize the model. After that, a column generation algorithm is proposed to solve it, which is given in section 4. In section 5, experiment results are given and section 6 gives conclusions.

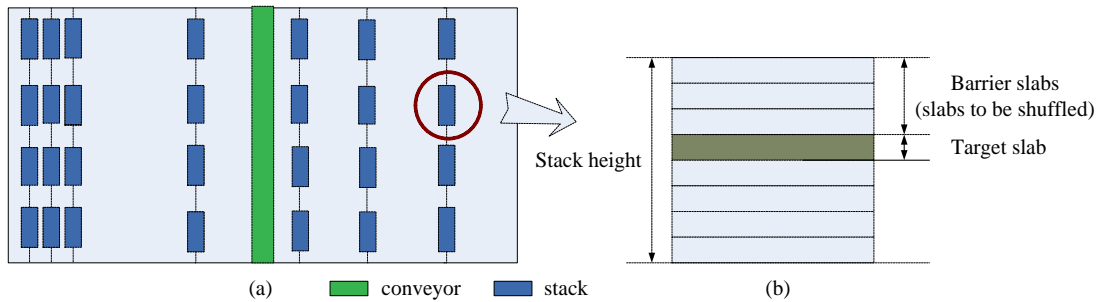
2. Problem Description and Mathematical Model

In this section, details about the problem and

2.1. Problem Description

As shown in Fig. 2(a), stacks are stored in slab yard, by column and row. Bridge cranes travel along overhead rail stacks fixed on the two sides of the area. In the middle of the two ends of the yard lies a roller conveyor, which can automatically transport slabs on it to the exit.

Figure 2: Layout of the Slab Yard and a Stack in it



In each stack in the yard, slabs are piled up one on top of another, as shown in Fig. 2(b). There is a permitted maximum stack height, which is the maximum number of slabs that a stack can hold. If a required slab is not on top of the stack, the slabs above it must be shuffled to other stacks before it can be retrieved and the number of shuffled slabs is referred to as *shuffle number* for the target slab.

Slabs stacked in the yard are raw materials for hot-rolling. Given an order, planers will choose some slabs from the yard which meet the order demand to form a hot-rolling schedule. If the chosen slab (target slab) stacked in the lower tier of a stack, the crane should move away the slabs above it in advance to make the target slab expose on the top, then 'shuffle' occurs. The increase in shuffles will lead a longer time spent on feed preparation which delay hot-rolling production and also disturb the coordinate production between continuous-casting and hot-rolling. SSS problem is to select specified slabs corresponding to each item in hot-rolling schedule, aiming at the minimum shuffles during the whole retrieval process. In this paper, we assume that slab yard is large enough that a barrier slab can always be shuffled onto a stack in which no target slab stacks in.

2.2. Mathematical Model of SSS

A mathematical model is constructed for the problem in this section. Following notations are introduced for the formulation.

Parameters:

- i Index of rolling item, $i \in \{1, 2, \dots, M\}$, which is the set of rolling items in hot-rolling schedule;
- S_i Slab family for the i th rolling item, $i = 1, 2, \dots, M$, and $S = \bigcup_{i=1}^M S_i$ denotes the set of candidate slabs for all the items;
- Φ Slab set, $\Phi = \{1, 2, \dots, j, \dots, n\}$;
- φ_j The stack that slab j initial stored in;
- D_j The number of slabs above slab j in φ_j .

Decision variables:

$$X_{ij} = \begin{cases} 1, & \text{if slab } j \text{ is selected for the } i\text{th item,} \\ 0, & \text{otherwise.} \end{cases}$$

S_{ij} Nnumber of shuffles occur if slab j is selected for the i th item.

Based on the above notations, the SSS problem can be formulated as model IP_1.

$$(IP_1) \quad \text{Min} \quad \sum_{i=1}^m \sum_{j=1}^n S_{ij} X_{ij} \quad (1)$$

s. t.

$$\sum_{j \in S_i} X_{ij} = 1 \quad \text{for } i = 1, 2, \dots, M \quad (2)$$

$$\sum_{i=1}^M X_{ij} \leq 1 \quad \text{for } \forall j \in S \quad (3)$$

$$X_{ij} \in \{0, 1\} \quad \text{for } i = 1, 2, \dots, M, j \in S \quad (4)$$

where,

$$S_{ij} = \begin{cases} D_j - 1, & \text{if } R = \emptyset; \\ D_j - \max D_{j'}, & \text{if } R \neq \emptyset; \end{cases} \quad (5)$$

$$\text{in which } R = \left\{ j' \mid \phi_j = \phi_{j'}, D_j > D_{j'}, X_{ij'} = 1, i \in M, j' \in \Phi \right\}$$

In the above model, S_{ij} denotes the shuffles occur when slab j is selected for the i th item. The objective function minimizes the required total shuffle number corresponding to S_{ij} . Constraint (2) ensures that each rolling item is assigned to a slab. Constraint (3) ensures each slab can be chosen for only one item. Constraint (4) defines the range of decision variable. The objective function is nonlinear, which makes the original problem even harder to solve.

3. Integer Programming Model of SSS

To decouple the calculations of shuffle numbers in different stacks, each related stack (the stack has at least one candidate slab in it) will be considered individually.

Definition 1. For any item i , $i \in \{1, 2, \dots, M\}$, and slab $j \in S_i$, we call the binary combination (j, i) a candidate match.

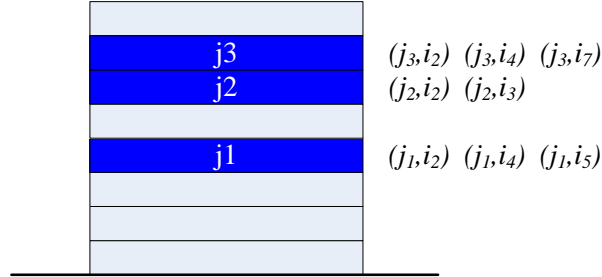
It is clear that for two different candidate matches (j, i) and (j', i') , if $i = i'$ or $j = j'$, then they cannot be adopted simultaneously.

Definition 2. Two different candidate matches (j, i) and (j', i') are *compatible* with each other iff $i \neq i'$ and $j \neq j'$; otherwise, they are *incompatible* with each other.

Let $Sc(\tau) = \{(j, i) \mid \varphi_j = \tau, j \in S_i \text{ and } i = 1, 2, \dots, M\}$ denote the set of candidate matches involving stack τ .

Definition 3. A match set $s \subseteq Sc(\tau)$ is called a *stack-scheme* with respect to stack τ iff $s \neq \emptyset$ and any two candidate matches in s are compatible with each other.

Figure 3: Candidate Matched in Stack τ



For example in Figure 3, three candidate slabs (j_1, j_2, j_3) are in a stack and related to four items in stack τ , such as i_2, i_3, i_5, i_7 . $Sc(\tau) = \{(j_1, i_2), (j_1, i_4), (j_1, i_5), (j_2, i_2), (j_2, i_3), (j_3, i_2), (j_3, i_4), (j_3, i_7)\}$. According to Definition 3, Candidate match sets $\{(j_1, i_2), (j_2, i_3)\}$, $\{(j_2, i_3), (j_3, i_2)\}$ and $\{(j_1, i_5), (j_2, i_3), (j_3, i_4)\}$ are all stack-schemes with respect to the stack τ , but $\{(j_1, i_2), (j_2, i_2)\}$ is not due to the incompatibility between item i_2 which is can not be matched to two slabs.

As implied by formula (5), the net shuffle number in a stack is independent with the situation in other stacks and thus we can individually calculate the needed shuffle number associated with a stack-scheme. Then, a linear model is given as follows:

Parameters:

- Γ Set of stacks;
- $\omega_{\tau s}$ The *shuffle number* of stack-scheme s of stack τ ;
- φ_j The stack that slab j initial stored in;
- D_j The number of slabs above slab j in φ_j ;
- $\Upsilon = \bigcup_{\tau \in \Gamma} Sc(\tau)$ The whole set of candidate stack-schemes;

Variables:

$$x_{\tau s} = \begin{cases} 1, & \text{stack-scheme } s \text{ of stack } \tau \text{ is adopted,} \\ 0, & \text{otherwise.} \end{cases}$$

$$\mu_{i\tau s} = \begin{cases} 1, & \text{stack-scheme } s \text{ of stack } \tau \text{ includes a match corresponding to item } i, \\ 0, & \text{otherwise.} \end{cases}$$

Based on the notations defined above and from the perspective of individual stack, the original model IP_1 can be reformulated as a master problem and a set of subproblems by Danzig-Wolf decomposition. Each subproblem is to make the optimal stack-scheme decision for each stack by enumerate all its stack-schemes

and the master problem is to decide which stack-scheme will be taken as the final optimal scheme. Model IP-2 is the master problem of Danzig-Wolf decomposition.

$$(IP-2) \quad \text{Max} \quad \sum_{\tau \in \Gamma} \sum_{s \in Sc(\tau)} \omega_{\tau s} x_{\tau s}, \quad (6)$$

$$s.t. \quad \sum_{\tau} \sum_{s \in Sc(\tau)} \mu_{i\tau s} x_{\tau s} = 1, \quad \forall i = 1, 2, \dots, M \quad (7)$$

$$\sum_{s \in \varphi(\tau)} x_{\tau s} \leq 1, \quad \forall \tau \in \Gamma \quad (8)$$

$$x_{\tau s} \in \{0, 1\}, \quad \forall \tau \in \Gamma, s \in \varphi(\tau) \quad (9)$$

In model IP_2, the objective (6) is total shuffles, which is virtually the same as the objective (1) of model IP_1. Constraints (7) impose that all the items are assigned to slabs which are included in the stack-schemes adopted. Constraints (8) ensure only one stack-schemes can be adopted from a stack, which also avoid that a slab is assigned to more than one item. Constraints (9) indicate that the decision variables are binary.

A column generation procedure is proposed to solve IP-2.

4. Column Generation Method for SSS

Given an initial feasible solution, IP_2 is known as the restricted master problem in the column generation context. In a column generation method, the subproblem must be able to find stack-schemes of each stack that have negative reduced cost with regard to a given dual solution to the linear relaxation of the restricted master problem. Consider the following dual variables:

π_i dual variables of constraint (2) for item $i = 1, 2, \dots, M$;

ν_{τ} dual variables of constraint (3) for stack $\tau \in \Gamma$;

Using the notations above, the reduced cost $\bar{c}_{\tau s}$ of scheme s in stack τ is given below:

$$\bar{c}_{\tau s} = \omega_{\tau s} - \pi_i \mu_{i\tau s} - \nu_{\tau} \quad (10)$$

Then the subproblem can be described as to find a stack-scheme for each stack with negative or the most negative value of $\bar{c}_{\tau s}$. The schemes with negative reduced cost are added to the master problem. Then a new iteration starts by solving the relaxation of the new master problem and the lower bound is updated to accelerate the search process of the branch-and-bound tree.

At each node of the branch-and-bound tree, we take the column generation procedure iteratively for solving the linear relaxation of the restricted master problem to get its lower bound. At each iteration process, linear relaxation of master problem restricted to a subset of stack-schemes is solved to get dual solutions. Given the dual variables, CG is taken until there is no negative column to add. If no such columns can be found, the current solution is optimal for the restricted master problem. Otherwise, solve the new generated restricted master problem and take CG iteratively until lower bound of the current node is found.

Theorem 1. The optimal objective function value of IP_2 can be viewed as the lower bound of the original integrated problem.

This is evident since the model IP_2 is equivalent to IP_1, and IP_1 formulates a relaxed problem for the original integrated problem.

Besides the lower bound of the original problem, a *slab selection scheme*, which assigns a target slab for each rolling item, can be obtained from the optimal solution to IP_2.

5. Computational Experiments

The proposed column generation algorithm has been developed in Visual Studio.net 2005. It employed the ILog Cplex to resolve the involved ILP model and performed on a PC with Intel Core Duo P8700 CPU and 1.94G RAM.

For testing performance of the proposed algorithm on examples which are of various kinds of scales, 3 groups of instances under different problem configurations are randomly generated. The randomly generated instance has 60 (group 1 and 2) or 90 (group 3) items separately, which is quite the same or even larger than that of practical data.

The slab distribution factor, equal to the ratio of the number of candidate slabs to the stacks that store these slabs, represents the aggregation degree of the candidate slab distributing among stacks. The slab distribution factor can be seen as an average number of candidate slabs in a related stack. Group 1 and 3 have the same slab distribution factor 2, compared with that of Group 2 is 3. The larger slab distribution factor, the more stack-schemes there exist. And also the scale of the model becomes larger which results in a longer computing time for CPU. Experiment results are as follows:

Table 1: Experiment Results on Random Generated Data

Group	Items	Test index	Schemes	Obj	LB	Gap(%)	CPU(s)
1	60	1	1399	35	35	0	14.0
		2	1128	53	53	0	13.9
		3	1659	26	26	0	14.4
2	60	1	10520	56	56	0	22.8
		2	13890	88	88	0	28.0
		3	32878	81	81	0	42.0
3	90	1	1678	56	56	0	25.1
		2	3098	62	62	0	24.8
		3	5003	39	39	0	23.0

Table 1 shows the average experiment results for 3 groups of instances, the instance in a same group are of the same scale. Table shows number of items of each group, average number of stack-schemes (Schemes), objective value (Obj), lower bound (LB), gap (Gap) and CPU-seconds (CPU-s) of each group separately. For testing the practical value of the algorithm proposed, experiments are also tested on real data collected from a large scale steel-iron enterprise in China which is shown in Table 2.

Table 2: Experiment Results on Real Data

Test index	Initial Obj	Obj	LB	Gap (%)	CPU (s)
1	14	10	10	0	0.6
2	42	34	34	0	1
3	16	8	8	0	0.5
4	6	6	6	0	0.1
5	28	28	28	0	1.1
6	48	20	20	0	1
7	30	16	16	0	0.9
8	16	14	14	0	0.5

From the experimental results, we can have the following observations:

- 1) The proposed CG can effectively obtain an optimum solution for the SSS problem.
- 2) The computing time increases with the slab distribution factor. Intuitively, the computing time is influenced by the computational complexity of the IP model, in terms of the number of stack-schemes (i.e. the number of decision variables involved in the model). It is implied by the definition that the number of stack-schemes in each stack increases exponentially with the number of its involved matches, which is tightly tied to both the factors.
- 3) Under the same slab distribution factor, computing time increases with the number of items. That is to say, number of items is another factor that has a direct effects on the scale of the problem.

6. Conclusions

SSS problem is hard for its nonlinear objective function which results from the calculation of shuffle number of different items. For the complexity of SSS, some intelligent algorithms have been taken for near-optimal solutions of SSS in previous research. For linearizing the model of SSS, a concept, *stack-scheme*, is proposed in this paper, which makes it possible to consider shuffle number of each stack individually. The proposition of *stack-scheme* helps to separate the original problem into a master problem and a set of sub-problems by Danzig-Wolf decomposition. As a result, the overlap element in shuffle calculation of SSS is decoupled. Then a branch-and-price algorithm is developed for it. The algorithm is tested on random generated instances and practical instances separately and experiment results proved the effectiveness of the algorithm proposed.

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A Continuous-Time Dynamic Pricing Model Knowing the Competitor's Pricing Strategy

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Abstract

In this paper we consider a dynamic pricing model for a firm knowing that a competitor adopts a static pricing strategy. We establish a continuous time model to analyze the effect of the dynamic pricing on the improvement of revenue in the duopoly market. Suppose that customers arrive to purchase tickets in accordance with a geometric Brownian motion. We derive an explicit closed-form expression for optimal pricing policy to maximize the expected revenue. It is shown that when the competitor adopts a flat rate pricing policy, a dynamic pricing is not always effective in terms of the expected revenue compared to the fixed pricing strategy. Moreover, we show that the size of reduction for expected revenue depends on the competitor's pricing strategy. Numerical results are presented to illustrate the dynamic pricing policy.

Keywords: revenue management; dynamic pricing; competition

1. Introduction

We consider a firm facing the problem of selling inventory by a fixed date, with no ability to reorder and no salvage value for unsold goods. Recently, a number of such firms frequently revise their online prices in response the competitors' as well as to the market conditions and short-term business opportunities. Examples of such a firm are low cost carriers (e.g., Easyjet, Ryanair), high-speed railways in Europe (e.g., TGV, Eurostar), sports teams (e.g., San Francisco Giants of the MLB) and ticket sales company (e.g., Ticketmaster). On the other hand, many firms continue to adopt a static pricing policy in which the multiple prices are determined in advance for different classes, and prices are fixed throughout a sales period. One reason for them to keep the fixed pricing strategy is that the static pricing provides a clear prices to customers and allows to implement the conventional price to protect their yield levels.

Literature related to the problem includes comparative study of the revenues between static and dynamic pricing policies for a monopoly firm (Gallego and van Ryzin 1994, 1997; Koenig and Meissner 2010). Gallego and van Ryzin (1994, 1997) show that if demand as a variable of price is known and there is no constraint on price setting, there exist no great benefits by using the dynamic pricing strategy. Koenig and Meissner (2010) investigate the difference between a list-price capacity control policy and a dynamic pricing policy which considers the cost of price changes. They numerically demonstrate that the list pricing can be a useful strategy when dynamic pricing is costly.

However, because of its flexible nature, dynamic pricing is apparently more effective compared with the static pricing in the price competitive market like online sales. From this point of view, this paper compares the dynamic pricing with the static one to demonstrate how dynamic pricing is effective in competitive market.

There are several papers that discuss dynamic pricing with competition as a game model (Levin et al. 2009, Lin and Sibdari 2008). One common assumption of these studies is that each firm has access to information on

its competitors' remaining capacity. This assumption is unrealistic in the most market.

Even if a firm displays seat availability at the time of booking, it may or may not be accurate if the customer needs to pay additional fees to choose a particular seat. A few papers study a dynamic pricing model under competition without this assumption. Currie et al. (2008) consider a dynamic pricing model which takes into account the competitor's reaction, and show the uniqueness of an optimal pricing policy. In this model, there are two firms in the market and the demand function is influenced by the competitor's price and the time remaining before the end of the sales period.

In our model, the demand function depends not only on the competitor's price, but also on the customer perception for the product offered by each firm. Marcus and Anderson (2008) consider the price competition between full-service carrier and low-cost carrier. On the assumption that the competitor does not respond to the price change, they derive a closed-form optimal pricing policy for low-cost carrier in the case of the deterministic demand. We do not take competitive reaction into consideration and derive an optimal policy in the stochastic demand setting. Xu and Hopp (2006) analyze a dynamic pricing model where the customer arrival rate follow a geometric Brownian motion, and shows a closed-form optimal pricing policy for the monopoly and oligopoly cases. In an oligopoly case, they establish the weak perfect Bayesian equilibrium for the price and inventory replenishment game. Furthermore, they show that the pricing equilibrium is cooperative even in a non-cooperative environment, and that the dynamic pricing is beneficial when there are a few competitors in the market.

We add to the monopoly model of Xu and Hopp (2006) an additional assumption that the customer demand is affected by the competitor's pricing strategy. In this case, an optimal policy can be obtained as a closed-form when the competitor's pricing strategy follows either flat rate, linear increasing or exponential increasing. Moreover, we investigate the effect of the dynamic pricing on the improvement of revenue when the competitor adopts static pricing.

The paper is organized as follows: In Section 2, we formulate a continuous-time dynamic pricing model for a firm, which competes with a firm using static pricing policy. Section 3 discusses three types of competitor's static pricing strategy, namely, constant, linear and exponential to derive a closed-form optimal pricing policy and an optimal ordering quantity. In Section 4, we show some analytical properties for the optimal policy obtained in previous section. Section 5 demonstrates the behavior of the optimal price throughout the sales period with numerical evidence. Finally, the last section concludes the paper with further comments.

2. The Model

There are two firms in the same market, and each firm sells the identical product, respectively. Index $i = 1$ represents own firm and $i = 2$ represents the competitor. Firm 1 orders some products y_0 with ordering cost c_1 at the beginning of the selling season $t = 0$. Let denote T the time of the end of season. At $t \in [0, T]$, firm 1 adjusts sales price based on the real-time inventory level of firm 1, y_t , the number of the customer in the market, x_t , and competitor's price. We denote $p_i(t)$ is the sales price of firm i , $i = 1, 2$, at time t .

We assume that the number of arrivals at time t , X_t , follows a geometric Brownian motion:

$$dX_t = \mu_t X_t + \sigma_t X_t dW_t, \quad X_0 = x \quad (1)$$

where μ_t is the growth rate, dW_t is the increment of a Wiener process, and σ_t is the volatility.

Arrival customers choose either to purchase product or not. The utility of the arrival customers taking product i at price $p_i(t)$ is defined by $U_i(t) = \alpha_i(t) + \epsilon_i(t) - p_i(t)$, where $\alpha_i(t)$ is customer perception and $\epsilon_i(t)$ is the random variable with mean 0. We define $Z_i(t) \equiv \alpha_i(t) + \epsilon_i(t)$ be the customer's preference for product i , and it is random variable with the probability distribution $F_i(\cdot)$. Suppose that arrival customers select a product with large utility, and if their preference is higher than the sales price, then they purchase the product.

Thus, the probability that the customer who arrives at time t purchase product i is given by the joint probability:

$$q_i(t, \mathbf{p}) = P(U_i(t) = \max_{j=1,2} U_j, U_i(t) \geq 0), \quad (2)$$

where $\mathbf{p} = (p_1 \ p_2)$.

Lemma 2.1. Suppose that $Z_i(t)$ has an exponential distribution with mean a_i . Then, the probability $q_i(t, \mathbf{p})$ can be expressed as follows:

$$q_i(t, \mathbf{p}) = e^{-\frac{p_i(t)}{a_i}} \left(1 - \frac{a_j}{a_i + a_j} e^{-\frac{p_j(t)}{a_j}} \right), \quad i \neq j \quad (3)$$

We call the mean a_i the *expected preference*. We assume that the choice of customer is made at an aggregate level, rather than at the individual customer level. Thus, the demand for product of firm 1 at time t is given by

$$D_1(t, \mathbf{p}, x) = q_1(t, \mathbf{p})X(t). \quad (4)$$

Define the information state at time t , (y_t, \mathbf{p}, x_t) . Letting $v(t, y, \mathbf{p}, x)$ denote the expected profit of firm 1 in the information state (y_t, \mathbf{p}, x_t) . Then the expected profit is given by

$$v(t, y, \mathbf{p}, x) = E \left[\int_t^{\hat{t}_{1,p,t,y}} (p_1(u) - c_1) D_1(u, \mathbf{p}, x) du \mid X_t = x \right], \quad (5)$$

where

$$\hat{t}_{1,p,t,y} \equiv \sup \left\{ t \in [s, T] \mid \int_s^t D_i(u, \mathbf{p}, x) du \leq y_s \right\} \quad (6)$$

presents the time when firm 1 runs out of inventory. If $t > \hat{t}_{1,p,t,y}$, we set $p_1(t) = \infty$. Therefore, our objective is to find an optimal price so as to maximize the expected profit function for firm 1:

$$V(t, y, p_2, x) = \sup_{p_1} v(t, y, \mathbf{p}, x). \quad (7)$$

3. Specification of the Competitor's Pricing Strategy and Derivation of an Optimal Policy

In this section, we determine the function of the competitor's pricing strategy $p_2(t)$ and derive an optimal ordering level and optimal pricing policy. The customer compares the price of firm 1 with a lowest available price offered by the competitor on the website. We consider the competitor's price functions for a constant, linear or exponential as follows;

$$p_2(t) = \bar{p}_2, \quad (\text{Constant price}), \quad (8)$$

$$dp_2(t) = g_1 dt, \quad (\text{Linear increasing price, } g_1 > 0), \quad (9)$$

$$dp_2(t) = g_2 p_2(t) dt, \quad (\text{Exponential increasing price, } g_2 > 0) \quad (10)$$

Here, we assume that the competitor's initial price of the linear and exponential is lower than the constant price, $p_2(0) < \bar{p}_2$. The following theorem provides a closed-form expression for an optimal pricing policy for firm 1.

Theorem 3.1. *If the information state (y_t, \mathbf{p}, x_t) and the competitor's pricing strategy is a constant, linear or exponential, then we have:*

(i) *The optimal price for firm 1 at time t is given by*

$$p_1^*(t, y, p_2, x) = a_1 \log \left(\frac{x_t}{y_t} m_1(t, p_2) \right), \quad (11)$$

where

$$m_1(t, p_2) = \int_t^T e^{\int_t^u \mu_l - \frac{1}{2}\sigma_l^2 dl} \left(1 - \frac{a_2}{a_1 + a_2} e^{-\frac{p_2(u)}{a_2}} \right) du. \quad (12)$$

(ii) *The maximum of the expected profit from t to T can be obtained as the product of inventory level and optimal profit of selling one product at time t :*

$$V(t, y, p_2, x) = y_t (p_1^*(t, y, p_2, x) - c_1). \quad (13)$$

(iii) *An optimal inventory level at time t is given by*

$$y_t^* = y_0 \frac{m_1(t, p_2)}{m_1(0, p_2)} \exp \left\{ \int_0^t \left(\mu_u - \frac{1}{2}\sigma_u^2 + \frac{m_2(u, p_2)}{(a_1 + a_2)m_1(u, p_2)} \right) du \right\}, \quad (14)$$

where

$$m_2(t, p_2) = \int_t^T e^{\int_t^u \mu_l - \frac{1}{2}\sigma_l^2 dl - \frac{1}{a_2} p_2(u)} p_2'(u) du. \quad (15)$$

Moreover, the inventory level vanishes at time T , that is, $y_T^* = 0$.

Proposition 3.1. *The expected profit of firm 1 is reduced by the existence of the competitor, and the amount of the reduction is given by*

$$V(0, y, p_2, X) - V(0, y, \infty, X) = a_1 y \log \left(1 - \frac{a_2}{a_1 + a_2} \frac{\int_0^T e^{\int_0^u \mu_l - \frac{1}{2}\sigma_l^2 dl - \frac{1}{a_2} p_2(u)} du}{\int_0^T e^{\int_0^u \mu_l - \frac{1}{2}\sigma_l^2 dl} du} \right) < 0, \quad (16)$$

where $V(0, y, \infty, X)$ represents the expected profit for firm 1 when there is no competitor in the market.

Theorem 3.2. *At time $t = 0$, an optimal ordering quantity $y_0^* \equiv \operatorname{argmax}_y E[V(0, y, p_2, X)]$ is given by*

$$y_0^* = m_1(0, p_2) e^{E[\log(X_0)] - 1 - \frac{c_1}{a_1}}. \quad (17)$$

Moreover, the maximum profit taking into account of ordering can be expressed in terms of the product of the expected preference and optimal order quantity:

$$\Phi^* = E[V(0, y^*, p_2, X)] = a_1 y_0^*. \quad (18)$$

Proposition 3.2. *The optimal ordering quantity for firm 1 when the competitor exists is lower than the one when there is no competitor exist in the market.*

4. Properties for Optimal Policy

In this section, we provide some analytical properties for the optimal pricing policy and expected values. We assume that the drift and volatility of the arrival process X_t are constant, $\mu_t = \mu$ and $\sigma_t = \sigma$. Thus, the solution to the equation (1) is given by

$$X_t = X_0 \exp \left\{ \left(\mu - \frac{1}{2} \sigma^2 \right) t + \sigma W_t \right\}. \quad (19)$$

Suppose that the notations $\{C\}$, $\{L\}$, $\{E\}$ represent a competitor's constant, linear and exponential pricing policy, respectively.

Proposition 4.1. *The monotone properties for p_1^* , y^* , V and Φ^* are given in Table 1.*

Table 1: Effect of Parameters on Optimal Values (\uparrow : Increasing, \downarrow : Decreasing.)										
	μ	σ	T	c_1	a_1	a_2	$p_2(0)$	\bar{p}_2	g_1	g_2
V, Φ^*, y_0^*	\uparrow	\downarrow	\uparrow	\downarrow	\uparrow	\downarrow	\uparrow	\uparrow	\uparrow	\uparrow
p^*	\uparrow	\downarrow	\uparrow	----	\uparrow	\downarrow	\uparrow	\uparrow	\uparrow	\uparrow

In order to compare the effect of the competitor's pricing strategy on the expected profit for firm 1, we define the following notations:

- $V^M \equiv V(0, y, \infty, X)$: Firm 1 is monopoly in the market.
- $V^C \equiv V(0, y, \bar{p}_2, X)$: Competitor's pricing policy is constant.
- $V^L \equiv V(0, y, p_2, X)$: Competitor's pricing policy is linear increasing.

Proposition 4.2. *The relationship between the expected profits of firm 1 for each case can be obtained as*

$$V^L < V^C < V^M. \quad (20)$$

Moreover, the relationship between the optimal ordering quantities are given by

$$y_L^* < y_C^* < y_M^*. \quad (21)$$

Next, we analyze the comparison between the dynamic pricing and static pricing policies for firm 1.

When firm 1 and firm 2 sell at a flat rate \bar{p}_1 and \bar{p}_2 , respectively, the expected profit for firm 1 with an initial inventory level y is given by

$$\tilde{V}(y, \bar{\mathbf{p}}) = (\bar{p}_1 - c_1) E \left[\min \left\{ y, \int_0^T D_1(u, \bar{\mathbf{p}}, x) du \right\} \right], \quad (22)$$

where $\bar{\mathbf{p}} = (\bar{p}_1 \ \bar{p}_2)$.

Lemma 4.1. *There exists a unique \bar{p}_1^* such that $\bar{p}_1^* \equiv \arg \max_{\bar{p}_1} \tilde{V}(y, \bar{\mathbf{p}})$. In addition, the maximal expected profit is given by*

$$\tilde{V}(y, \bar{p}_2) = \max_{\bar{p}_1} \tilde{V}(y, \bar{\mathbf{p}}) = \frac{(\bar{p}_1^* - c_1)^2 y}{\bar{p}_1^* - c_1 - a_1} \bar{N}(J(\bar{p}_1^*)), \quad (23)$$

where $N(\cdot)$ is the distribution function of random variable $M_T \equiv \int_0^T X_t dt$, $\bar{N}(\cdot) = 1 - N(\cdot)$ and

$$J(\bar{p}_1^*) = ye^{\frac{\bar{p}_1^*}{a_1}} \left(1 - \frac{a_2}{a_1 + a_2} e^{-\frac{\bar{p}_2}{a_2}} \right)^{-1}. \quad (24)$$

Theorem 4.1. *When the competitor adopts constant pricing policy, the constant pricing policy is favorable against a dynamic pricing policy, $V^C < \tilde{V}(y, \bar{p}_2)$, if and only if*

$$p_1^*(0, y, p_2, x) - c_1 < (\bar{p}_1^* - c_1) P \left(\int_0^T D_1(u, \bar{p}_1^*, \bar{p}_2, x) du \geq y \right). \quad (25)$$

Theorem 4.1 implies that the firm1 should be selected a constant pricing policy when the profit of selling one product with dynamic pricing policy at time 0 is less than the expected gain from using a constant pricing policy.

5. Numerical Examples

In this section, we show the optimal price and inventory paths for a sample arrival path when the competitor's price policy is exponential. We set $a_1 = 75$, $a_2 = 80$, $y = 100$, $X_0 = 1$, $\mu = 0.002$, $\sigma = 0.015$, $g_2 = 0.004$, $p_2(0) = 50$ and $T = 300$. Figure 1 shows the optimal price for firm1 throughout the selling period, and the corresponding inventory level is shown in Figure2. We can see that the optimal price of firm 1 is lower than the competitor's static price except for the last time of the selling season. It is due to the expected preference of a product produced by the competitor is larger than the one of firm 1, $a_1 < a_2$. From Figure 2, the inventory level hits 0 at the end of selling season. It is consistent with Theorem 3.1 (iii).

Figure 1: Optimal Price and the Competitor's Price during the Selling Season

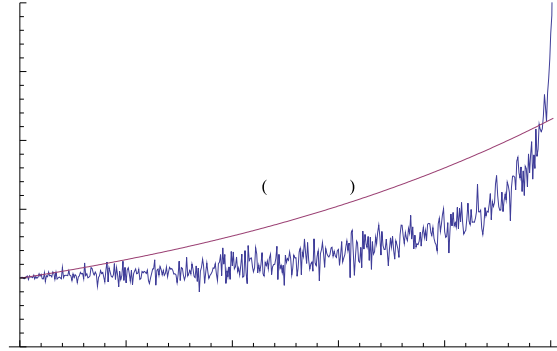
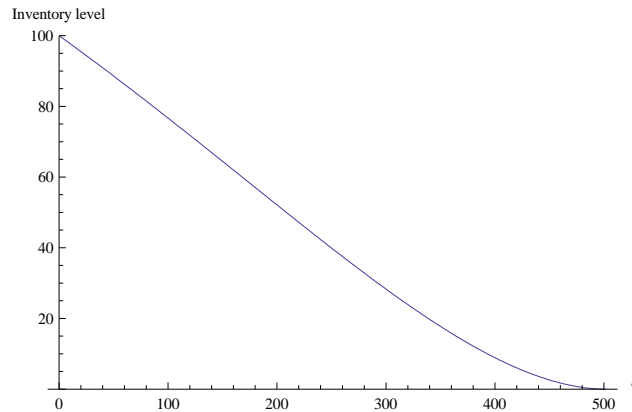


Figure 2: Inventory Level during the Selling Season



6. Conclusions

In this paper, we consider a continuous time dynamic pricing problem while a competitor adopts a static pricing policy. A closed-form optimal pricing policy is derived and the sensitive analysis of the optimal policy is investigated. By comparing the competitive case with the monopoly case, we show how the dynamic pricing affects on the firm's revenue. Moreover, we show a condition in which the dynamic pricing is more effective than the constant pricing policy when the competitor adopts the constant pricing policy.

As the future research, we wish to investigate what condition is needed for dynamic pricing to be favorable for a linear pricing policy. The other path for further research is to analyze the effect of a dynamic pricing when the competitor applies a linear pricing policy. In addition, it is of interest to extend it to the case that the competitor's price follows a stochastic process. This extension allows us to deem the competitor's price to be the lowest offered by multiple firms in a natural way. Finally, we also wish to explicitly incorporate the strategic customer behavior that customers wait their purchase in anticipation of future discount.

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The Simultaneous Reshuffle and Yard Crane Scheduling Problem in Container Terminals

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Abstract

This paper studies the simultaneous reshuffle and yard crane scheduling problem in the yard of container terminals, which is one of the key logistics problems affecting the operation efficiency in container terminals. Although the reshuffle scheduling problem has received many research attention due to its importance, the problem without considering yard crane is not very practical, which is because the shuffle process needs yard crane to carry out, and the improper yard crane scheduling will weaken the optimized shuffle planning, therefore the reshuffle and yard crane scheduling should be considered simultaneously. The problem in this paper is to choose appropriate objective locations for the reshuffled containers and obtain the picking up sequence for all the containers on the yard crane, with the objective to reduce the sum of the total completion time for all the containers and the reshuffling time for all the reshuffled containers. A mixed integer model is proposed for the problem. A Particle Swarm Optimization (PSO) algorithm is employed to obtain near optimal solutions of the problem. The experiment results show that the solutions of the simultaneous scheduling problem are better than the results obtained by solving the reshuffle scheduling problem and the yard crane scheduling problem, respectively.

Keywords: yard crane, reshuffle, PSO, simultaneous scheduling problem

1. Introduction

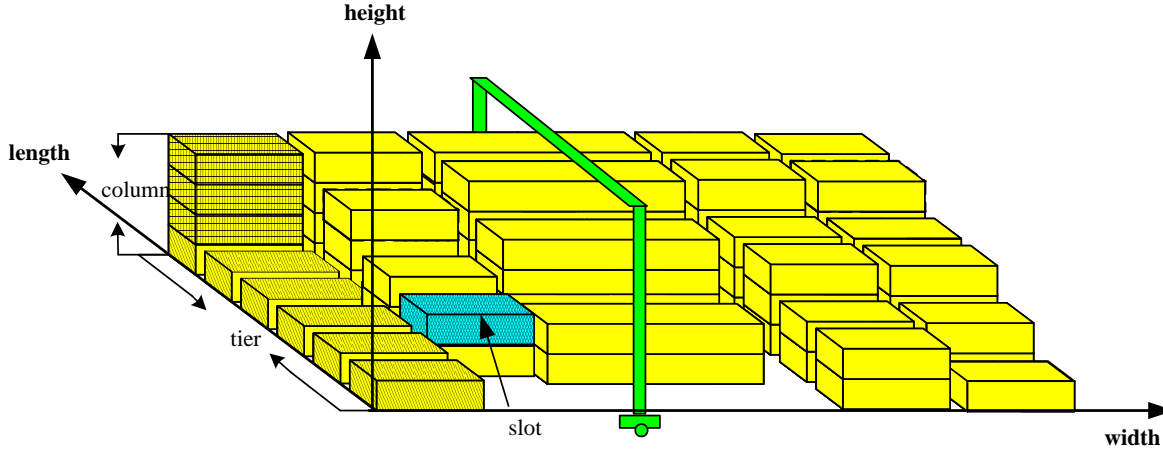
Container trade worldwide increases steadily in recent years, and the container yard have to stack more and more containers. To cope with the growth of container trade, it is important to utilize the limited equipments and resources, for example, yard cranes and yard space. Because the limit of the yard storage space and the difference between the arrival sequence and retrieve sequence of containers, the reshuffle often happened. When ships with unloaded containers arrive at container terminals, the containers have to be unloaded from the ships by quay cranes, and transported to yard and waiting for external truck to take away. If the container to be retrieved earlier is under some containers that will be retrieved latter, these upper containers have to be moved to other positions, and then the container can be retrieved, it is said that reshuffle happened. The reshuffle operation is unproductive moves and should be avoided.

Figure 1 is an example of a container block with a yard crane. A tier is consisted by the containers with the same height, and a column is consisted by the containers with the same width. A container position means a slot. A bay only can be served by one yard crane in the same time because of the width limit of the bay.

The reshuffle scheduling problem and the yard crane scheduling problem are often researched separately in the pervious literatures, it is not very practical because the reshuffle operation are carried out by yard cranes. In the simple yard crane scheduling problem, reshuffles between containers may often happen, it is because that the retrieve sequence is decided without considering the feasibility in practice (Ng and Mak, 2005). For example, the real storing location of retrieved container is under some other containers which is retrieved latter than this container. Therefore, the study on the simultaneous reshuffle and yard crane scheduling problem is helpful to improve the productivity of container terminals.

In this paper, we model the reshuffle and yard crane scheduling problem in container terminals to minimize the sum of the total completion time for all the containers and the reshuffling time which helps to improve the efficiency for container terminals. The solution of the reshuffle and yard crane scheduling problem will decide the sequence for all the containers to be retrieved and the completion time for each container, as well as the position that each blocking container to be moved to. A PSO algorithm is developed to solve the problem.

Figure 1: An Example of a Container Block with a Yard Crane



This paper is organized as follows. Section 2 gives a brief review of previous literatures related to reshuffle scheduling problem and yard crane scheduling problem in container terminals. The problem description is given in Section 3, and the model of the simultaneous reshuffle and yard crane scheduling problem is presented in this section. Section 4 describes the PSO algorithm for the simultaneous scheduling problem. Section 5 reports the experiments results of the simultaneous scheduling problem, as well as the results of the reshuffle scheduling problem and the yard crane scheduling problem solved separately. Finally, Section 7 gives the conclusions.

2. Literature Review

Due to the significance of reshuffle in container terminals, it has received much research attention. Kim (1997) estimates the expected number of reshuffles when picking up a random container and the total number of reshuffles to retrieve all the containers in a bay with given configuration, and he proposed a methodology to obtain the results. The weights of containers are considered by Kim *et al.* (2000) to decide the storage location for each arrival export container. In their research, containers are divided into three kinds, heavy, medium and light, and the heavier containers should be loaded onto ships earlier. A dynamic programming model with the objective to minimize the expected number of reshuffles for loading operation is presented in their paper. Wan *et al.* (2009) studies the assignment of storage locations to containers in a stack with the objective to minimize the total number of reshuffle.

There are many algorithms to solve the reshuffle scheduling problem, for example, Kim and Hong (2006) propose a branch and bound algorithm and a heuristic algorithm ENAR to minimize the number of reshuffles and determine the storage positions for reshuffled containers. Kang *et al.* (2006) present a method based on a simulated annealing search to obtain a good stacking strategy for containers with uncertain weight information, and experiments results show that the method is more effectively to reduce the number of reshuffles compared to the traditional same-weight-group-stacking strategy. The reshuffling index heuristic is proposed by Murty *et al.* (2005) to determine a storage position with the objective to minimize the possible caused number of reshuffle. The scheduling problem of equipment in yard have been researched by Kim and Kim (2003), Laik and Hadjiconstantinou (2008), and Li *et al.*

There are several literatures that both considered the scheduling sequence and reshuffle scheduling. Meisel

and Wichmann researched the container sequencing problem for quay cranes with internal reshuffles for unloading containers in the arriving ship (2010). The simultaneous stowage and load planning for a container ship with container rehandle in yard stacks is researched by Imai et al. (2006), but they considered the stowage and load planning, the crane scheduling has not been researched.

Yard crane is one of the most important equipment to handle containers to storage in the yard or transfer the containers onto trucks to be transported. Ng and Mak (2005) studies the scheduling problem with a single yard crane, and there are some certain containers with different ready times have to be processed. The handling sequence of all the containers processed are needed to determined to minimize the total waiting time of the external trucks.

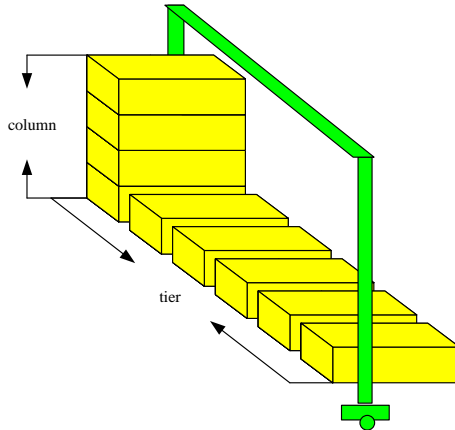
3. Problem Description and Formulation

3.1. Problem Description

In this problem, the configuration of the stack is known in advance, it means that the indexes of column and tier for each container is obtained. The elements to be determined are the retrieval sequence for all the containers in a certain stack and the objective locations for reshuffled containers, with the objective to minimize the sum of the total completion time for all the containers and the reshuffling time for all the blocking containers. An example of a container stack with a yard crane is shown in Figure 2.

In previous researches, the reshuffle scheduling problem and the yard crane scheduling problem are often studied separately. In the yard crane scheduling problem, the situation of reshuffle is usually ignored (Ng and Mak, 2005) or transformed into certain time and did not decide the retrieval sequence for containers, and in the reshuffle scheduling problem, the retrieval sequence for containers are considered as known (Wan *et al.*, 2009). In this paper, we study the two problems simultaneously and decided the retrieval sequence for all the containers and the objective locations for the reshuffled containers, which not only make the total completion time for all the containers earliest, but also minimize the reshuffling time for all the blocking containers.

Figure 2: An Example of a Container Stack with a Yard Crane



3.2. The model for the simultaneous reshuffle and yard crane scheduling problem

The reshuffle scheduling problem in container terminals was studied by Wan et al. (2009), in which the retrieve sequence was assumed as given information; and the yard crane scheduling problem has been researched by Ng and Mak (2005), and the reshuffle has not been considered in their paper. Considering on the relationship between the above two problem and the models of the above two literatures, we formulate the model of the simultaneous scheduling problem, and the following symbols are used for defining the parameters and variables.

Parameters:

- N – The number of containers will be retrieved;
- C – The number of columns in a stack;
- P – The number of tiers in a stack;
- i, j – The index of container;
- d_{ij} – The traveling time for yard crane from container i to container j ;
- h_i – The handling time of container i ;
- r_i – The ready time of external truck for container i ;

Decision variables:

- t_i – The completion time of container i ;
- s_i – The retrieving sequence of container i , $s_i=1, \dots, N$;
- $X_{ij} = \begin{cases} 1 & \text{if container } i \text{ is handled before container } j \\ 0 & \text{otherwise} \end{cases}$
- $x_{s_i, j, c, p} = \begin{cases} 1 & \text{if container } j \text{ is at positon } p \text{ of column } c \text{ when retriving container } s_i \\ 0 & \text{otherwise} \end{cases}$
- $u_{s_i, j} = \begin{cases} 1 & \text{if the column index of container } j \text{ is no less than that of container } s_i \\ 0 & \text{otherwise} \end{cases}$
- $v_{s_i, j} = \begin{cases} 1 & \text{if the column index of container } j \text{ is no greater than that of container } s_i \\ 0 & \text{otherwise} \end{cases}$
- $z_{s_i, j} = \begin{cases} 1 & \text{if containers } j \text{ and } s_i \text{ are in the same column} \\ 0 & \text{otherwise} \end{cases}$
- $y_{s_i, j} = \begin{cases} 1 & \text{if container } j \text{ is shuffled in the retrieval of container } s_i \\ 0 & \text{otherwise} \end{cases}$
- $w_{s_i, j, k} = \begin{cases} 1 & \text{if containers } j \text{ and } k \text{ are shuffled when retrieving container } s_i \\ & \text{and container } k \text{ is at a higher position than container } j \text{ before reshuffling} \\ 0 & \text{otherwise} \end{cases}$

Based on the definition of the parameters and variables, we give the model as follows:

$$\text{Min} \sum_{i=1}^N t_i + \sum_{s=1}^{N-1} \sum_{i=s+1}^N \alpha y_{s,i} \quad (1)$$

s.t.

$$r_i + h_i \leq t_i \quad i = 1, 2, \dots, N \quad (2)$$

$$t_j - t_i \geq d_{ij} + h_j - (1 - X_{ij})M \quad i, j = 1, 2, \dots, N \text{ and } i \neq j \quad (3)$$

$$X_{ij} + X_{ji} = 1 \quad i, j = 1, 2, \dots, N \text{ and } i \neq j \quad (4)$$

$$X_{ij} \in \{0, 1\} \quad i, j = 1, 2, \dots, N \text{ and } i \neq j \quad (5)$$

$$\sum_{j=1, j \neq i}^N X_{ij} = N - s_i \quad i, j = 1, 2, \dots, N \text{ and } i \neq j \quad (6)$$

$$Cu_{s_i, j} \geq \sum_{c=1}^C \sum_{p=1}^P cx_{s_i, j, c, p} - \sum_{c=1}^C \sum_{p=1}^P cx_{s_i, s_i, c, p} + 1 \quad 1 \leq s_i < j \leq N, 1 \leq i \leq N \quad (7)$$

$$Cu_{s_i, j} - C \leq \sum_{c=1}^C \sum_{p=1}^P cx_{s_i, j, c, p} - \sum_{c=1}^C \sum_{p=1}^P cx_{s_i, s_i, c, p} \quad 1 \leq s_i < j \leq N, 1 \leq i \leq N \quad (8)$$

$$Cv_{s_i, j} \geq \sum_{c=1}^C \sum_{p=1}^P cx_{s_i, s_i, c, p} - \sum_{c=1}^C \sum_{p=1}^P cx_{s_i, j, c, p} + 1 \quad 1 \leq s_i < j \leq N, 1 \leq i \leq N \quad (9)$$

$$Cv_{s_i,j} - C \leq \sum_{c=1}^C \sum_{p=1}^P cx_{s_i,s_i,c,p} - \sum_{c=1}^C \sum_{p=1}^P cx_{s_i,j,c,p} \quad 1 \leq s_i < j \leq N, 1 \leq i \leq N \quad (10)$$

$$z_{s_i,j} = u_{s_i,j} + v_{s_i,j} - 1 \quad 1 \leq s_i < j \leq N, 1 \leq i \leq N \quad (11)$$

$$y_{s_i,j} \geq z_{s_i,j} - 1 + (\sum_{c=1}^C \sum_{p=1}^P px_{s_i,j,c,p} - \sum_{c=1}^C \sum_{p=1}^P px_{s_i,s_i,c,p}) / P \quad 1 \leq s_i < j \leq N, 1 \leq i \leq N \quad (12)$$

$$y_{s_i,j} \leq z_{s_i,j} \quad 1 \leq s_i < j \leq N, 1 \leq i \leq N \quad (13)$$

$$(\sum_{c=1}^C \sum_{p=1}^P px_{s_i,s_i,c,p} - \sum_{c=1}^C \sum_{p=1}^P px_{s_i,j,c,p}) / P \leq 1 - y_{s_i,j} \quad 1 \leq s_i < j \leq N, 1 \leq i \leq N \quad (14)$$

$$\sum_{c=1}^C \sum_{p=1}^P x_{s_i,j,c,p} = 1 \quad 1 \leq s_i < j \leq N, 1 \leq i \leq N \quad (15)$$

$$\sum_{j=s_i}^N x_{s_i,j,c,p} \leq 1 \quad 1 \leq s_i \leq N, 1 \leq c \leq C, 1 \leq p \leq P \quad (16)$$

$$\sum_{j=s_i}^N x_{s_i,j,c,p} \leq \sum_{j=s_i}^N x_{s_i,j,c,p-1} \quad 1 \leq s_i \leq N, 1 \leq c \leq C, 2 \leq p \leq P \quad (17)$$

$$\sum_{p=1}^P x_{s_i+1,j,c,p} \leq 2 - y_{s_i,j} - \sum_{p=1}^P x_{s_i,s_i,c,p} \quad 1 \leq s_i < j \leq N, 1 \leq c \leq C \quad (18)$$

$$2 - y_{s_i,j} - y_{s_i,k} + w_{s_i,j,k} \geq (\sum_{c=1}^C \sum_{p=1}^P px_{s_i,k,c,p} - \sum_{c=1}^C \sum_{p=1}^P x_{s_i,j,c,p}) / P \quad 1 \leq s_i < j \leq N, 1 \leq s_i < k \leq N, j \neq k \quad (19)$$

$$y_{s_i,j} + y_{s_i,k} + w_{s_i,j,k} \leq 3 + (\sum_{c=1}^C \sum_{p=1}^P px_{s_i,k,c,p} - \sum_{c=1}^C \sum_{p=1}^P x_{s_i,j,c,p}) / P \quad 1 \leq s_i < j \leq N, 1 \leq s_i < k \leq N, j \neq k \quad (20)$$

$$w_{s_i,j,k} \leq y_{s_i,j} \quad 1 \leq s_i < j \leq N, 1 \leq s_i < k \leq N, j \neq k \quad (21)$$

$$w_{s_i,j,k} \leq y_{s_i,k} \quad 1 \leq s_i < j \leq N, 1 \leq s_i < k \leq N, j \neq k \quad (22)$$

$$\sum_{p=1}^P px_{s_i+1,j,c,p} - \sum_{p=1}^P px_{s_i+1,k,c,p} \geq -P(1 - w_{s_i,j,k}) - P(1 - y_{s_i,j}) - P(1 - y_{s_i,k}) - P(1 - \sum_{p=1}^P x_{s_i+1,j,c,p}) \quad 1 \leq s_i < j, k \leq N, j \neq k, 1 \leq c \leq C \quad (23)$$

$$x_{s_i+1,j,c,p} - x_{s_i,j,c,p} \geq -y_{s_i,j} \quad 1 \leq s_i < j \leq N, 1 \leq c \leq C, 1 \leq p \leq P \quad (24)$$

$$x_{s_i,j,c,p} - x_{s_i+1,j,c,p} \geq -y_{s_i,j} \quad 1 \leq s_i < j \leq N, 1 \leq c \leq C, 1 \leq p \leq P \quad (25)$$

$$x_{1,j,c,p} = X_{1,j,c,p} \quad 1 < j \leq N, 1 \leq c \leq C, 1 \leq p \leq P \quad (26)$$

$$x_{s_i,j,c,p} = X_{1,j,c,p} \quad 2 \leq s_i \leq \min\{j, l_{s_i}\}, s_i \leq j \leq N, 1 \leq c \leq C, 1 \leq p \leq P \quad (27)$$

$$u_{s_i,j}, v_{s_i,j}, w_{s_i,j,k}, y_{s_i,j}, \text{ and } z_{s_i,j} \in \{0, 1\} \quad 1 \leq s_i < j, k \leq N, j \neq k, 1 \leq c \leq C, 1 \leq p \leq P \quad (28)$$

$$x_{s_i,j,c,p} \in \{0, 1\} \quad 1 \leq s_i \leq j \leq N, 1 \leq c \leq C, 1 \leq p \leq P \quad (29)$$

Formula (1) is the objective to minimize the sum of the total completion time for all the containers and the total time of reshuffle. Constraints (2) is the definition of variable t_i , and describes the relationship between the completion time, ready time and handling time of each container. Constraints (3), (4) and (5) define variable X_{ij} , and guarantee the precedence relationship between different containers. Constraints (6) give the relationship between X_{ij} and s_i , and it defines the retrieving sequence for container i . Constraints (7) and (8) defined the variable $u_{s_i,j}$, if $\sum_{c=1}^C \sum_{p=1}^P cx_{s_i,j,c,p} - \sum_{c=1}^C \sum_{p=1}^P cx_{s_i,s_i,c,p} + 1 \geq 0$, and constraints (7) make $u_{s_i,j}$ to be 1. If

$\sum_{c=1}^C \sum_{p=1}^P cx_{s_i,j,c,p} - \sum_{c=1}^C \sum_{p=1}^P cx_{s_i,s_i,c,p} < 0$, and constraints (8) make $u_{s_i,j}$ to be 0. Constraints (9) and (10) defined the variable

$v_{s_i,j}$. if $\sum_{c=1}^C \sum_{p=1}^P cx_{s_i,s_i,c,p} - \sum_{c=1}^C \sum_{p=1}^P cx_{s_i,j,c,p} \geq 0$, and constraints (9) make $v_{s_i,j}$ to be 1. If $\sum_{c=1}^C \sum_{p=1}^P cx_{s_i,s_i,c,p} - \sum_{c=1}^C \sum_{p=1}^P cx_{s_i,j,c,p} < 0$, and

constraints (10) make $v_{s_i,j}$ to be 0. Constraints (11) defined the variable $z_{s_i,j}$, if container s_i and container j are in the same column, then $z_{s_i,j}=1$. Constraints (12), (13) and (14) defined the variable $y_{s_i,j}$, if $z_{s_i,j}=1$ and container j is laid higher than container s_i , then constraints (12) make $y_{s_i,j}=1$. If $z_{s_i,j}=0$, it means that container j and container s_i are in the different column, then constraints (13) make $y_{s_i,j}=0$. if $z_{s_i,j}=1$ and container j is laid lower than container s_i , then constraints (14) make $y_{s_i,j}=0$. Constraints (15) ensure that each container can only be at one slot. Constraints (16) ensure that each slot can only be occupied by at most

one container when retrieving any container. Constraints (17) ensure that any one container can not float in air, there must be one or more container below it or it touch the ground. Constraints (18) ensure that one container must be reshuffled to another column which is not the column the container is at when retrieving container s_i . Constraints (19) - (22) defined the variable $w_{s_i, j, k}$. Constraints (23) describe the height relationship of containers j and k when retrieving container s_i . Constraints (24) and (25) describe the relationship of variables $x_{s_i, j, c, p}$ and $y_{s_i, j}$. Constraints (26) and (27) assign known values to variable $x_{s_i, j, c, p}$. Constraints (27) means that the container that has not to be reshuffled, it will stay at the initial position until being retrieved. Constraints (28) and (29) are binary constraints.

Now we take an example in the literature of Ng and Mak (2005) and give locations for each container to illustrate the simultaneous reshuffle and yard crane scheduling problem. For example, there are six containers have to be retrieved from the yard and transported by external trucks, and one yard crane is available in the stack. The bay number of these containers and the arrival time of external trucks waiting for these containers are shown in Table 1.

Table 1. The Information of Containers

Container no.	Location (column, tier)	r_i	h_i
1	1,1	2	4
2	2,2	5	4
3	2,1	7	4
4	3,1	13	4
5	1,2	15	4

A feasible solution of the example is shown in Table 2.

Table 2. The Result of the Example

Container no.	Sequence on crane	Reshuffle or not	The location after reshuffle (column, tier)	t_i
1	1	no	/	6
2	5	yes	(4,1)	35
3	2	no	/	11
4	3	no	/	17
5	4	yes	4,1	24

4. PSO algorithm

PSO (Particle swarm optimization) is first proposed by Eberhart and Kennedy (1995), which is a kind of stochastic and swarm intelligence-based optimization algorithm, and with the advantage of fast convergence speed and the less setting parameters. PSO algorithm is effective to solve scheduling problems (Ching *et al.*, 2007), and the simultaneous reshuffle and yard crane scheduling problem is a practical scheduling problem in container terminals. The practical problem usually has to be solved quickly, and the PSO algorithm is with the advantage of converging fast. Therefore, we adopt PSO algorithm to solve the simultaneous scheduling problem in this paper.

The common formulations for updating velocity and position is as bellowed:

$$v_{ik}^{t+1} = v_{ik}^t + c_1 r_1 (x_{pbest_{ik}}^t - x_{ik}^t) + c_2 r_2 (x_{gbest_{ik}}^t - x_{ik}^t) \quad (30)$$

$$x_{ik}^{t+1} = x_{ik}^t + v_{ik}^t \quad (31)$$

In the formulations (30) and (31) v_{ik}^t and x_{ik}^t represent the velocity and the position of the i th particle on k th dimension in the t th iteration, respectively. c_1 and c_2 are acceleration weights, r_1 and r_2 are generated in $[0, 1]$ randomly. $x_{pbest_{ik}}^t$ is the best position of the i th particle on k th dimension in the t th iteration, and $x_{gbest_k}^t$ is the best position of the global best particle on k th dimension in the t th iteration, from above we can see that, PSO is concerned to the own position of the particle and the positions of the whole swarm.

4.1. Initial particles generation and solution representation

We generate the initial population randomly to assure the diversity of the particles.

The problem in this paper is to decide the retrieval sequence of all the containers and the objective locations of the reshuffled containers in the stack. The retrieval sequence of all the containers can be done independently. Therefore in the proposed PSO we use a particle to represent the retrieval sequence of all the containers. Because there are N containers in total, we define a particle as an N -dimensional vector. The i^{th} element of the N -dimensional vector, X_i , indicates the retrieval sequence of container i .

Corresponding to each particle is an retrieval sequence of containers. We now present a method to obtain a retrieval sequence of containers. Let R be the set of values of X_i in the particle. We rank the containers in R in non-decreasing order of their value of X_i , and then obtain a set R' and the retrieval sequence of containers.

With the obtained retrieval sequence a simple heuristic is proposed to decide the objective locations for all the reshuffled containers. The detail procedure is as follows.

- Step 1:** $i=1$. For the container i in R' , if there is any container j ($j=1,2,\dots,N$ and $j \neq i$) which is in the same column with container i and is in the upper tier than container i , go to step 2.
- Step 2:** If there are some empty locations, select one empty location randomly and lay container j there. Otherwise, find one container of which the retrieval sequence is bigger than container j , randomly, and lay the reshuffled container on this container, then the second reshuffle of container j can be avoided.
- Step 3:** If there is any container k ($j=1,2,\dots,N$ and $j \neq i$) which is in the same column with container i and is in the upper tier than container i , go to step 2; Otherwise, go to step 4.
- Step 4:** If all containers in R' are considered, stop; Otherwise, $i+1$ and go to step 1.

4.2. Velocity updating strategy

The major merit of PSO algorithm is that it has very fast speed to converge, but accordingly the major fault of PSO algorithm is that it is easy to fall into the local optimal solution. This is because particle only flies towards the best position it has reached and the global best position of all the particles. The problem in this paper is for scheduling and it is suitable to be solved by PSO algorithm. Nevertheless the problem itself is hard to solve and the short of PSO, it is difficult to find the better solutions by the standard PSO algorithm. For this reason, Shi and Eberhart (1998) proposed the idea of inertia weight, and modified the velocity update formulation as below:

$$v_{ik}^{t+1} = w' v_{ik}^t + c_1 r_1 (x_{pbest_{ik}}^t - x_{ik}^t) + c_2 r_2 (x_{gbest_k}^t - x_{ik}^t) \quad (32)$$

In the formulation (32), the coefficient w' is the inertia weight, and $w' = \frac{wt_{\max} - t}{wt_{\max}} (wt_{\max} - wt_{\min}) + wt_{\min}$, where wt_{\max} and wt_{\min} are the biggest and the smallest value of the inertia weight. In this paper, we adopt formula (32) to update the velocity in PSO algorithm.

Generally, PSO algorithm converge fast, but it is easy to be trapped into a local optimum. This is because each particle flies based on its reached best position and the global best position of all the particles. We add a

disturbance strategy to the PSO algorithm to overcome this drawback. We initialize λ particles of the particles when the best solution has not been updated after γ iterations.

The detailed method is as followed: when the best solution has not been updated after some iterations, we select several particles randomly, and initialize them again. If the new solution of the particle is better than its current solution, accept the new position value of the particle, and update the best position of the particle; otherwise, remain the current position of the particle.

4.3. Construction of PSO algorithm

In this paper, the PSO procedure to solve the simultaneous reshuffle and yard crane scheduling problem is as below:

Step1. Initialize L particles as a swarm. Set iteration number $\tau = 1$.

Step2. For $l=1, 2, \dots, L$, encode a set of container R, and obtain the retrieval sequence for all the containers in the stack. Then find the shuffled containers and reshuffling time based on the retrieval sequence.

Step3. For $l=1, 2, \dots, L$, calculate the fitness value, which is equal to that the sum of the completion time for all the containers and the total reshuffling time.

Step4. Update pbest which is the best position of every particle.

Step5. Update gbest which is the best position of the swarm.

Step6. Update the velocity and the position of each particle.

Step7. If $\tau = \gamma$, select λ particles, and initialize them. If the new solution of the particle is better than its current best solution, update the best position of the particle;

Step8. If the stopping criterion is met, when $\tau = T$, stop. Otherwise, $\tau = \tau + 1$ and return to step 2.

5. Computation Experiments

In this section, the PSO algorithm is coded by C++ language. Experiments are carried out on a personal computer with Intel core 2 CPU running at 2.83 Ghz.

All the experiment data are generated based on Ng and Mak (2005) and Wan *et al.* (2009). The retrieval time for one container ranges from 2 to 4 min, the traveling time between two container is from 0 to 10 min, the ready time for each container generated from an exponential distribution with a mean of $120/N$ (N is the container number) min randomly. The stacks are of 6 columns in all the experiments, and tier ranges from 2 to 5. The number of container in the stacks is not less than $0.2(\text{column}-1)\text{tier}+1$, $0.5(\text{column}-1)\text{tier}+1$ and $0.8(\text{column}-1)\text{tier}+1$, respectively. The locations of each container is generated randomly, and not floating, if any, to touch the ground or the lower containers which is at the same column. In our PSO algorithm, we set $\gamma = 3$ and $\lambda = 3$ based on experiments.

In order to test the performance of our proposed simultaneous scheduling problem, we first solve the yard crane scheduling problem presented by Ng and Mak (2005) using CPLEX 11.0 software to obtain the total completion time for all the containers, which is expressed as F1. Second, we solve the reshuffle scheduling problem described by Wan *et al.* (2009) using CPLEX 11.0 software, and then get the number of reshuffle, in order to compare with the results of our proposed simultaneous scheduling problem, we multiply the number of reshuffle by a certain value α ($\alpha=4$, which is received by the practical time for one single reshuffle in container terminal) and transfer it into values by units of time, and we use F2 to indicate the result. At last, F1 plus F2 is the sum of the total completion time for all the containers and the total reshuffling time, which is recorded as F.

The results of the simultaneous scheduling problem in this paper is solved by PSO algorithm, and we record it as F'. Then we compare F' with the value of F, which is obtained by solving the yard crane scheduling problem and the reshuffle scheduling problem separately. The detail is shown in Table 3.

Table 3: Comparison Results between the Separately Solved Problem and Simultaneous Scheduling Problem

N	Stack size	YCS model (F1 and cpu time)	MRIP model (F2 and cpu time)	F	PSO (F' and cpu time)
C_1_1	6-2-3	27, 0.25	0, 0.50	27	27, 0.015
C_1_2	6-2-6	90, 0.75	2, 0.25	98	94, 0.031
C_1_3	6-2-9	192, 6.26	3, 0.75	204	192, 0.079
C_2_1	6-3-4	44, 0.26	0, 0.26	44	44, 0.015
C_2_2	6-3-8	161, 1.01	2, 0.26	169	167, 0.063
C_2_3	6-3-9	212, 10.00	3, 1.75	224	220, 0.063
C_3_1	6-4-5	69, 0.25	1, 0.25	73	73, 0.031
C_3_2	6-4-9	196, 8.50	2, 0.25	204	200, 0.078
C_3_3	6-4-11	282, 368.11	5, 4.25	302	298, 0.11
C_4_1	6-5-6	90, 3.25	1, 0.28	94	90, 0.046
C_4_2	6-5-9	175, 6.00	3, 0.75	187	187, 0.079
C_4_3	6-5-11	270, 351.52	3, 1.50	282	280, 0.109

From the results in Table 3, we can see that the solutions of the simultaneous scheduling problem are better than or equal to the solutions of the reshuffle scheduling problem and the yard crane scheduling problem solved separately, and the computation time for the simultaneous scheduling problem is less than 1s for all the problems by PSO algorithm. It shows that PSO algorithm is effective to solve the simultaneous scheduling problem.

6. Conclusions

The efficiency of large container terminals greatly depends on the effectiveness of resource schedule. Reshuffle is a key factor to block the efficiency of the container terminals, and the reshuffle operation is executed by yard crane, the performance of reshuffle is influenced by the yard crane scheduling. This paper formulates a integer-programming model about the simultaneous reshuffle and yard crane scheduling problem in container terminals. A PSO algorithm is used to solve this simultaneous scheduling problem. Computation experiments indicate that the simultaneous scheduling problem can obtain more better solution than the reshuffle scheduling problem and the yard crane scheduling problem solved separately.

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Logistics Optimization of Slab Relocation Problem in the Steel Industry

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Abstract

The practical situation that slabs are disorganized in slab warehouse is a bottleneck of the hot-rolling production in the steel industry. In the slab relocation problem (SRP), N slabs are given that belong to G different groups according to the steel grade and width of slabs. To make the disorganized layout regular, slabs of the same group should be piled up in the least stacks. The operation that relocated slab is called a relocation.

The relocation can shift one slab from one stack to another one. A relocation sequence of minimum length has to be determined to make the layout of slabs regular. A concept named “cost of layout” is introduced to measure the effect of relocation. When the cost of layout is zero the slabs are all placed regularly. For SRP, a 0-1 IP model and two tree search methods are proposed. Combining the tree search methods with man-machine interactive methods, the hot-rolling slab relocation (HRSR) system has been developed. The experimental results indicate that the system can adapt to the different practical situations effectively.

Keywords: hot-rolling, warehouse, slab relocation, cost of layout, tree search

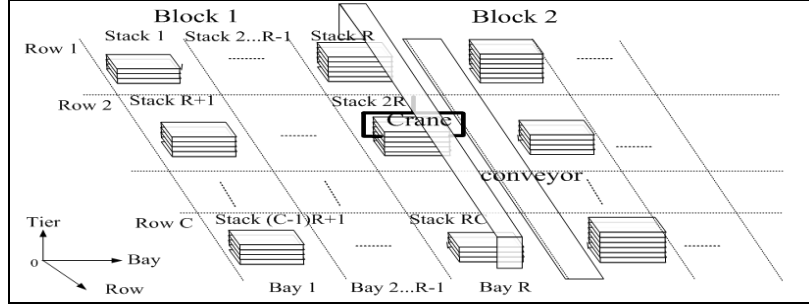
1. Introduction

A slab warehouse serves as a storage buffer between continuous-casting and hot-rolling in the steel industry. To show the importance of solving SRP, we first describe how slabs are operated in slab warehouse. Slabs transported from warehouse to hot-rolling are called export slabs and slabs transported from continuous-casting to the slab warehouse are called import slabs. A slab warehouse should enable an efficient slab flow between continuous-casting and hot-rolling, but the disorganized layout of slabs makes the import and export operations difficulty.

To make the logistics smooth, the slabs need be relocated. The SRP, a combinatorial optimization problem that can be formulated as follows: we are given S stacks and each stack has H slots. An arbitrary distribution of N slabs of G groups to S stacks is called an initial layout.

The slabs are usually divided into groups in accordance with the steel grade and width of slabs. All slabs with the same attributes belong to one slab group. If the slabs of a stack are all the same group, we say that the stack satisfies the “unification” demand. But the slab group may be still not regular, for example the group has 33 slabs in 5 stacks and a stack contains 15 slabs at most. For saving two stacks to store other slabs, we should put the slabs of this group in three stacks. We call the demand of slabs “concentration”. If the slabs of one group satisfy the demands of unification and concentration, we call these slabs “regular”. To show the regularity of slab warehouse, a concept named “cost of layout” and a measuring procedure is given in Section 4.1.

Figure 1: Layout of Slab Warehouse



The warehouse is divided into several blocks by the conveyors, and each block consists of several rows or bays, see Figure. 1. Each block has the same number of stacks. Each stack has the same number of slots. The crane can only transport one slab at a time and access the topmost slab in a stack.

The regular layout has three advantages for practical production: 1) It makes the import operation easier. The import operation transports the import slab to the suitable stack which only contains slabs of the same group with the import slab. 2) It reduces the cost of export operation. The export operation transports the suitable slab whose group is demanded and which has the least slabs above itself. A slab lower down in the stack is to be taken out of warehouse, all the slabs above it have first to be transferred to other stacks. If the stack only contains the slabs of the same group, we can just use the top slab without relocation. 3) It can ensure the safety of the import and export operations. The stack which contains slabs of different widths is easier to collapsing during some operations.

The following two assumptions are valid: 1) The time of moving a slab does not depend on the distance between the stacks. Because this time is negligible compared to the time that takes to pick up or deposit the slab. 2) Only moves within a block are permitted. This assumption is often justified because the moves over the borders of a block via a crane is very time-consuming.

Even though the disorganized layout of steel slab warehouse always exists, there is no publication that addresses the SRP and fewer publications that deal with the stacking problems in the slab warehouse. See Tang et al. (2002) for a slab shuffle problem in a steel slab warehouse. The relocation problem in container terminals has been attempted earlier and had more results. Watanabe (1991) suggested an accessibility index method to estimate the number of relocations in container terminals. Kim (1997) also proposed a formula to estimate the number of relocations for import containers and showed that his method is better than Watanabe's (1991) method in the accuracy. To minimize the number of relocations, Kim et al. (2000) suggested a model and a dynamic programming technique for locating export containers. They assumed that the containers are classified into three groups, according to their weight. Thus, when containers arrive at the yard, placing heavier containers onto higher tiers will reduce the expected number of relocations. Although Kim et al. suggested decision trees for locating export containers, the case in their study was a special one which had three groups of blocks. The concept of group is similar to the group of slabs. And we refer to the idea of decision trees and propose the tree search methods for SRP.

The container pre-marshalling problem (CPMP) is fairly similar to SRP. They are all using minimum relocations to reach different goals. The goal of CPMP is to premarshal the containers according to the pickup sequence, resulting in a layout that would allow the containers to be removed without any further relocation. Algorithms for the CPMP were developed by Bortfeldt (2004), Lee and Hsu (2007), Lee and Chao (2009), Caserta and Voß (2009) and recently by Bortfeldt and Forster (2012). Compared with CPMP, SRP is to make the disorganized layout of slab warehouse regular.

2. Model for SRP

We present a mathematical model for the SRP based on the problem description provided in the introduction. A layout may be represented by a matrix L with H rows and S columns. The matrix L assigns a group index g ($1 \leq g \leq G$) to each slot, given by a pair (i, j) (layer: $i = 1, \dots, H$, stack: $j = 1, \dots, S$). We assume that the initial

layout contains N slabs, labeled $1, \dots, N$. Furthermore, we define the time horizon by introducing time periods $t = 1, \dots, T$, where each time period t is defined by a single move. T is a constant got by a greedy heuristic (cf. Section 3.1). The h_{it} indicates the height of stack i in time period t and g_n indicates the group number of the slab n . R_g is the number of regular stacks which only contain slabs of group g and satisfy the demand of concentration. M is a big enough constant. The proposed model requires four variables. The first one aims at defining feasible configurations, the second is used to define feasible moves. We figure out how many stacks are disorganized in time t period by the third variable. The fourth variable ensures that the regular stacks satisfy the demand of concentration. More formally, let us define

$$x_{tijn} = \begin{cases} 1, & \text{if slab } n \text{ is in slot } (i,j) \text{ in time period } t, \\ 0, & \text{otherwise;} \end{cases}$$

$$z_{tijkln} = \begin{cases} 1, & \text{if slab } n \text{ is relocated from slot } (i,j) \text{ to slot } (k,l) \text{ in time period } t \text{ and } i \neq k, \\ 0, & \text{otherwise;} \end{cases}$$

$$y_{ti} = \begin{cases} 1, & \text{if stack } i \text{ is disorganized in time period } t, \\ 0, & \text{otherwise;} \end{cases}$$

$$w_{tig} = \begin{cases} 1, & \text{if stack } i \text{ is the stack which only contains the slabs of group } g \text{ in time period } t, \\ 0, & \text{otherwise;} \end{cases}$$

Let $\lambda_1, \lambda_2, \lambda_3 \in [0, 1]$ be three preset constants such that $\sum_{i=1}^3 \lambda_i = 1$. Using the notations and variables described

above, the 0–1 IP model for the SRP can be formulated as follows.

$$\text{Min } \lambda_1 \cdot \sum_{t=1}^T \sum_{i=1}^S \sum_{j=1}^H \sum_{k=1}^S \sum_{l=1}^H \sum_{n=1}^N z_{tijkln} + \lambda_2 \cdot \sum_{t=1}^T \sum_{i=1}^S y_{ti} + \lambda_3 \cdot \sum_{t=1}^T \sum_{g=1}^G \left| \sum_{i=1}^S w_{tig} - R_g \right| \quad (1)$$

s.t.

$$\sum_{i=1}^S \sum_{j=1}^H x_{tijn} = 1, \quad t = 1, 2, \dots, T; n = 1, \dots, N \quad (2)$$

$$\sum_{n=1}^N x_{tijn} \leq 1, \quad t = 1, 2, \dots, T; i = 1, 2, \dots, S; j = 1, \dots, H \quad (3)$$

$$\sum_{n=1}^N x_{tj+1,n} - \sum_{n=1}^N x_{tjn} \leq 0, \quad t = 1, 2, \dots, T; i = 1, \dots, S; j = 1, \dots, H-1 \quad (4)$$

$$\sum_{i=1}^S \sum_{j=1}^H \sum_{k=1}^S \sum_{l=1}^H z_{tijkln} \leq 1, \quad t = 1, 2, \dots, T \quad (5)$$

$$\sum_{i=1}^S \sum_{j=1}^H x_{t+1,ijn} + \sum_{i=1}^S \sum_{j=1}^H x_{tijn} \leq 2 - \sum_{i=1}^S \sum_{j=1}^H \sum_{k=1}^S \sum_{l=1}^H z_{tijkln}, \quad t = 1, 2, \dots, T; n = 1, \dots, N \quad (6)$$

$$\sum_{j=1}^H x_{t+1,ijn} \geq \sum_{j=1}^H x_{tijn} - \sum_{j=1}^H \sum_{k=1}^S \sum_{l=1}^H z_{tijkln}, \quad t = 1, 2, \dots, T; n = 1, \dots, N; i = 1, \dots, S \quad (7)$$

$$\sum_{j=1}^H x_{t+1,ijn} \leq \sum_{l=1}^H x_{tijn} + \sum_{j=1}^H \sum_{k=1}^S \sum_{l=1}^H z_{tijkln}, \quad t = 1, 2, \dots, T; n = 1, \dots, N; i = 1, \dots, S \quad (8)$$

$$\sum_{j=1}^H \sum_{k=1}^S \sum_{l=1}^H z_{ijkln} \leq \sum_{j=1}^H x_{tijn}, \quad t = 1, 2, \dots, T; n = 1, \dots, N; i = 1, \dots, S \quad (9)$$

$$\sum_{i=1}^S \sum_{j=1}^H \sum_{l=1}^H z_{ijkln} \leq \sum_{l=1}^H x_{t+1,kl n}, \quad t = 1, 2, \dots, T; n = 1, \dots, N; k = 1, \dots, S \quad (10)$$

$$\sum_{j=1}^H \sum_{l=1}^H z_{ijkln} \geq \sum_{j=1}^H x_{tijn} + \sum_{l=1}^H x_{t+1,kl n} - 1, \quad t = 1, 2, \dots, T; n = 1, \dots, N; i = 1, \dots, S; k = 1, \dots, S \quad (11)$$

$$\left| \sum_{j=1}^{h_i} \sum_{n=1}^N g^n \cdot x_{tijn} - \sum_{n=1}^N g^n \cdot x_{ti1n} \right| \geq y_{ti}, \quad t = 1, 2, \dots, T; i = 1, 2, \dots, S \quad (12)$$

$$y_{ti} \geq \left| \sum_{j=1}^{h_i} \sum_{n=1}^N g^n \cdot x_{tijn} - \sum_{n=1}^N g^n \cdot x_{ti1n} \right| / M, \quad t = 1, 2, \dots, T; i = 1, 2, \dots, S \quad (13)$$

$$\left| \sum_{n=1}^N (g^n \cdot x_{ti1n}) \cdot (1 - y_{ti}) - g \right| \leq (1 - w_{tig}) \cdot M, \quad t = 1, 2, \dots, T; i = 1, \dots, S; g = 1, \dots, G \quad (14)$$

$$1 - w_{tig} \leq \left| \sum_{n=1}^N (g^n \cdot x_{ti1n}) \cdot (1 - y_{ti}) - g \right|, \quad t = 1, 2, \dots, T; i = 1, \dots, S; g = 1, \dots, G \quad (15)$$

$$x_{0ijn} = x_{0ijn}, \quad i = 1, \dots, S; j = 1, \dots, H; n = 1, \dots, N \quad (16)$$

$$x_{tijn} \in \{0, 1\}, \quad t = 1, 2, \dots, T; i = 1, \dots, S; j = 1, \dots, H; n = 1, \dots, N \quad (17)$$

$$y_{ti} \in \{0, 1\}, \quad t = 1, 2, \dots, T; i = 1, \dots, S \quad (18)$$

$$w_{tig} \in \{0, 1\}, \quad t = 1, 2, \dots, T; i = 1, \dots, S; g = 1, \dots, G \quad (19)$$

$$z_{ijkln} \in \{0, 1\}, \quad t = 1, 2, \dots, T; i = 1, \dots, S; j = 1, \dots, H; k = 1, \dots, S; l = 1, \dots, H; n = 1, \dots, N \quad (20)$$

The objective function Eq. 1 includes three kinds of penalties: the first is the penalty of the number of relocations, the second is the penalty for disorganized stacks after every move and the third is the penalty for dispersiveness of slabs of the same group after every move. Eq. 2 ensures that each slab must be within one slot in each time period. Eq. 3 ensures that each slot (i, j) must be occupied by at most one slab in each time period. Eq. 4 ensures that no gaps are allowed within each stack, i.e., if a slab in slot (i, j) is moved, then the slot above the slab must be empty. Moreover, no slab can be moved to a position above an empty slot. Eq. 5 ensures that at most one move is allowed in each time period. If slab n is relocated in time period t, Eq. 6 ensures that the slab in time period t+1 is not in the former slot. If not, constraints Eqs. 7-8 ensure that slab n is still in the former slot in time period t+1. Eqs. 9-11 define the variable z_{ijkln} . Eqs. 12-13 define the variable y_{ti} . Eqs. 14-15 define the variable w_{tig} . Eq. 16 initializes the message of slots in the warehouse. Finally, the integrality conditions on the decision variables are specified by Eqs. 17-20. By using ILOG OPL 5.5, we are able to solve small instances of the SRP to optimality. However, due to the exponential growth in computation time, this approach seems to be not applicable to most real-world scenarios. So we propose the tree search methods to solve the practical problem faster and more efficiently.

3. Classification of stacks and relocations

3.1. Classification of stacks

(1) The final stack of group g : The stack which will only contain slabs of group g after all relocations is the final stack of group g . According to the demands of the unification and concentration we first decide the number of final stacks of group g in the following way: R_g is the number of regular stacks which only contain slabs of group g and satisfy the demand of concentration. F_g is the number of final stack of group g after all relocations. N_g is the number of slabs of group g . If $N_g \% H = 0$ $F_g = N_g / H$; else $F_g = N_g / H + 1$. The final stacks are classified as follow: 1) The final receiver stack of group g : The stack which will be the receiver stack of slabs of group g is not full. The cost of slab in this stack is 1. 2) The unrelated stack of group g : The stack which only contains slabs of group g is full. The cost of slab in this stack is 0. 3) The prepared stack of group g : When stacks of group g are regular, the stack of group g which is not full is prepared to be the temporary stack of group g . The cost of slab is 0.

(2) The temporary stack of group g with slabs of group h : The stack is used to store the slabs of group h for the time being. When slabs of group h have the final receiver stack of group h , the temporary stack will be the final receiver stack or prepared stack of group g . If the slab of group h has the final receiver stack, the cost of slab of group h is 10. If not, the cost is 15. If the stack is prepared stack before storing slabs of group h , the cost of slab of group g is 0. If not, the cost of slab of group g is 1.

(3) The surplus stack of group g : If $R_g > F_g$, after deciding F_g final stacks the left $R_g - F_g$ stacks are the surplus stacks. The slabs of this stack are the surplus slabs of group g . The cost of slab of group g is 1.

(4) The disorganized stack of group g : Except the above defined stacks the stack which is not empty is the disorganized stack. After the least removes, the stack will only contain the slabs of group g . The slabs which will be removed are the waiting slabs. The left slabs are the undecided slabs. The cost of undecided slab is 5. The waiting slab of group h with high level is the slab which has a final receiver stack of group h . Number i is equal to the number of slabs of this stack minus the layer of the slab. 30 minus i is the cost of slab. The waiting slab of group h with low level is the slab which has no final receiver stacks of group h . The cost of slab is equal to 15 minus i .

According to the cost of slabs, we propose an easy method to measure the regularity of a stack or a layout: The cost of one stack which is represented to the regularity of stack is sum of cost of slabs in the stack. The cost of layout is sum of cost of slabs in the layout. The method can measure the effectiveness of relocation by comparing cost of layout before and after relocation.

3.2. Classification of relocations

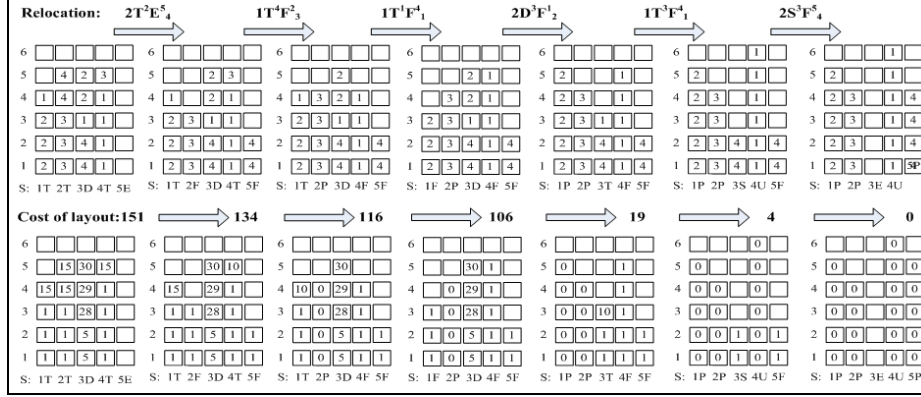
First, A relocation can be written as pair (d, r) of different stacks. The first stack d is called the donator stack, the second stack r is said to be the receiver stack. Then we define a serie of relocations which are successive to move slabs of the same group. The number of relocations of group g referred as N . So the classifications of the relocations are shown in Table 1. For example, $3S^1F^3_4$ means that there are three relocations of slabs of group 4 from the surplus stack 1 to the final receiver stack 3.

Table 1: Classification of the Relocations ($d, r=1, \dots, s, d \neq r, g=1, \dots, G$).

Donator stack	Receiver stack	Abbreviation	A serie of the relocations of group g
Surplus stack	Final receiver stack	SF	$NS^dF^r_g$
Temporary stack	Final receiver stack	TF	$NT^dF^r_g$
	Empty stack	TE	$NT^dE^r_g$
	Prepared stack	TP	$NT^dP^r_g$
	Temporary stack	TT	$NT^dT^r_g$
disorganized stack	Prepared stack	DP	$ND^dP^r_g$
	Empty stack	DE	$ND^dE^r_g$

	Final receiver stack	DF	$ND^d F_g^r$
	Temporary stack	DT	$ND^d T_g^r$
	disorganized stack	DD	$ND^d D_g^r$

Figure 2: A Simple Example of the Relocation



The classifications of stacks and relocations are needed for describing the tree search methods for the SRP. In the following, the functions of the classification and cost of layout are explained using the example layout L in Figure. 2. The costs of layout in the different moments of the process decrease significantly. These costs demonstrate the effectiveness of the relocations.

4. Two tree search methods for the SRP

For the tree search methods, we propose a greedy algorithm to get the initial solution of a layout. According to the different branching strategies, we propose two tree search methods. The mongline search method (MSM) only generates one tree branch and the multi-thread search method (MTSM) has many paratactic tree branches which are generated by the child nodes of root node in one iteration.

4.1. Determining an initial solution S_{GREEDY} with the minimum cost heuristic

The heuristic listed in Figure. 3 begins with an initial layout, in each step it is determined according to the specified order. For instance a $NS^d F_g^r$ is found, then don't find moves with lower priority for the current layout. If the layout is still not regular, at least one of the ten type relocations is available. The reasons of priority order are as follows: 1) If a $NS^d F_g^r$ is possible, the surplus stack may turn into an empty stack to store the slabs of other group. 2) A temporary stack may turn into a new final stack after relocation without using an empty stack. 3) The height of a disorganized stack will be reduced after relocations. And the final target stack will get more slabs of the same group. 4) A temporary stack and an empty stack may turn into two final target stacks. Because of wasting a empty stack, the operation has lower priority than above operations. 5) A disorganized stack may turn into a temporary stack and an empty stack turns into a final target stack. 6) At the moment there is no empty stacks or final target stacks to store the temporary slabs. So put the temporary slabs to the prepared stack, the temporary stack may turn into the final target stack which will receive the waiting slabs of the same group. 7) If the temporary slabs of the two temporary stacks are focused on one temporary stack, the other stack will be the final target stack. 8) If the waiting slabs of disorganized stack need to be the temporary slabs, a prepared stack is the best candidate to be temporary stack. 9) The temporary stack is the second candidate for waiting slabs. 10) If we wish a disorganized stack could be a final target stack, the worst case is to put the waiting slabs to other disorganized stack.

If many relocations of the same priority are found for the current layout, the relocation of these is chosen according to the minimum cost of layout after this relocation. As soon as a serie of relocations is selected, it is appended to the solution and applied to the layout.

Figure 3: Procedure Find_Initial_Solution

```

find_initial_solution (in: L {initial layout}, out: s {greedy solution})
s := ∅; {initialise solution as empty list of relocations}
while the cost of layout is not 0 do
Sf := set of all SF relocations in L;
if Sf ≠ ∅ then determine  $NS^dF_g^r \in Sf$  so that the cost of the layout is minimum after the relocations.
    s := s +  $NS^dF_g^r$ ; L := L ⊕  $NS^dF_g^r$ ;
else Tf := set of all TF relocations in L;
    if Tf ≠ ∅ then determine  $NT^dF_g^r \in Tf$  so that the cost of layout is minimum after the relocations.
        s := s +  $NT^dF_g^r$ ; L := L ⊕  $NT^dF_g^r$ ;
    else Df := set of all DF relocations in L;
        if Df ≠ ∅ then determine  $ND^dF_g^r \in Df$  so that the cost of layout is minimum after the relocations.
            s := s +  $ND^dF_g^r$ ; L := L ⊕  $ND^dF_g^r$ ;
        else Te := set of all TE relocations in L;
            if Te ≠ ∅ then determine  $NT^dE_g^r \in Te$  so that the cost of layout is minimum after the relocations.
                s := s +  $NT^dE_g^r$ ; L := L ⊕  $NT^dE_g^r$ ;
            else De := set of all DE relocations in L;
                if De ≠ ∅ then determine  $ND^dE_g^r \in De$  so that the cost of layout is minimum after the relocations.
                    s := s +  $ND^dE_g^r$ ; L := L ⊕  $ND^dE_g^r$ ;
                else Tp := set of all TP relocations in L;
                    if Tp ≠ ∅ then determine  $NT^dP_g^r \in Tp$  so that the cost of layout is minimum after the relocations.
                        s := s +  $NT^dP_g^r$ ; L := L ⊕  $NT^dP_g^r$ ;
                    else Tt := set of all TT relocations in L;
                        if Tt ≠ ∅ then determine  $NT^dT_g^r \in Tt$  so that the cost of layout is minimum after the relocations.
                            s := s +  $NT^dT_g^r$ ; L := L ⊕  $NT^dT_g^r$ ;
                        else Dp := set of all DP relocations in L;
                            if Dp ≠ ∅ then determine  $ND^dP_g^r \in Dp$  so that the cost of layout is minimum after the relocations.
                                s := s +  $ND^dP_g^r$ ; L := L ⊕  $ND^dP_g^r$ ;
                            else Dt := set of all DT relocations in L;
                                if Dt ≠ ∅ then determine  $ND^dT_g^r \in Dt$  so that the cost of layout is minimum after the relocations.
                                    s := s +  $ND^dT_g^r$ ; L := L ⊕  $ND^dT_g^r$ ;
                                else Dd := set of all DD relocations in L;
                                    if Dd ≠ ∅ then determine  $ND^dD_g^r \in Dd$  so that the cost of layout is minimum after the relocations.
                                        s := s +  $ND^dD_g^r$ ; L := L ⊕  $ND^dD_g^r$ ;
                                    endif; endif; endif; endif; endif; endif; endif; endif; endif; endif;
endwhile;
end

```

In the process of minimum cost heuristic, we need record the nodes for the tree search. If there is group g which will have its new final target stack after some relocations. Record the layout as a child node of the tree search after these relocations. From the initial layout, we can get many different child nodes according to the decisions on the new final target stacks which may be generated after relocations. Oppositely if the only one final target stack of group g will turn into a temporary stack or unrelated stack after relocations. We also record the layout as a child node of the tree search.

To keep the search effort within acceptable limits. The number of child nodes from a branch node is restricted. At most maxCN different child nodes are applied alternatively to the branch nodes. So we first sequence the child nodes in the ascending order of the cost of child nodes. If the number of child nodes is greater than maxCN, we select the first maxCN child nodes.

4.2. Mongline search method

The MSM only generates one tree branch in one iteration. In the search procedure shown in Figure .4, two steps are made to generate the solutions for a given layout L. First, the initial solution is calculated from the

root node using the minimum cost heuristic. And the branch nodes are recorded and sorted from leaf node to root node. Second, we regard branch node as root node. Then use MSM to get other leaf nodes which are generated from the branch nodes by ascending order. The pathes that have been searched or aborted are recorded for avoiding repetitive search.

The Advantage of the search direction is to get more leaf nodes within the time limit. From the tree map of MSM which is shown in Figure .5, we find the second leaf node has the same father node with the first one. The relocations from L_1 to L_{N+1} are the same relocations of L_{f1} and L_{f2} . So we can get the second solution with the least time on the basis of the first solution. From L_1 to L_{N+1} , the search time increases greatly, because the same relocations gets fewer. But MSM also has a disadvantage that the solutions are lacking diversity because of the same relocations. In order to overcome the disadvantage, we propose the multi-thread search methods in Section 4.3.

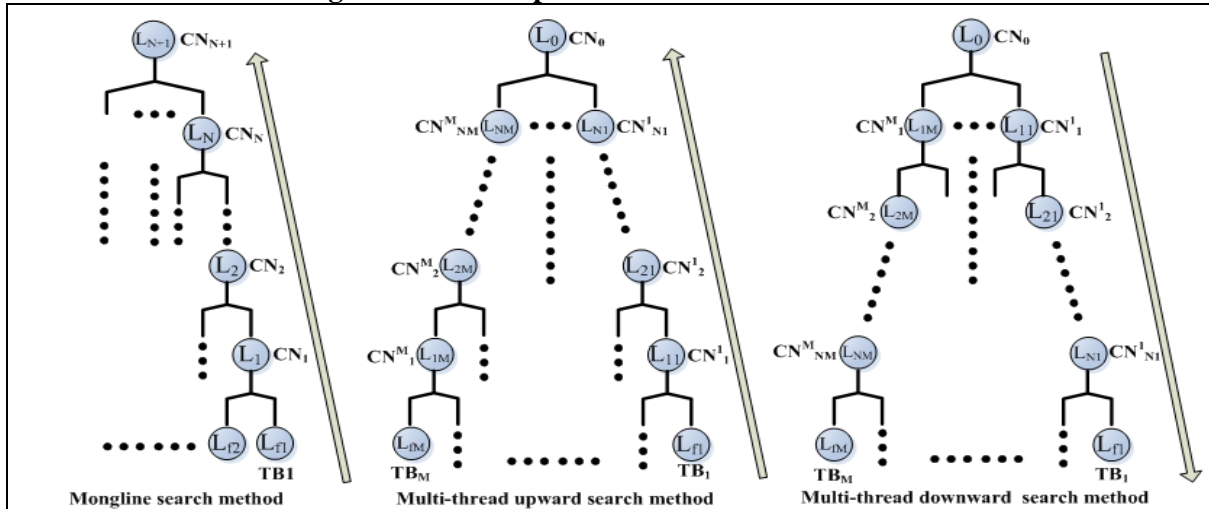
Figure 4: Procedure Mongline_Search_Method

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mongline_search_method (in:  $s^*$ {current best solution},  $L$ {current layout},  $s'(L)$ {existed relocation sequence before  $L$ },  $LC$  {child nodes set of  $L$ })
if time limit exceeded then return; endif;
find_initial_solution(in:  $L$ ; out:  $s$  {greedy solution,  $n(s)$  is the number of relocations by the greedy solution},  $L_n$  {the branch nodes in the TB1,  $n=1...N+1$ },  $LC_n$  {child nodes set of  $L_n$ ,  $n=1...N+1$ },  $C(L')$ {the cost of the layout after relocations by the greedy solution})
{If  $n(s+s'(L))=n(s^*)\neq 0$  and  $C(L')\neq 0$ ,abort the search path during the heuristic}
if  $n(s^*)=0$  then  $n(s^*)=n(s+s'(L))$ 
  elseif  $n(s+s'(L)) < n(s^*)$  and  $C(L')=0$  then  $s^* := s+s'(L)$ ;
endif;
endif;
for  $n=1, n\leq N+1, n++$  do
  While  $LC_n\neq\emptyset$  do
    mongline_search_method( $s^*$ ,  $s'(L_n)$ ,  $L_n$ ,  $LC_n$ );
  endwhile
endfor;
end.

```

Figure 5: Tree Maps of the Tree Search Methods



4.3. Multi-thread search method

The multi-thread search method (MTSM) generates many tree branches which are decided by the child nodes of the root node in one iteration. In the procedure multi-thread_search_method two steps are made to generate the solution for a given layout L . First, the initial solutions are calculated from the child nodes of the root node

using the minimum cost heuristic. Then we regard the branch nodes as root nodes. Then use these root nodes as the input of MTSM by the ascending order.

The MTSM promotes the diversity of solutions by generating many tree branches. On this basis, we propose the downward search method to promote the diversity of the solutions further. For example, from the tree map of multi-thread downward search method(MTDSM) which is shown in Figure .5, L_{11} which is the first branch node will generate many different solutions with the fewer same relocations than L_{21} . From L_{11} to L_{N1} the same relocations become more and more, and the search time becomes less and less. Within the time limit the diversity of the solutions will be maximized, but the solutions become fewer than that by MSM. So we combine the advantages of branching strategy and the upward search direction to design the multi-thread upward search method (MTUSM). The procedures of MTDSM and MTUSM are shown in Figure .6

Figure 6: Procedure Multi-Thread Search Method

```

multi-thread_search_method (in:  $L$ {current layout},  $D$ {search direction},  $s^*$ {current best solution},
 $s'(L)$ {existed sequence from the initial layout},  $LC$  {child nodes set of  $L$ })
if time limit exceeded then return; endif;
{get the child nodes of  $L$ ; the number of the child nodes is  $M$ ; the relocations add to  $s'(L)$ }
for  $m=1, m \leq M, m++$  do
find_initial_solution (in:  $L_m$  {layout of  $m$  child node }; out:  $s_m$  {greedy solution},  $L_{nm}$  {branch nodes in
the  $TB_m$ ; if  $D=0$  downward,  $n=1 \dots N_m$ , else upward,  $n=N_m \dots 1$ ;  $N_m$  is the number of the branch nodes in the
 $TB_m$ },  $LC_{nm}$  { child nodes set of  $L_{nm}$  },  $C(L')$ {the cost of the layout after relocations by  $s_m$ });
{If  $n(s_m+s'(L_m))=n(s^*) \neq 0$  and  $C(L') \neq 0$ , abort the search path during the heuristic}
if  $n(s^*)=0$  then  $n(s^*)=n(s_m+s')$  ;else  $n(s_m+s'(L_m)) < n(s^*)$  and  $C(L)=0$  then  $s^* := s_m+s'(L_m)$ ; endif;
endfor;
for  $m=1, m \leq M, m++$  do
if  $D=0$ , for  $n=1, n \leq N_m, n++$  do
    multi-thread_search_method ( $L_{nm}, D, s^*, s'(L_{nm}), LC_{nm}$ );
endfor;
else for  $n=N_m, n \geq 1, n--$  do
    multi-thread_search_method ( $L_{nm}, D, s^*, s'(L_{nm}), LC_{nm}$ );
endfor;
endif;
end.

```

5. Computational experiments and implementation of the HRPS system

To test the performance of the HRSP system, we collect the data from a steel slab warehouse in China. The programs for the experiment were constructed by VC++ 6.0. All tests were conducted on an Intel Core 2 Duo processor with 2.53 GHz and 2 GB RAM. Throughout the computational experiments, we have used the parameter setting maxCN=3 and a time limit of 250s. The test block consists of 30 stacks. In total, 18 different test cases were defined as indicated in the first three columns of Table 2. Each test case consists of 30 different instances with a constant number of slabs and groups. The mean computation time, mean number of relocations and mean number of solutions are presented as T , N_r and N_s . Based on the results presented in Table 2, the following observations can be made:

1) The heuristic is greedy and only generates one solution. So the computational time of the heuristic was less than 2s which is within the level that can be used in practical production. In contrast, for the same test case the computational time of the tree search methods exceeded 190s. But the methods can also be used during the maintenance period of steel slab warehouse because there is a long time to run the tree search program and executive the operations according to the solution from HRSP system.

2) MTDSM can abort the non-optimal search path earlier to save the search time because MTDSM get the better solution earlier from the diversified solutions. In the applications of HRSR system, compared with MTUSM and MSM, the operator often runs the MTDSM program to get a better solution than the heuristic by using less time.

3) MSM has searched the solutions from only one tree branch that makes the solutions fall into the local optimum easily. The downward search strategy and the branching strategy of MTDSM improve the diversity of solutions. But these solutions are less than those by MSM within the time limit. Compared with MSM and MTDSM, MTUSM has the advantages of other tree search methods that MTUSM can generate more diversified solutions with less time. So when the situation is complicated the operator can run MTUSM program of HRSR system to get a better near-optimal solution.

Table 2: Results of the Proposed Methods for the SRP Test Cases

No. of slabs	No. of groups	Cost of L	Heuristic			MSM			MTDSM			MTUSM		
			N _s	T	N _r	N _s	T	N _r	N _s	T	N _r	N _s	T	N _r
260	15	1073.3	1	2	186	86	203	163	81	192	163	83	197	163
	20	1238.5	1	2	211	91	212	184	85	201	184	90	210	184
	25	1474.3	1	2	249	95	227	211	90	215	211	93	222	211
280	15	1267.6	1	2	209	88	208	182	83	201	182	84	204	182
	20	1501.1	1	2	233	93	220	201	87	209	201	91	215	201
	25	1678.3	1	2	256	99	241	229	92	229	229	95	233	229
300	15	1395.3	1	2	248	90	209	218	86	204	218	88	211	218
	20	1562.7	1	2	271	97	228	244	91	212	244	96	225	244
	25	1707.2	1	3	290	107	220	259	99	203	259	102	211	259
320	15	1531.8	1	3	263	102	215	246	95	199	246	99	209	246
	20	1715	1	3	289	111	229	269	100	209	269	106	216	269
	25	1896.5	1	3	311	123	245	289	106	211	289	114	227	289
340	15	1694.9	1	3	293	119	241	277	101	213	277	109	230	277
	20	1821.1	1	3	313	121	250	281	109	229	281	114	237	281
	25	1982.4	1	3	333	119	250	309	111	250	295	117	250	289
360	15	1837.3	1	3	307	121	250	291	108	250	293	119	250	281
	20	2011.6	1	3	331	122	250	312	110	250	304	117	250	291
	25	2234.4	1	4	353	119	250	331	105	250	320	118	250	311

6. Conclusions

In this paper, we investigated the practical SRP in steel industry and proposed a 0-1 IP model for SRP. The tree search methods that are based on a greedy heuristic and the suitable search strategies were designed to solve SRP. Combining the tree search methods with man-machine interactive methods, a practical HRSR system has been developed. The computational results on the practical instances show that the programs of HRSR system can adapt to the different practical situations.

Acknowledgements

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Research on Location Planning for Emergency Logistics Centers faced with Earthquake Disasters

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Abstract

Earthquakes occurred frequently and brought huge damage to society in recent years. Emergency management and emergency logistics for earthquakes are being more and more important today. Emergency logistics centers, as important nodes and infrastructure, are also becoming a heated topic today. This paper proposed a research approach to study the location for emergency logistics center system, which is made up by emergency logistics centers at different grades. A mixed integer programming model is designed to solve this problem, an index system and a weighted distance matrix are also deployed in the research approach. At last, a simulated emergency logistics center system is proposed based on the real data of Xinjiang Province in China to verify the feasibility of this research method.

Keywords: emergency logistics center, location planning, mixed integer programming, stochastic damage risk

1. Introduction

In the past decades, many research results on common logistics node location planning have been published. Xiao-dong ZHANG (2004) constructed a frame of logistics parks location planning theory, which consists of three levels: strategic planning of macro spatial location, tactic planning of site selection and executive planning of micro design. Genetic Algorithms and other methods were also adopted in the logistics node location planning (Kar Yan Tam, 1992), and the location models are divided towards 2 aspects: single node location problems and several node location problems. Considering the characteristics of emergency logistics, some targeted research results appeared. Masood ABadri (1998) established a multi-objective mathematical model to choose the location of a fire station which are considered a series of conflicting goals. Yi TAO (2010) adopted the barrier area concept to establish a Genetic algorithm model to raise an emergency logistics center location proposal. Considering constraints of relief abilities and the tradeoff between efficiency and cost, some heuristic methods were also used in location planning in the emergency research field (Xuedong Gao, 1994; Quanzhou Dong, 2010).

Based on the existing research about single-point logistics node location planning, this paper designs a location method for an emergency logistics center system. This system is made up by several emergency

logistics centers, meets the target region's relief demands and has enough feasibility.

2. Grade Division Features and Reliable Characteristics of Emergency Logistics Centers

Emergency logistics center system is different from single-point logistics centers. It should conclude several nodes which cooperate with each other tightly. On one side, emergency logistics center system has a strong grade division feature, the emergency logistics center have different amounts, functions and abilities. On the other side, emergency logistics centers should cooperate with each other, improve the system's reliability.

2.1 Grade Division Design of Emergency Logistics Center System

Emergency logistics center system should be a network structure. Moreover, it will be divided into different grades by different earthquake risks and the functions in the system.

This paper divides the emergency logistics centers into 3 grades: first-grade emergency logistics center, second-grade emergency logistics center and third-grade emergency logistics center.

First-grade emergency logistics centers are on the highest level but fewest in the system, which are connected with several transportation modes, such as highways, railway and airports. Amount and types of emergency materials in the first-grade emergency logistics centers are the most, can meet the relief demands of 15,000 people one time.

Second-grade emergency logistics centers have smaller relief abilities but a larger amount. They are connected with several highways or roads, some of them can also use airway or railway transportation. Amount of emergency materials in a second-grade emergency logistics centers can meet the relief demands of 9,000 people one time.

Third-grade emergency logistics centers are on the lowest level but biggest amount in the emergency logistics center system. They are connected with one or two roads at least. Amount of emergency materials in a second-grade emergency logistics centers can meet the relief demands of 4,000 people one time.

2.2 Optimization of Emergency Service Reliability

Different from common logistics nodes, emergency logistics center system should be highly reliable faced with earthquakes. Reliability can be reflected in 2 aspects. Firstly, emergency logistics centers should not be established in regions which are at a high earthquake risk. Therefore, fewer emergency logistics centers will be destroyed in earthquakes, the reliability will also be improved.

Secondly, emergency materials should come from two or more emergency logistics centers. Although any emergency logistics centers are destroyed in earthquakes, the affected regions can also get emergency materials from other emergency logistics centers.

3. Basic Ideas and Method of Location Planning for Emergency Logistics Center System

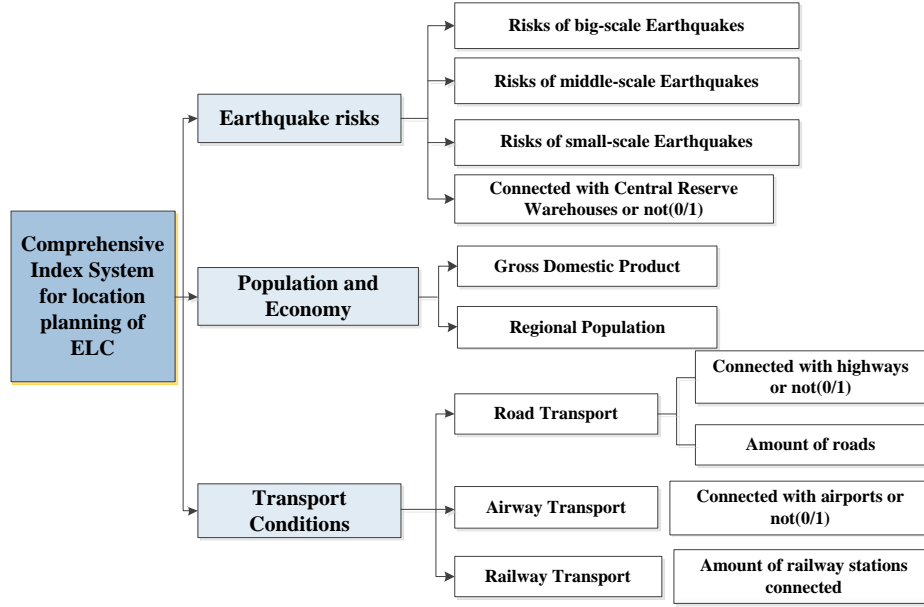
3.1 Basic Ideas

Based on the principles of location planning for emergency logistics center system, this paper raises a research idea and method about location planning for emergency logistics center system. Firstly, earthquake disaster risks, population, economic development and transportation conditions of target regions are analyzed. It can help to know one region's relief demand and the flexibility degree to develop an emergency logistics center. Secondly, whether the materials can be sent from one region to another in the golden time of rescue will be calculated. During this process, earthquake risks of the target regions and paths between them should be taken into consideration. Thirdly, a mathematic model based on the above principles and constraints is established, in order to solve the location problem.

3.2 Comprehensive Evaluation for Target Regions of Emergency Logistics Centers

This paper established an index system to check the flexibility of developing emergency logistics centers for every region. The index system is made up by 13 factors within 3 perspectives. The 3 perspectives are: risk of earthquake disasters, population and economy, transport conditions, shown in Figure 1.

Fig 1: The Comprehensive Index System for Location Planning of Emergency Logistics Center System



This paper adopts Fuzzy Comprehensive Evaluation to estimate the feasibility degree to develop an emergency logistics center for every region according to the index system. Data is calculated by Entropy Method and Grey Correlation Method. Furthermore, the feasibility of the target regions can be known.

3.3 Across Regions Weighted Distance Matrix

Emergency rescue is with strict time requirements and emergency materials should be sent to affected areas after disasters rapidly. According to the governments' requirements of time limit for disaster relief, this paper set the timetable as follows: first-grade emergency logistics centers should send materials to affected regions in 9 hours; second-grade emergency logistics centers should send materials to affected regions in 6 hours; third-grade emergency logistics centers should send materials to affected regions in 3 hours. It will be a very important constraint whether materials can be sent from one region to another in required time in the location planning process.

Meanwhile, the uncertainty of earthquakes and disaster risks of target regions should also be considered. The weighted distance of every region to another can be calculated as equation (1) and (2) below:

$$\delta_{ij} = \mu_{ij} - \begin{cases} 1, \varphi_{ij} \geq \varphi_0 \\ 0, \varphi_{ij} < \varphi_0 \end{cases} \quad (1)$$

$$\mu_{ij} = \begin{cases} 0, s_{ij} \cdot \left(1 + \frac{k_{ij}}{\max(k_{ij})} \right) \geq s_0 \\ 1, s_{ij} \cdot \left(1 + \frac{k_{ij}}{\max(k_{ij})} \right) < s_0 \end{cases} \quad (2)$$

s_{ij} is the distance between I and j ; μ_{ij} is a 0-1 variable, means whether emergency materials can be sent from i to j in required time; k_{ij} is the earthquake disaster risk of target regions; φ_{ij} is a random variable, means the probability of path between i and j is destroyed in earthquakes; φ_0 is a constant, φ_{ij} is bigger than φ_0 means that the path between i and j is destroyed; the weighted distance δ_{ij} is a 0-1 variable, the value is 1 means that materials from i can be sent to j in required time under earthquake risks.

3.4 Dynamic Optimization Model

On the premise of meeting all the relief demands of the target regions, this paper established an optimization model. The model aims at a smallest cost of an emergency logistics center system, as follows:

a) Object Function:

$$\min U = \left(C^1 \cdot \sum_i^m \frac{Z_i^1}{G_i} + C^2 \cdot \sum_i^m \frac{Z_i^2}{G_i} + C^3 \cdot \sum_i^m \frac{Z_i^3}{G_i} \right) \cdot (1-5\%) / \phi \quad (3)$$

b) Subject to:

$$M \left(\delta_{ij}^1 \cdot Z_i^1 + \delta_{ij}^2 \cdot Z_i^2 + \delta_{ij}^3 \cdot Z_i^3 \right) - k_{ij} \geq 0, i = 1, 2, \dots, m; \quad (4)$$

$$\sum_{i=1}^m k_{ij} \geq K_j, \forall j, i = 1, 2, \dots, m; \quad (5)$$

$$\sum_{j=1}^n k_{ij} \leq V^1 \cdot Z_i^1 + V^2 \cdot Z_i^2 + V^3 \cdot Z_i^3, \forall i, j = 1, 2, \dots, m; \quad (6)$$

$$M \cdot (Z_i^1 + Z_i^2 + Z_i^3) - \sum_{j=1}^n k_{ij} \geq 0, \forall i, j = 1, 2, \dots, n; \quad (7)$$

$$K_0 / K_j - (Z_{i=j}^1 + Z_{i=j}^2) \geq 0, \forall j; \quad (8)$$

$$G_i - G^1 \cdot Z_i^1 \geq 0, \forall i; \quad (9)$$

$$G_i - G^2 \cdot Z_i^2 \geq 0, \forall i; \quad (10)$$

$$Z_i^1 + Z_i^2 + Z_i^3 - 1 \leq 0, \forall i; \quad (11)$$

$$Z_i^1 \in \{0, 1\}, \forall i; \quad (12)$$

$$Z_i^2 \in \{0, 1\}, \forall i; \quad (13)$$

$$Z_i^3 \in \{0, 1\}, \forall i; \quad (14)$$

c) Variable Meanings:

C^1 、 C^2 、 C^3 : the building costs of first-grade, second-grade and third-grade emergency logistics center;

Z_i^1 、 Z_i^2 、 Z_i^3 : 0-1 variable, value of 1 means that a region is chosen to be a carrier city of an emergency logistics center;
 δ_{ij}^1 、 δ_{ij}^2 、 δ_{ij}^3 : the weighted distance (explained before);
 V^1 、 V^2 、 V^3 : the biggest relief ability of first-grade, second-grade and third-grade emergency logistics center, the data are from the rescue population;
 k_{ij} : emergency materials from i to j , the data are from the affected population;
 ϕ : depreciable life, 20 years;
 K_j : the total relief demands of region j ;
 K_0 : a standard of earthquake disaster risks, regions with a higher earthquake risk is not fit to develop a first-grade or second-grade emergency logistics center;
 M : an infinite positive;
 G_i : the evaluation score of every region to develop emergency logistics centers;
 G^1 、 G^2 : a standard of the evaluation score, regions should have a higher score to develop first-grade and second-grade emergency logistics centers.

d) Constraints Meanings:

- Constraint (4): only if the value of δ_{ij} is 1, j can accept materials from i ;
- Constraint (5): the materials which j accepts should bigger than or equal to the total demand of j ;
- Constraint (6): emergency materials from emergency logistics centers should be fewer than its relief ability limit;
- Constraint (7): if one region sends materials to another region, the value of Z_i should be 1;
- Constraint (8): only if the earthquake risk of one region is smaller than a certain standard, the region can develop a first-grade or second-grade emergency logistics center;
- Constraint (9): the evaluation score of one region should higher than a standard, the region can develop a first-grade emergency logistics center;
- Constraint (10): the evaluation score of one region should higher than a certain standard, the region can develop a second-grade emergency logistics center;
- Constraint (11): one region cannot develop two or more emergency logistics centers;
- Constraint (12-14): Limits the range of variables.

4. Case Study

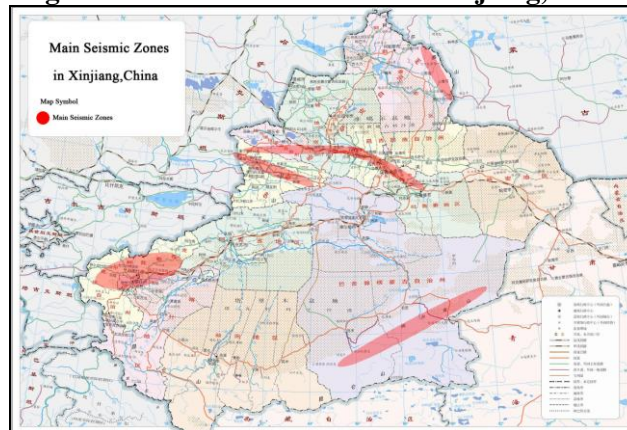
This paper adopts data of Xinjiang, China as an example to design a location proposal, check the feasibility of the above ideas and methods.

4.1 The Target regions of Location Planning for Emergency Logistics Center System

The main seismic zones in Xinjiang, China are Altay Seismic Zone, Horgos- Manas– Turpan Seismic Zone, Yining- Xinyuan Seismic Zone, West Kunlun Seismic Zone and Aytln Seismic Zone and so on, earthquakes occur frequently, shown as fig. 2. According to Administrative divisions, Xinjiang can be divided into 88

regions, as the target regions of the location planning for emergency logistics center system.

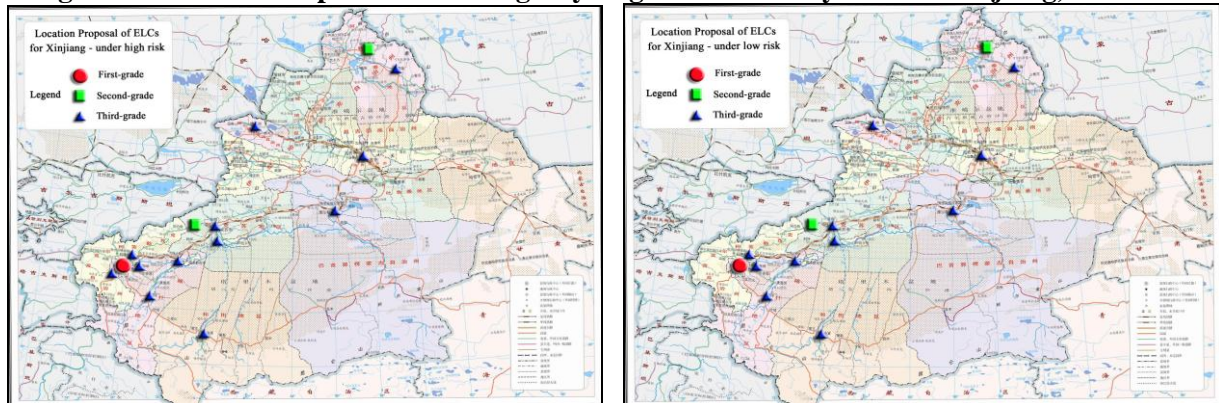
Figure 2: Main Seismic Zones in Xinjiang, China



4.2 Location Proposal Design

Because of the unpredictable feature of earthquakes, this paper designs location planning proposals under a high disaster risk and a low disaster risk. In equation (1), as to the variable of φ_0 , value of 1 represents the low-risk and value of 0.1 represents of high-risk. After the comprehensive estimation and calculation towards the weighted distances, this paper adopts the LINGO software to calculate the model and gets two proposals towards the high-risk and low-risk as shown in fig. 3. For the high-risk, this emergency logistics center system is made up by 1 first-grade emergency logistics centers, 2 second-grade emergency logistics centers and 12 third-grade emergency logistics centers. For low-risk, the figure is 1, 2, 11.

Figure 3: Location Proposals for Emergency Logistics Center System for Xinjiang, China



a. Location proposal under high-risk

b. Location proposal under low-risk

Through the comparison of the two proposals, we can see that more emergency logistics centers should be built under high earthquake risks. Thus, the relief capacity of the system is strengthened; the average distance between emergency logistics centers is shorter; the stability and invulnerability will also be improved.

Table 1: Comparison of Location Proposals under High-Risk and Low-Risk

IFSPA		
Index	High-risk	Low-risk
Relief Capacity	1	94.7%
Cost	1	97.9%
Average distance between emergency logistics centers	1	102.1%

5. Conclusions

The paper focuses on the location planning problem and raises an integrated idea and method towards this problem. This paper establishes an evaluated index system to check the feasibility of one region to develop emergency logistics centers and designs an equation to calculate a weighted distance between the regions on consideration of earthquake risks. Finally, this paper designs a dynamic optimization model based on Mixed Integer Programming to make an optimized location proposal. And the method are proved reasonable and effectively by the case of Xinjiang Province in China. It can illustrate that the model and method raised in this paper could sufficiently meet the practical solution need.

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Appendices

Table 1: Feasibility Degree for Target Regions to Develop Emergency Logistics Centers (Part)

No.	Target Region	Evaluation Score	No.	Target Region	Evaluation Score
1	Urumqi	5.27	45	Ulugqat	1.98
2	Yining	3.75	46	Lop	1.97
3	Tacheng	3.60	47	Qapqal	1.90
4	Korla	3.59	48	Pishan	1.89
...
43	Kashgar	2.92	87	Alar	0.12
44	Chira	1.99	88	Tumxuk	0.07

Figure 1: LINGO Software Running Interface for the Model Running

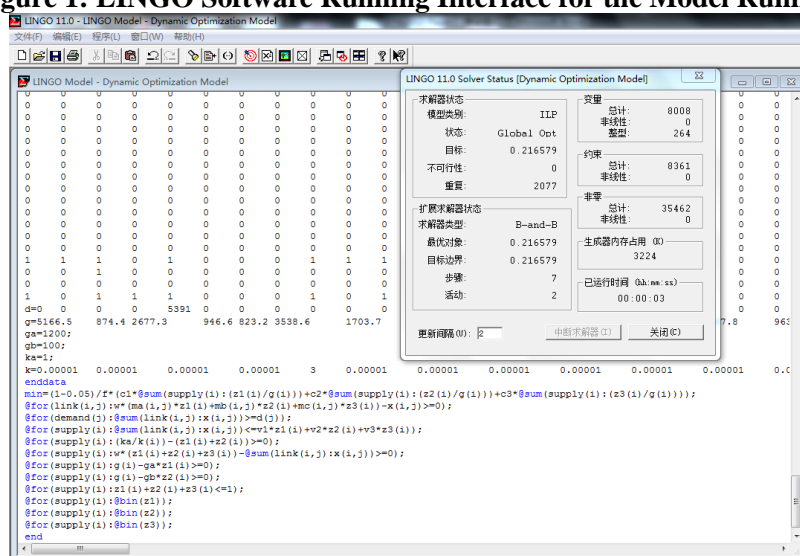


Table 2: Location Results from the Dynamic Optimization Model (Part)

No.	Target Region	First Grade	Second Grade	Third Grade	No.	Target Region	First Grade	Second Grade	Third Grade
1	Urumqi	0	0	1	45	Ulugqat	0	0	0
2	Yining	0	0	0	46	Lop	0	0	0
3	Tacheng	0	0	0	47	Qapqal	0	0	0
4	Korla	0	0	1	48	Pishan	0	0	0
...
43	Kashgar	1	0	0	87	Alar	0	0	0
44	Chira	0	0	0	88	Tumxuk	0	0	0

A Lexicographic Optimization Approach for Berth Schedule Recovery in Container Terminals

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Abstract

In container terminals, the planned berth schedules often have to be revised because of disruptions caused by severe weather, equipment failures, technical problems and other unforeseen events. In this paper, the problem of berth schedule recovery is studied to reduce the influences caused by disruptions. A multi-objective multi-stage model is proposed considering the characteristics of different customers and the trade off of all parties involved in the container terminal system. A method incorporating the lexicographic optimization is proposed to deal with the multi-criteria nature of the problem. Numerical experiments were provided to illustrate the validity of the proposed model and algorithms. Results indicate that the designed model and algorithm can tackle the berth plan recovery problem efficiently because that the trade off among all parties involved are considered. And, it is more flexible and feasible with the aspect of practical applications considering that the objective order can be adjusted by decision makers.

Keywords: Container terminals, berth schedule, disruption management, lexicographic optimization

1. Introduction

Berths are important resources of container terminals and the good scheduling of berths can improve operation efficiency, decrease the vessel turnaround time and lead to higher competitive of container terminals. However, during operation, irregular disruptions caused by unforeseen events such as severe weather, equipment failures and technical problems etc. often occur. These events may cause tremendous disruption, and thus decrease the operation efficiency and service level of container terminals. Once these disruptions happen, the initial plan may be infeasible, and modification of current or future schedule should be undertaken to minimize the negative impacts of the disruption.

Disruption management is a methodology that copes with disruptions in real time (Yu and Qi, 2004). The primary difference between disruption management and rescheduling is that rescheduling focuses on the minimization the original objective function whereas disruption management also aims to minimize the deviation of the new schedule from the original one (Kuster et. al. 2008). Disruption management is a field receiving increasing attention, and successful applications include airline operations, supply chains and machine scheduling etc.

Comparing existing studies on disruption management, the disruption management of berth schedule has following characteristics: (1) Complex constraints. The operation system of container terminal consists of many interrelated sub-processes. When optimizing the recovery scheme of berth schedule, the relation of berth schedule with quay crane schedule and other sub-processes should be considered. (2) Benefit trade off

and customer priorities. The modification of berth schedule influences the benefits of shipowners, terminal operators, port authorities and trailer companies etc. Moreover, the sensitivity to ship delay differs according to the customers (mainly liner companies). Benefit trade off and customer characteristics should be considered when modelling the problem of berth schedule recovery. (3) Computation complexity. Berth schedule is an NP-hard problem (Kim *et al.* 2003), and the characteristics of disruption management require the high speed and efficiency of solution algorithms.

This article addresses the problem of berth schedule recovery based on disruption management method. A multi-objective multi-stage model is developed considering the characteristics of different customers and the benefit trade off of all parties involved in the container terminal system. The article is organized as follows. In Section 2, a brief review of previous works is given. In Section 3, model for berth schedule recovery is developed. Solution algorithms are designed in Section 4. Numerical experiments are provided to illustrate the validity of the proposed method in Section 5. Conclusions are given in Section 6.

2. Literature Review

Issues related to berth schedule have been receiving much attention these days. And many models and algorithms have been developed to optimize the berth allocation plan. E.g. Nishimura *et al.* (2001) developed a discrete berth schedule model and designed a solution method based on genetic algorithm. Imai *et al.* (2003) further developed a berth schedule model considering the docking priorities of different shipping companies. Kim and Moon (2003) solved the discrete berth schedule model with simulated annealing. Imai *et al.* (2005, 2007) developed models for continuous berth schedule problem and designed heuristics algorithms to solve the models. Wang *et al.* (2007) treated the berth allocation problem as a multi-stage decision problem and solved the problem with a stochastic beam searching algorithm.

There is inherent interrelationship between the allocation and scheduling of berth and quay cranes. Increasing studies are focus on simultaneous berth and quay crane scheduling issues. E.g. Park and Kim (2003) developed a mixed integer program to determine the berthing positions, berthing times, and the QC assignments. Imai *et al.* (2008) developed a model to optimize berth schedule and quay crane allocation simultaneously, and a heuristic algorithm was designed to solve the problem. Meisel and Bierwirth (2009) also studied the simultaneous berth allocation and QC assignment problem. A local refinement procedure and two meta-heuristics are presented. Moreover, in the model for simultaneous berth and quay crane scheduling problem developed by Liang *et al.* (2009), the influence of quay crane quantity on average operation efficiency was considered.

The above studies were based on the supposition of certainty environment, and no impact of uncertainty factors on berth schedule was considered in these studies. However, uncertainty (e.g. vessel arrival and loading/unloading time) and disruption events widely exist in terminal operation system and have influence on the performance of terminal operation. Researchers begin to address the problem of terminal scheduling under uncertainty. E.g. Han *et al.* (2010) studied the berth and quay crane scheduling problems with uncertainties of vessel arrival time and container handling time. A mixed integer programming model was proposed to generate robust berth and quay crane schedule. Angeloudis and Bell (2010) studied job assignments under uncertainty for AGV in automated container terminals. A new AGV dispatching approach was developed, which can operate under uncertain conditions within a detailed container terminal model.

Disruption management is another method to tackle scheduling problem with uncertainties. Models and algorithms have been developed to tackle disruptions in supply chains, machine scheduling and airline operation etc. E.g. Yu (2004) developed a disruption management model for airline scheduling and designed a solution system called Crew-Solver. Liu *et al.* (2008), Abdelghany *et al.* (2008), and Clausen *et al.* (2010) further analysed the main problems in airline disruption management and developed disruption recovery models. Oke and Mohan (2009), Xiao *et al.* (2007) studied the coordination and recovery of supply chain after disruptions. Petrovic and Duenas (2006), Qi *et al.* (2006) developed disruption recovery models for machine scheduling and designed solution algorithms. Walker *et al.* (2005) developed a disruption management model for recovery of rail timetable schedule and crew assignment.

For the disruption management of container terminals, Zeng et al. (2011) developed a disruption recovery model for berth and quay crane schedule. And a solution method based on local rescheduling and tabu search was designed. Based on exist studies, this paper proposed a multi-objective and multi-stage disruption recovery model for berth schedule. The model considers the sensitivity of different customers to vessel delay and the benefit trade off of different parties.

3. Disruption Recovery Model

3.1. Model assumptions

Generally, berth schedule is to determine the berth times and positions of each vessel within a given planning horizon considering priority, length, arrival and handling time of each vessel. In this paper, the continuous berth schedule method is used, and quay crane assignment is considered. In the berth schedule model, the berth position, berth time and number of quay craned assigned to each vessel are optimized, but the routing of each quay crane is not considered. The objective is to minimize the penalty cost resulting from vessel delays and the additional cost resulting from no-optimal berthing location of vessels.

We formulate the model for berth schedule recovery considering that the berth schedule is pre-determined. And the following assumptions are made:

- (a) Berth schedule is represented by a two dimension axis, with vertical axis representing the berth position and horizontal axis the representing berth time;
- (b) There are no physical restrictions, that is, the water depth of terminal berth can meet all vessels;
- (c) Vessel operation time is inverse proportional to the number of quay cranes assigned;
- (d) There is a minimum number of quay cranes assigned to a vessel;
- (e) If a vessel is delayed because of disruptions events, the berth plans of successor vessels need to be modification, and also the quay crane assignment.

3.2. Variables and parameters

To formulate the disruption recovery model, the following parameters and variables are defined:

Parameters:

- L : Total length of a berth line which is denoted by the number of 10m segments;
- N : The number of unfinished vessels when disruptions happen;
- Q : The number of quay cranes;
- T : Set of time points represented by hour;
- a_i : Expected arrival time of vessel i ;
- d_i : Expected departure time of vessel i , which is usually determined by the contracts between shipping companies and terminal operators;
- l_i : The length of vessel i , which is represented by the number of 10m segments;
- b_i : The optimal berthing location of vessel i , Where yard trailers have the minimum transport cost;
- q_i^{\min} : The minimum number of quay cranes required to serve vessel i simultaneously;
- q_i^{\max} : The maximum number of quay cranes allowed to serve vessel i simultaneously;
- w_i : The number of quay crane hours needed to finish the operation of vessel i ;
- c_{1i} : The unit additional cost (yard trailers transport cost) of vessel i , resulting from non-optimal berthing location, which is given as USD/m;
- c_{2i} : The unit delay penalty cost of vessel i , which is given as USD/h;
- c_3 : Unit operation cost rate of quay cranes, which is given as USD per quay crane hour;
- M : A sufficient large constant;

x_i^0 : The berthing position of vessel i in initial berth schedule;
 y_i^0 : The berthing time (operation starting) of vessel i in initial berth schedule.

Variables:

x_i : Integer, the berthing position of vessel i in recovery schedule;
 y_i : Integer, the berthing time of vessel i in recovery schedule;
 e_i : Integer, the time that the operation of vessel i is completed according to recovery schedule;
 r_{itq} : Binary, set to 1 if q quay cranes are assigned to vessel i at time point t , and 0 otherwise;
 Z_{ij}^x : Binary, set to 1 if vessel i is located to the left of vessel j in the recovery schedule, and 0 otherwise;
 Z_{ij}^y : Binary, set to 1 if vessel i is berthed before vessel j in the recovery schedule, and 0 otherwise.

3.3. Model formulation

The berth schedule recovery influences the benefit of terminal operators and liner companies. To reflect the benefit trade off and decrease disruptions to all parties involved, a multi-objective programming method is used. The objective is to minimize the deviation between initial and recovery schedule, vessel delay and operation cost etc. When disruptions happen, recovery scheme is searched based on current resources, constraints and operation states. The model can be formulated as follows:

$$\min f_1 = \sum_{i=1}^N \{c_{1i}|x_i - b_i| + c_3 \sum_{t \in T} q_{it}\} \quad (1)$$

$$\min f_2 = \sum_{i=1}^N c_{2i}(e_i - d_i)^+ \quad (2)$$

$$\min f_3 = \sum_{i=1}^N (x_i - x_i^0)^+ \quad (3)$$

$$\min f_4 = \sum_{i=1}^N (y_i - y_i^0)^+ \quad (4)$$

s.t.

$$\sum_{i \in N} \sum_{q \in R_i} q \times r_{itq} \leq Q, \forall t \in T \quad (5)$$

$$\sum_{q \in R_i} r_{itq} = r_{it}, \forall i = 1, \dots, N, \forall t \in T \quad (6)$$

$$\sum_{t \in T} r_{it} = e_i - y_i, \forall i = 1, \dots, N \quad (7)$$

$$\sum_{q \in R_i} q \times r_{itq} \geq w_i, \forall i = 1, \dots, N \quad (8)$$

$$x_i + l_i \leq x_j + M(1 - z_{ij}^x), \forall i, j = 1, \dots, N, i \neq j \quad (9)$$

$$e_i \leq y_j + M(1 - z_{ij}^y), \forall i, j = 1, \dots, N, i \neq j \quad (10)$$

$$z_{ij}^x + z_{ji}^x + z_{ij}^y + z_{ji}^y \geq 1, \forall i, j = 1, \dots, N, i \neq j \quad (11)$$

$$y_i \geq a_i, \forall i = 1, \dots, N \quad (12)$$

$$x_i \in \{0, 1, \dots, L - l_i\}, \forall i = 1, \dots, N \quad (13)$$

$$R_i \in (q_i^{\min}, q_i^{\max}), \forall i = 1, \dots, N \quad (14)$$

$$z_{ij}^x, z_{ij}^y = 1, \text{ or } 0, \forall i, j = 1, \dots, N, i \neq j \quad (15)$$

Eq.1 is to minimize the operation cost including additional costs resulting from non-optimal berth locations of vessels and the operation cost of quay cranes. Eq.2 is to minimize the vessel delay. Eq.3-4 are to minimize the deviation between recovery and initial schedule, namely to minimize the modifications and thus decrease the system disruptions.

Constraints are represented by Eq.5-15. Eq.5 denotes that the maximum quay crane can be used simultaneously. Eq.6-8 defines the operation starting and ending time for each vessel. Eq.9 is the relation of berthing location between two vessels. Eq.10 is the relation of berthing time between two vessels. Eq.11 ensures there are no conflicts between two vessels with respect to berthing time and location. Eq.12 ensures that each vessel berths after its expected arrival time. Eq.13 ensures that each vessels berths within the quay line. E.q.14 constrains the maximum and minimum quay cranes assigned to a vessel.

4. Lexicographic Optimization Approach

4.1. Lexicographic optimization

Usually, the concept of Pareto optimality is used for the multi-objective optimization problem. A solution \vec{z}^* of the multi-objective optimization problem presented in Eq.1-15 is said to be Pareto optimal if there is not another $\vec{z} \in Z$ that $f_i(\vec{z}) \leq f_i(\vec{z}^*)$ for all $i \in N$ and $f_j(\vec{z}) < f_j(\vec{z}^*)$ for at least one index j . According to the definition of Pareto optimality, moving from on Pareto solution to another needs trading off. Weighting methodology is a widely used trading off approach, in which priority of the objectives are reflected by the weights. However, the most obvious problem with weighting methodology is the difficulty of choosing the weight as weights is based either on vague intuition or error experimentation with different weighting values of users (Miettinen, 1999). Moreover, it is involved a linear combination of different criteria thus has the limitation that can not find solutions in a non-convex region of the Pareto front (Li, 1996).

The lexicographic approach has several advantages over weighting (Marler and Arora, 2004) and has been started to be widely used in engineering applications (Ocampo et al. 2008). Lexicographic optimization establishes a hierarchical order among all the optimization objectives (Prats et al. 2010). If priority exists, a unique solution exists on the Pareto hyper-surface (Kerrigan and Maciejowski, 2002).

A standard process for lexicographic optimization approach is to solve a sequential order of single objective optimization problems. The objective functions are arranged from the most important f_1 to the least important f_n . The most important objective function is minimized first ($f_1^* = \min_{z \in \mathcal{P}} [f_1(z)]$), subject to the original constraints. If there is only one solution, it is the solution of the whole multi-objective problem. Otherwise, the second most important objective function is minimized. A new constraint is added to ensure that the most important objective function preserves its optimal value. The process goes on iteratively until all the objectives are considered. A solution obtained according a more important objective serves as an

additional constraint of a less important objective, which can be represented by $f_i^* = \min_{z \in \mathcal{P}} [f_i(z) | f_j(z) \leq f_j^*, j = 1, \dots, i-1]$.

4.2. Lexicographic optimization approach for berth schedule recovery

Usually, the contracts between terminal operators and shipping companies specify the details of vessel operation time. Different vessels have different sensitivity to operation delay. There is also different influence on terminal operators. Therefore, in the berth schedule recovery, the objective hierarchical order is different for different kinds of vessels.

According to customer importance and delay sensitivity, vessels are segmented to three types, namely, key line vessels, trunk line vessels and feeder line vessels etc (the segmentation criterion is shown in Table 1). Base on this segmentation, the berth schedule recovery is solved by three stages.

The first stage: recovery model for key line vessels

$$\text{Lex min}[f_2, f_3, f_4, f_1] \quad (16)$$

$$\text{s.t.} \quad (5)-(15)$$

Key line vessels are most sensitive to delay, and there are strict constraints to vessel turnaround time in operation contract. Therefore, key line vessels should be considered first in berth schedule recovery, and vessel delay f_2 is the most important objective. Moreover, f_3 and f_4 are also important objectives as the changing of berthing location and time may result in increasing of system adjust time and decreasing of system reliability.

The second stage: recovery model for trunk line vessels

$$\text{Lex min}[f_2, f_1, f_3, f_4] \quad (17)$$

$$\text{s.t.} \quad (5)-(15)$$

Vessels of international trunk lines are important customers for terminal operators and also have high sensitivity to delay. When modifying berth plan for this kind of vessel, vessel delay is the most important objective, then the operation cost and lastly the deviation of berthing location and time.

The third stage: recovery model for feeder line vessels

$$\text{Lex min}[f_1, f_3, f_4, f_2] \quad (18)$$

$$\text{s.t.} \quad (5)-(15)$$

Comparing to vessels of key and trunk lines, feeder line vessels are more flexible in operation and are less sensitive to vessel delay in terminals. Therefore, for berth schedule recovery of this kind of vessels, the objective order is operation cost, schedule deviation and vessel delay.

Table 1: Customer Segmentation Criterion

Criterion	Key line vessels	Trunk line vessels	Feeder line vessels
Type of shipping lines	Key lines	International trunk lines	Short or feeder lines
Sensitivity to delay	Very sensitive	Sensitive	Not sensitive
Importance to terminal operators	Very important	Very important	Important
Penalty cost to delay	Very high	High	Normal

5. Solution Algorithms

The design of solution algorithms is based on vessel segmentation and objective sequential optimization. The process of berth schedule recovery is divided to three stages, namely, rescheduling key line vessels first, then, trunk line vessels, and finally feeder line vessels. In each stage, the objective sequential optimization method is used.

In the first stage, the algorithms are iterated four times. In the first iteration, the berth schedule is optimized according to objective f_2 , and an optimal value f_2^* is obtained. In the second iteration, the objective function is f_3 , and $f_2 \leq f_2^*$ is added to constraints. The optimal value f_3^* for f_3 is obtained. In the third iteration, the objective function is f_4 , and $f_2 \leq f_2^*$, $f_3 \leq f_3^*$ is added to constraints. Optimal value f_4^* is obtained when the iteration is finished. In the last iteration, the objective function is f_1 , and $f_2 \leq f_2^*$, $f_3 \leq f_3^*$, $f_4 \leq f_4^*$ is added to constraints.

The processes for the second and third is similar to the first stage. The objective sequential orders are given by Eq.17-18. In iterations of each stage, tabu search is used to search the optimal solution. Main operations of tabu search are as follow:

Encoding and decoding of solutions: A solution is represented by a two dimension (x_i, y_i) encoding method. Vessels are added to a time-location plane ensuring rectangles are not overlapped. It is similar to two dimensional bin packing problem which has been widely studied. And the encoding method for bin packing problem is used. To improve the solution efficiency, the number of quay crane assigned is supposed to be same as initial schedule, but the constraints of quay crane capacity is ensured.

Initial solutions: The berth schedule recovery is based on initial schedule, thus the module for initial solution generation is not needed. The state that disruptions happen is used as initial solution. This supposition can overcome the dependence of tabu search to initial solution.

Neighbor space searching: Two moves, namely ‘swapping’ and ‘varying’ are used to obtain neighbor solutions. ‘Swapping’ moves are to exchange the berthing position (location and time) of two vessels. ‘Varying’ moves change berth location (x_i) or time (y_i) of a vessel. The moving units for berthing location and time are 10m/move, 1h/move respectively. In neighbor space searching, each ‘swapping’ move includes multiple ‘varying’ moves.

Tabu conditions: For ‘swapping’ moves, the tabu condition is the two vessels that exchange berthing positions, which is represented by $tabu(i, j) = l$. If vessel i and j exchange berth positions, ‘swapping’ moves are forbidden within l times searching. Tabu condition for ‘Varying’ is represented by $tab(x_i, y_i, d^x, d^y) = c$, which means that the same moves are forbidden c times once a ‘varying’ move happens.

Aspiration criteria: Aspiration criteria are based on objective value. If the value of a solution is less than the optimal value currently obtained, the solution is not restricted by tabu table.

Stopping criterion: After a pre-determined iteration is reached, algorithm stops. The manimun iterations for ‘swapping’ and ‘varying’ moves are 50, 20 respectively.

6. Numerical Experiments

Numerical examples are given to illustrate the validity of proposed model and algorithms. Firstly, the model in this paper (model A) is compared with model developed by Zeng et.al. 2011 (model B). In model B, the objective function is the sum of cost of vessel delay, quay cranes and yard trailers. The berth reschedule strategy is selected for comparison.

Data of a container terminal in Tianjin Port are used. Vessel arrival data from July 15 to July 22 in 2007 are selected. The length of berth line is 1202 meters, and the number of quay cranes is 12. The unit efficiency of quay cranes is 30 moves/h. c_{1i} , c_{2i} and c_3 are set to $100l_i/230$ USD/m, $2000l_i/230$ USD/h, and 200 USD respectively.

There are 25 vessels are considered in the plan horizon. The numbers of key line vessels, trunk line vessels and feeder line vessels are supposed to 8, 10 and 7 respectively. Seven scenarios are set supposing vessels 2, 6, 8, 10, 14, 15, 19 are delayed 12 hours separately. Results are given in Table 2.

Comparing to model B, the proposed model (model A) increases the total vessel delay and yard trailer operation cost. The average increase of total vessel delay increase 2 percent and the average yard trailer operation cost increase 3.5 percent. However, the delay for key line vessels decreases greatly. Moreover, schedule deviation decreases greatly in proposed model as the schedule deviation is treated as the second or third objective in key line vessels recovery.

Although the proposed model increases total vessel delay, it more feasible to practical application considering that the delay costs of key line and trunk line vessels are high and have serious impact on terminal development. In addition, the proposed model decreases the schedule deviation, thus reduces the influence of disruption events on operation system.

Table 2: Results for Different Scenarios

Scenarios		Model A				Model B			
No	Delayed vessel	Total vessel delay(h)	Delay for key line vessels (h)	Cost increase for yard trailer (USD)	Schedule deviation f_3 (m)	Total vessel delay(h)	Delay for key line vessels (h)	Cost increase for yard trailer (USD)	Schedule deviation f_3 (m)
1	2	289.0	6.9	3700	762	277.9	68.3	3,558	852
2	6	230.4	5.8	4292	602	223.7	42.0	4,123	698
3	8	242.3	7.2	3104	482	234.8	57.2	2,988	635
4	10	238.9	6.8	3536	184	231.7	40.7	3,391	360
5	14	215.0	0	3364	72	209.1	36.5	3,235	163
6	15	220.3	4.8	3285	93	214.5	31.0	3,165	194
7	19	274.3	0	3422	84	267.6	24.3	3,307	152

Secondly, experiments are used to find the influence of vessel structure. Based on scenario 1 in Table1, seven scenarios are designed by increasing key line vessels, decreasing trunk and feeder line vessels. Results are given in Table 3.

With the increase of key line vessels, the total vessel delay increases firstly, and then decreases. When the number of key line vessels is more than 15, the total vessel delay of model A is less than that of model B. This is because that vessel delay is the most important objective when recovering schedule for key line vessels, total vessel delay decreases with the increase of key line vessel ratio. In addition, the operation cost for yard trailers increases with the increase of key line vessels, which indicates that the cost of berth schedule recovery increases with the increase of key line vessels.

Table 3: Impacts of Vessel Structure

Scenarios		Model A				Model B			
No	Number of key line vessels	Total vessel delay(h)	Delay for key line vessels	Cost increase for yard trailer	Schedule deviation f_3 (m)	Total vessel delay(h)	Delay for key line vessels	Cost increase for yard trailer	Schedule deviation

			(h)	(USD)			(h)	(USD)	n_{f_3} (m)
1	2	274.5	0	3632	437	277.9	68.3	3,558	852
2	5	279.6	0	3658	694	277.9	68.3	3,558	852
3	8	289.0	6.9	3700	762	277.9	68.3	3,558	852
4	10	302.9	22.4	3748	784	277.9	118.3	3,558	852
5	15	266.4	46.2	3852	761	277.9	168.3	3,558	852
6	20	259.2	125.4	3985	816	277.9	248.2	3,558	852
7	25	243.6	243.6	4293	831	277.9	277.9	3,558	852

7. Conclusions

In this paper, a multi-stage and multi-objective model is proposed to minimize the negative impacts of disruptions on berth schedule. And a lexicographic optimization based method is designed to solve the model. Numerical experiments indicate the validity of the proposed model and algorithms. The model considers the characteristics of different customers and benefit trade off of all parties involved, thus can improve the scientific of berth schedule recovery. Moreover, it is more flexible and feasible with the aspect of practical applications as the objective order can be adjusted by decision makers.

The objective of disruption management for berth schedule is to obtain modification scheme efficiently after disruptions happen. In fact, the recovery difficulty and cost can be reduced by improving the schedule robust at the stage of berth planning. Moreover, the analysis and evaluation of disruption events are also helpful to the forming of robust scheduling strategy. Therefore, the combination of robust scheduling and disruption management is a new and valid method for container terminal scheduling under uncertainty, which is an interesting topic for future study.

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Technical Change and Bias in Container Shipping Industry

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Abstract

This paper is aimed to measure and analyze the technical change and bias for container shipping lines. By utilizing Binswanger's (1974) model, a translog cost function and the associated cost share function are formatted to measure the magnitude of the rates of technical change (*RTC*) for three Taiwanese container shipping lines. Among them, there are only two shipping lines to show, on average, a positive but trivial *RTCs* with less than 1% annual growth rate. The result implies that the *RTCs* of the shipping lines seem to be very sluggish or even degenerate, regardless of aggressively delivering larger containerships and fleet. By decomposing the *RTCs* into its sources, this study uncovers that the technical change for a shipping line should focus on improving the cost efficiency with respect to reduce personnel and administrative costs and to collect more shipments to fully utilize the invested fleet slots. As to the technical change bias, the result indicates that the bias has shifted the utilization of factor inputs toward more heavily using the intermediate material input. On account of the soaring oil prices, it is a fairly reasonable reaction for a shipping line to switch the utilization of factor inputs to be more fuel-saving pattern. In addition, the finding also suggests that it should be very cautious to interpret the technical change bias, if the variations of observable historical cost share are incorrectly applied.

Keywords: Technical change, technical change bias, container shipping, translog cost function

1. Introduction

Over the past two decades, the container shipping industry has undergone dramatic changes on the scale of containerships and fleet delivered. The initial driving force behind introducing large ships is to achieve the cost benefit of size economies (Jansson and Shneerson, 1987; Talley, 1990; Lim, 1998; Cullinane and Khanna, 1999, 2000). However, the decisions among the major shipping lines to greatly deliver large containerships into market have caused a severe over-tonnage situation and pushed the freight rate to be an unprofitable level. Alternatively, the significant increase of ship size or the huge investment on the terminal and stevedoring operations are usually expected to improve the productivity of a container shipping line.

For alleviating the burden on the huge capital cost and the operational and financial risk associated with the deployment of large containerships, in addition, it has also driven the major shipping lines to cooperate with each other in the form of strategically shipping alliance (Cullinane and Khanna, 2000; Talley, 2000). By coordinating sailing schedules, marketing efforts and utilization of slots capacity, a shipping alliance enables an individual member to maintain the quality of service without purchasing or chartering in entire vessels. As a result, a shipping alliance has brought a great impact on the operational and managerial skills for a shipping line. In general, productivity growth depends both on technical change applied in the process of production and on the organizational and managerial innovation. Evidently, the deployment of large containerships and fleet by running with a shipping alliance implies that the operational skills and technology has to be changed accordingly.

On assessing the impact of technical change on the cost structure, literaturally, it is a widely discussed issue to study the variations of factor input utilization over time. For example, to deliver a large containership with double slots capacity does not necessarily require an equally proportional increase in the use of factor inputs. For reaching an optimal combination of factor inputs, in addition, the variations of input prices will also alter

the utilization of factor inputs for a shipping line. By deducting the effect of input price changes from the observed cost shares of factor inputs, in theory, the Hick's technical change bias is designed to measure the extent of variations of factor input utilization while the prices of factor inputs are hold constantly.

In literatures, Talley (2000) demonstrates that the technical improvement in shipping industry, containerization, has revolutionized the ocean transportation of general cargo. Focusing on the subsidized U.S. liner shipping industry, Klein and Kyle (1997) presents a translog variable profit function to estimate the technological change. By applying a translog cost function, the aim of paper is to investigate the technical change and bias for the container shipping lines in Taiwan. The paper is organized as follows: In section 2, a theoretical model is developed by applying a translog cost function to analyze the rate of technical change (hereafter, *RTC*) and bias. Based on the theoretical derivations, in section 3, an empirical study is performed to measure and decompose the *RTC* for the three container shipping lines in Taiwan. Finally, some conclusions are drawn in section 4.

2. Theoretical Model

2.1 Specification of cost function

Besides the labor and fuel variables, an intermediate material variable is also included into the production function to represent the all factor inputs, except labor and fuel inputs, invested for the terminal, stevedoring, sailing, administrative and managerial activities by a shipping line. As like the general specification of cost function (Caves *et al.*, 1981; Nelson, 1989; Wang and Chen, 2005), a time trend variable (T) is added into the function to express the technical changes over time. Also, the function incorporates a variable representing the average ship size (S) to act as another proxy variable of technical changes which separates the effect of delivering large containerships from the neutral technical changes over time. That is, it is hypothesized that a shipping line would reach an optimal combination of factor inputs under a given level of output (Q) and existing technical conditions (S and T). Accordingly, the production function for a shipping line can be specified as:

$$Q = f(L, F, M, K, S, T) \quad (1)$$

where L , F , M and K represent the quantities of labor, fuel, intermediate material inputs and stock of capital invested, respectively.

By the theory of duality, a total cost function corresponding to the above production function can be specified as:

$$TC = f(P_X, Q, K, S, T) \quad (2)$$

where P_X is the price vector corresponding to the vector of factor inputs, X .

With reference to Christensen *et al.* (1975) and Christensen and Greene (1976), the translog variable cost function applied in this study can be specified in the following form:

$$\begin{aligned} \ln VC = & \beta_0 + \sum_f \delta_f D_f + \sum_i \beta_i \ln P_i + \beta_Q \ln Q + \beta_K \ln K + \beta_S \ln S + \beta_T T + \frac{1}{2} \sum_i \beta_{ii} \ln P_i^2 + \frac{1}{2} \beta_{QQ} (\ln Q)^2 \\ & + \frac{1}{2} \beta_{KK} (\ln K)^2 + \frac{1}{2} \beta_{SS} (\ln S)^2 + \frac{1}{2} \beta_{TT} T^2 + \sum_{i \neq j} \beta_{ij} \ln P_i \ln P_j + \sum_i \beta_{Qi} \ln Q \ln P_i + \sum_i \beta_{Ki} \ln K \ln P_i \\ & + \sum_i \beta_{Si} \ln S \ln P_i + \sum_i \beta_{Ti} \ln T \ln P_i + \beta_{QK} \ln Q \ln K + \beta_{QS} \ln Q \ln S + \beta_{QT} \ln Q \ln T + \beta_{KS} \ln K \ln S \\ & + \beta_{KT} \ln K \ln T + \beta_{ST} \ln S \ln T \end{aligned} \quad (3)$$

where $i, j = F, L, M$; and D_f is a dummy variable for a shipping line f to allow for the difficulties on measuring the distinctly managerial and operational skills among the shipping lines studied. In addition, these

immeasurable attributes are also assumed to remain constant over time. Given the translog variable cost specified in Eq. 3, the restriction corresponding to the condition of linear homogeneity in input prices can be set as:

$$\sum_i \beta_i = 1 \quad (4)$$

In order to form a symmetrical Hessian matrix to satisfy the regular property: symmetry in input prices, it requires some additional restrictions:

$$\sum_i \beta_{ij} = \sum_i \beta_{Qi} = \sum_i \beta_{Ki} = \sum_i \beta_{Si} = \sum_i \beta_{Ti} = 0 \quad (5)$$

to imply $\beta_{ij} = \beta_{ji}$. For enhancing the efficiency of the estimation process, economically, the Zellner's seemingly unrelated regression (SUR) technique is generally applied to estimate the parameters of the cost function by treating the cost function and the associated cost share functions as a simultaneous equation system (Caves *et al.*, 1981; Nelson, 1989; Azzez, 2001). By Shephard's lemma, the cost share equations for variable factor inputs can be derived by logarithmically differentiating Eq. 3 with respect to the prices of variable factor inputs. Accordingly, the cost share equation for factor input i can be written as:

$$S_i = \frac{\partial \ln VC}{\partial \ln P_i} = \beta_i + \sum_j \beta_{ij} \ln P_j + \beta_{Qi} \ln Q + \beta_{Ki} \ln K + \beta_{Si} \ln S + \beta_{Ti} T \quad (6)$$

2.2 Measure of technical change

The *RTCs* over time are usually used to measure the level of technical change for a firm (Stevenson, 1980; Kopp and Smith, 1985; Apergis and Rezitis, 2004). In term of revealing the cost efficiency of the technical changes for a firm over time, the general contribution of technical change can be obtained from the negative of the elasticity of cost with respect to time. The negative sign reflects the sense that a positive effect of technical change implies a reduction in cost. Thus, the *RTC* can be measured by taking the partial derivative of Eq. 3 with respect to time as follow:

$$RTC = -\frac{\partial \ln C}{\partial T} = -(\beta_T + \beta_{TT}T + \sum_i \beta_{iT} \ln P_i + \beta_{KT} \ln K + \beta_{QT} \ln Q + \beta_{ST} \ln S) \quad (7)$$

By utilizing Eq. 7, the *RTC* for a shipping line in each period can be further decomposed into several different effects of technical change as follows:

$$T_T = -(\beta_T + \beta_{TT}T) \quad (8)$$

$$T_P = -\sum_i \beta_{iT} \ln P_i \quad (9)$$

$$T_K = -\beta_{KT} \ln K \quad (10)$$

$$T_Q = -\beta_{QT} \ln Q \quad (11)$$

$$T_S = -\beta_{ST} \ln S \quad (12)$$

To follow economics theory, T_T represents a pure shift of cost function geometrically parallel toward to the origin with leaving input shares unchanged and is generally viewed as neutral technical change. In contrast, the terms shown in Eqs. 9-12 represent the non-neutral effects of technical change. Theoretically, T_P captures

the shift of cost function for optimally adjusting the mix of inputs due to the changes of factor prices. The two terms, T_K and T_S , are set to indicate the effects of technical change by expanding the slots capacity of fleet and individual containership, respectively. These two effects are important for researchers to investigate the so-called size economies of a shipping line operating with steadily growing size of fleet and individual containership. The term of T_Q expresses the effect of technical change through moving more containers annually and can be applied to measure the effect of scale economies on the *RTC*. In practice, the term of scale economies reflects the effectiveness of marketing activities on fully utilizing the provided slots capacity.

2.3 Measure of technical change bias

Conceptually, the technical change bias is to measure the non-neutral efficiency difference if the technical change does not make the isoquant curve shift inwards homothetically. The concept of Hicks neutrality (Binswanger, 1974) in a form of continuous time is used in this study to define the technical change bias for a factor input i at time T as:

$$B_i = \frac{dS_i^*}{dT} \frac{1}{S_i} \quad (13)$$

where dS_i^* indicates the cost share change of factor input i as the relative factor prices are held constant. To follow Hicksian sense of technical change, the bias is defined as factor i -saving if $B_i < 0$, i -neutral if $B_i = 0$, and i -using if $B_i > 0$.

Since the technical change bias defined in Eq. 13 is measured at constant input prices ratio, it is impossible for a researcher to know the bias through simply observing the changes of historical cost shares which are corresponding to the real prices of factor inputs over time. Furthermore, the observable changes of historical cost shares can be separated into two unobservable parts. The first one, shown as Eq. 13, represents the technical change bias measured at a constant ratio of input prices. The second one represents the factor substitution, reflecting with the optimal adjustment of input combination in response to the changes of factor input prices. In summary, a change of historical cost share is determined by the relative scales of the two unobservable parts. Therefore, a technical change bias toward a pattern of factor i -saving may be enhanced or offset by the substitution effect to result in a respectively higher or lower change of historical cost share. If the two unobservable parts show an identical direction in their variations, as a result, an observed cost share may have a much stronger change than the unobserved technical change bias.

Empirically, the problem is to sort out to what extent the historical cost share changes have been due to unobservable technical change bias and to what extent to price ratio changes (Binswanger, 1974). For a given historical cost share change, the first part has to be estimated before the second one can be measured and vice versa. To follow the definition of technical change bias shown in Eq. 13, the unobservable term, dS_i^* , can be estimated by taking a total differentiation to the Eq. 6 with the factor prices being remained constant:

$$dS_i^* = \beta_{Q_i} d \ln Q + \beta_{K_i} d \ln K + \beta_{S_i} d \ln S + \beta_{T_i} dT \quad (14)$$

The relationship between unobservable dS_i^* and observable dS_i can be further expressed as:

$$dS_i^* = dS_i - \sum_j \beta_{ij} d \ln P_j \quad (15)$$

In Eq. 15, it states that the technical change bias for factor input i , dS_i^* , can be sorted out by subtracting the unobservable portion of cost share change which is caused by the changes of input prices from the observed cost share change of factor input i . Theoretically, the technical change bias demonstrates how much the ratio of factor inputs has been shifted away from the original level, if the ratio of factor prices is held constant. In

contrast, the term, $\sum_j \beta_{ij} d \ln P_j$, contains the substitution parameters of cost function which determine by how much the changes in factor price ratios along have altered the cost share of factor input i . In theory, it represents the adjustment of cost share for reaching an optimal combination of factor inputs in response to a change of factor prices ratio.

3. Empirical Application

3.1 Data Sources

The data used in the empirical study is taken from a sample covering the three largest container shipping lines in Taiwan. The sample period spans from 1991 to 2009. The data is mainly drawn from the annually financial statements of the three shipping lines. The financial statements are required by the law of government to be published in public and available at the website of Taiwan Stock Exchange Incorporation (<http://newmops.tse.com.tw/>). The data regarding to the slots capacity of the owned and chartered-in containerships for each shipping line studied are drawn from the relevant issues of the *Containerisation International Yearbook*.

3.2 Model Estimation

As stated in section 2.1, the SUR technique is applied to estimate the parameters in the model. Since the summation of the all cost share equations must be one by definition, the labor cost share equation is deleted from the regression system to avoid a singular covariance matrix in estimation. The estimates of parameters are invariant with respect to the selection of the deleted equation. Due to the limitation of paper length, the estimated parameters of the translog variable cost equation along with their t -ratios are available upon request from the author. The R^2 values for translog variable cost, fuel share and intermediate materials share equations are 0.99, 0.955, and 0.935, respectively. Of the total 38 parameters in the translog variable cost equation, there are 23 parameters to be statistically significant at 10% level. And, the two set of estimated parameters in the two share equations all present 6 out of 8 parameters to be statistically significant at 10% level.

3.3 Results on the Rate of Technical Change

In Table 1, it shows that the RTC s for the shipping lines studied are inconsistent. Apart from the shipping line C, on average, the other two shipping lines present a positive but trivial RTC with less than 1% annual growth rate. It implies that the technical changes of the shipping lines seem to be very sluggish or even degenerate, regardless of aggressively delivering larger containerships and fleet by the shipping lines. In terms of decomposing the RTC into its sources, the numbers presented in Table 1 indicate that the fleet scale variable (K), ship size variable (S) and output variable (Q) are the three major components on determining the signs of the RTC s. Among the three major components, the fleet scale variable contributes the major component on determining the RTC s for the three shipping lines. Alternatively, the ship size variable also presents a positive but less strong contribution on the RTC s. Totally, the positive effects of the fleet scale and ship size variables on the RTC s suggest that the uprisng fleet scale and containership size have significantly brought a significant contribution on the improvement of the cost efficiency for the shipping lines studied. Compared to T_K and T_S , the values of T_P show that the adjustments for reaching an optimal factors combination corresponding to the variations of factor prices create a trivial contribution to the RTC s. This result indicates that the shipping lines have effectively but insignificantly improved the cost efficiency by adjusting the optimal combination of factor inputs while the prices of factor inputs are changed.

In contrast, the output variable plays a critical but negative role on determining the RTC s of the shipping lines studied. This negative dominance strongly implies that the annual containers shipped by the shipping lines are not enough to efficiently utilize the offered fleet capacity. Regardless of the effectiveness on improving the cost structure with deploying large fleet and containerships, obviously, the expected size economies not really exploited by the shipping lines due to too less containers shipped. In other words, the totally annual amount of containers shipped by a shipping line presents a more critical role on increasing the RTC . And therefore, it

implies that to collect and transpose more containers may be rather effective way to improve the cost efficiency for a shipping line.

Surprisingly, the term of neutral technical change, T_T , shows a negative and minor contribution on the RTC s of shipping lines studied. One possible explanation for the negatively neutral technical change could be the rigidity on hiring a nearly fixed number of crews, regardless of how large a containership being deployed. Meanwhile, it may be also resulted from doing a more sophisticated transshipment and more times of lifting movements per container shipped, when a shipping line expands its service network by deploying a larger containership fleet. Furthermore, the growing organization for administrative, marketing and operational activities associated with the expansion of service network is the other reason to cause a negatively neutral technical change. Except carrier C, overall, the negatively neutral technical change in absolute value is less than the non-neutral effects of technical change. The finding suggests that the technical change for a container shipping line should focus on improving the cost efficiency with respect to reduce personnel and administrative costs and collect more shipments to fully utilize the invested slots capacity.

Table 1: The Decomposition of the Rates of Technical Change for Shipping Lines

	T_T	T_P	T_K	T_Q	T_S	RTC
Carrier A	-0.0045	0.0032	0.0497	-0.0525	0.0070	0.0028
Carrier B	-0.0045	0.0032	0.0467	-0.0513	0.0069	0.0009
Carrier C	-0.0045	0.0032	0.0434	-0.0490	0.0062	-0.0008

Note: figures above are all measured at the mean values of sample period.

3.4 Results on the Technical Change Bias

Since the scale and direction of technical change bias in each period may not be consistently developed during sample period, it should be very cautious to interpret the long-run trend of technical change biases for a given factor input. By accumulating the short-run biases, however, the long-run trend of biases becomes much easier to observe and interpret. For knowing the evolutionary path of technical change biases after base year t_0 , a series of cost share of factor input i with fixed factor prices will be developed firstly. In a discrete time variable, mathematically, the series of cost share of factor input i in absence of factor price changes can be expressed as:

$$S_{i,t_n}^* = S_{i,t_0} + \sum_{t=t_1}^{t_n} \Delta S_{i,t}^* \quad (16)$$

Conceptually, the series in each period shown in Eq. 16 reveals the summation of the real cost share at base year and the accumulated bias since base year. Furthermore, the series of standardized values can be computed by dividing the accumulated bias at year t_n by the cost share at base year t_0 as:

$$R_{i,t_n} = \frac{S_{i,t_n}^*}{S_{i,t_0}} = 1 + \sum_{t=t_0}^{t_n} \frac{\Delta S_{i,t}^*}{S_{i,t_0}} \quad (17)$$

For the factor input i , the series of R_{i,t_n} shows the ratio of cost share at time t_n associated with constant factor prices to the real cost share at base year. By taking the first difference of Eq. 17, a discrete change which is equivalent of Eq. 13 to compute technical change bias is expressed as:

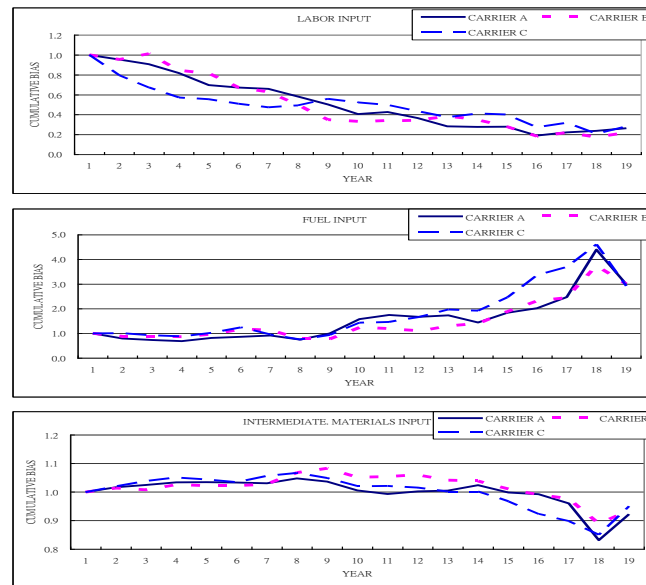
$$\frac{\Delta R_{i,t_n}}{\Delta t} = \frac{\Delta S_{i,t_n}^* / \Delta t}{S_{i,t_0}} = \frac{\Delta S_{i,t_n}^*}{\Delta t} \frac{1}{S_{i,t_0}} \quad (18)$$

Theoretically, the Eq. 18 illustrates that slopes of the line corresponding to Eq. 17 in each year are equivalent to the loci of short-run biases for a given factor input, if the Hick's definition shown in Eq. 13 is applied. For

comparing to the unobservable technical change bias shown in Eq. 18, the observable historical changes of real cost share of factor input i over time can be measured by replacing the $\Delta S_{i,t}^*$ term in Eq. 17 with $\Delta S_{i,t}$. Accordingly, two kinds of plots representing the revolutionary variations of cost share based on changed and unchanged factor input prices will be developed. At first, three plots which represent the historical changes of real cost share for the three factor inputs over the sample period are presented in Figure 1. Clearly, the plots indicate that the three shipping lines do have experienced a similarly evolutionary path for each factor input on the variations of real cost share over the past two decades.

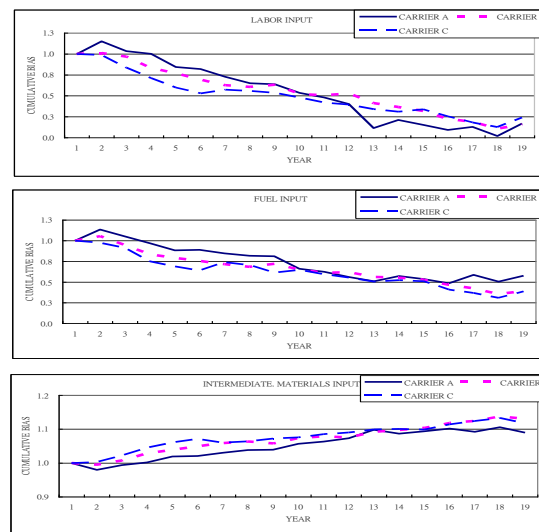
Meanwhile, the real cost shares among the shipping lines have gradually evolved to spend more cost expenditure on the fuel input, compared to the expenditures on labor and intermediate material inputs. In fact, the uprising cost shares for fuel input are resulted from the soaring oil prices during the sample period, especially after 2005. If the variations of the real cost share for a given factor input are incorrectly applied to interpret the technical change bias, apparently, the positive slope of fuel input shown in Figure 1 seems to be counter-intuitive. That is, it will incorrectly suggest that the utilization of factor inputs have been gradually shifted toward fuel-using, regardless of the fuel prices being increased significantly. Nevertheless, a totally different pattern of technical change bias has been derived, if Eq. 18 is followed to compute the bias.

Figure 1: The Changes of Cost Shares for Different Factor Inputs



By following Eq. 18, the technical change biases for the three shipping lines during the sample period are presented in Figure 2. Same as the plots shown in Figure 1, the consistent signs of slopes among the three shipping lines for each factor input indicates that the shipping lines have all developed a similarly evolutionary pattern of technical change biases during the past two decades. On interpreting the technical change bias, however, the evolutionary pattern is totally different from the one implied by the plots shown in Figure 1. Among the plots in Figure 2, the negative slopes of the lines for labor and fuel inputs definitely suggest that the technical changes for the three shipping lines have been steadily shifted toward the pattern of labor-saving and fuel-saving. In contrast, a positive slope for the intermediate input indicates that the bias has shifted the operational technologies and skills toward a pattern with more heavily using the intermediate material input. Since the performance of a container shipping line is quite vulnerable to the fluctuations of oil prices, most shipping lines have introduced more fuel efficient vessels with more efficient engines, devices and use of waste energy over the past decades. Facing with soaring fuel prices, it is a fairly reasonable reaction for a container company to change the utilization of factor inputs to be fuel-saving.

Figure 2: The Technical Change Biases for Different Factor Inputs



4. Conclusion

By applying Binswanger's (1974) model, a translog cost function and the associated cost share function are formatted to measure the direction and magnitude of the *RTC*s for three shipping lines in Taiwan. The outcomes deliver some implications for the cost efficiency of deploying large containerships fleet, and the variations of factor input utilization in absence of varying the factor input prices. Among the three shipping lines studied, on average, there are only two shipping lines to show a positive but trivial *RTC*s. It implies that the technical changes for the shipping lines seem to be very sluggish or even degenerate, regardless of aggressively adapting larger containerships and fleet. By decomposing the *RTC* into several components, categorized as neutral and non-neutral effects of technical change, the finding uncovers that the absolute value of negative neutral technical change is less than the positive summation of the non-neutral technical effects. Implicitly, it suggests that the technical change for a container shipping line should focus on improving the cost efficiency with respect to reduce personnel and administrative costs and collect more shipments to fully utilize the invested capacity slots. Finally, a Hicksian sense of technical change bias is applied to study the long-run pattern of biases on the utilization of factor inputs. The result shows that the technical change bias has shifted the utilization of factor inputs toward a pattern with more heavily using the intermediate material input. In response to the soaring oil prices, it is a fairly reasonable reaction for a shipping line to switch the utilization of factor inputs to be a more fuel-saving pattern. In addition, the finding also suggests that it should be very cautious to interpret the technical change bias, if the variations of observable historical cost share are incorrectly applied.

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A Comparison of Statistical Technique and Neural Networks Forecasting Techniques for Container throughput in Thailand

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Abstract

Containerization is the one of the important factors for Thailand's economic. However, forecasting is an important tool for predicting of container throughput growth of Bangkok Port, Private Wharves along the Chao Phraya River, Laem Chabang Port and Songkhla Port are the significant ports of Thailand. Moreover, the existing literature emphasizes only Statistical Technique.

The purpose of this paper is to explore Statistical Technique and ANN for predicting future container throughput at four main ports in Thailand: Bangkok Port, Private Wharves along the Chao Phraya River, Laem Chabang Port, and Songkhla Port. Bangkok Port and Private Wharves are located on the bank of the Chao Phraya River that connected marine transport to Bangkok. Laem Chabang Port is a deep-sea port in the Eastern region, while Songkhla Port is a port in the Southern Area.

Research methodology starts with identify factors affecting cargo throughput for all four ports and then collect data from several sources such as the Bank of Thailand, Office of the National Economic and Social Development Board, World Bank, Ministry of Interior, and Energy Policy and Planning Office. These factors are entered into Statistical technique and MLP forecasting models that generate a projection of cargo throughput. Subsequently, the results are measured by the Root Mean Squared Error (RMSE) and the Mean Absolute Error (MAE).

Keywords: Forecasting, Neural Network, Statistical Techniques, Root Mean Squared Error and Mean Square Error, Container throughput

1. Introduction

Today container transport is an important transportation system in the rapid growth of international trade, especially in the country dominating both of importing and exporting like Thailand. The economic expansion increases the volumes of containers at Bangkok Port, and the growth of this container throughput is one of the most important determinants of the large investment for container terminal. Therefore, the forecasting accuracy of the future throughput is crucial to both of private sectors and government offices for planning and managing their future development.

Nowadays, Port Authority of Thailand applies linear regression method and time series to forecast the number of containers in Bangkok Port. The factors are adopted following as: GDP, exchange rate and world GDP (PAT, 2010). The weakness of this approach is the non-consideration of the regression on the relationship between the volumes of containers and the important macroeconomic variables such as interest rate and inflation rate.

Many researchers have been interested in the relationship between the factors of economics and the volumes of import and export. Greenaway and Nam (1988) analyzed the various indicators of industrialization and macroeconomic. Ram (1985) used a regression model to analyze the relationship between export and economic growth. Their study has confirmed the strong relationship of the export performance and the economic growth. The other research is written by Ahaugar et al. (2010). They defined the macroeconomic variables for forecasting such as Growth rate of industrial production, inflation rate, interest rate, exchanged rate, rate of return on stock public, unemployment rate, oil price, GDP and money supply. Chou et al. (2008) presented the importance of the non-stationary relationship between the volumes of containers and the macroeconomic variables. They used volumes of export containers, volumes of import containers, population, industrial production index, GNP, GNP per capita, wholesale GDP, agricultural GDP, industrial GDP and service GDP for the factors in the regression analysis. As the contributions of previous researches, Thailand's key economic indicators affected to exporting and importing and then the main economic indicators which are GDP, world GDP, exchange rate (compare to the U.S. dollar), population, inflation rate, interest rate and the fuel price were applied in this research. This paper is based on the literature gap of previous work from Peng and Chu (2009). They suggested exploring other forecasting methods which apply the latest technologies such as neural networks, artificial intelligence or advanced data mining techniques to predict container throughput volumes. This paper applied neural network model and linear regression for forecasting container throughput volumes in Bangkok Port, Private Wharves along the Chao Phraya River, Laem Chabang Port and, Songkhla Port. As the existing, forecasting technique for Bangkok Port focuses only linear regression method, the comparison of the existing technique and the neural network technique is necessary to find the most appropriate for predicting the container throughput at Bangkok Port, Private Wharves along the Chao Phraya River, Laem Chabang Port, and Songkhla Port. Therefore, the purpose of this paper is to explore and compare the neural network method and linear regression technique for predicting the container throughput at Bangkok Port and the others.

The structure of this paper is organized as follows: Section 2 reviews the relevant literature. Section 3 presents the research methodology. Section 4 presents the results and gives a discussion of the results. Finally, some conclusions are provided in Section 5.

2. Literature Review

This section is devoted to the various techniques of forecasting and the comparison of forecasting techniques.

2.1 Forecasting technique classification review

Forecasting is a method or a technique for estimating many future aspects of a business or other operation. Forecasting methods can help estimate many such future aspects of a business operation. It serves many predicting information and help people and organizations planning in the future and making decisions. There are three types of forecasting models: Time Series, Cause-and-Effect, and Judgmental (Armstrong, 2001).

2.1.1 Time series Model

Time series is an ordered sequence of values of a variable or data at equally spaced time intervals. The factors are not affected for this forecasting, but the predicting depends on the past values such as the growth in sale, gross national product or stock market analysis.

The example of time series methods is Simple Moving Average, Autoregressive Moving Average (ARMA), Exponential Smoothing, Extrapolation, Linear Prediction, Trend Estimation, Growth Curve and Box-Jenkins. Time Series Analysis is used for many applications such as Economic Forecasting, Sales Forecasting, Budgetary Analysis, Stock Market Analysis, Process and Quality Control and Inventory Studies.

2.1.2 Cause-And- Effect Model

The second forecasting model is cause-and-effect.

Cause-and-effect model assumes that the variable to be forecasted is exhibited by the explanatory relationship with one or more independent variable. The purpose of this model is to discover the form of the relationship and to forecast future the variable (Makridakis et al., 1998). Regression Analysis can be applied for several purposes including data description, parameter estimation and control. Linear regression applications are adopted almost every fields, engineering, physical sciences, economics management and so on (Montgomery, 1982).

The other technique of cause-and-effect model is a neural network. This method is used for many applications such as financial, exchange rate, water flow, and inventory demanding and so on. The first research adopts neural networks method for weather forecasting (Hu and Root, 1962). The main characteristic of neural network is the ability to learn from the environment, and to improve its performance through learning (Haykin, 1999; Skapura, 1996).

Multilayer perceptrons (MLPs) are fed-forward neural networks, and train with the standard back propagation algorithm. MLPs are supervised networks then they learn how to transform input data into a desired response, and widely used for modeling prediction problems (Lippmann, 1987).

2.1.3 Judgmental Model

This model does not require data in the same manner as quantitative forecasting methods and is mainly the product of judgment and accumulated knowledge. Estimating method that relies on expert human judgment combines with a rating scale, instead of on hard (measurable and verifiable) data. For example, for a new product, there are no past data on sales on which to base estimates of future sales. Qualitative methods consist of three kinds of data are open-end interviews, direct observation and written documents (Patton, 1990).

2.2 The comparison of Linear Regression and Neural Networks forecasting

The comparison of Neural Networks and traditional forecasting methods are applied following as, forecasting the performance of inventory management (Mitea, 2009), river flow forecasting (Baareh et al., 2006 and Zhang, 2001), prediction about investment opportunities (Noori et al, 2010), prediction for Bank Performance (Baker and Tahir, 2009), evaluation of the capital structure (Pao, 2008), forecasting water demanding (Pulido-Calvo et al., 2007), water temperature (Sahoo et al., 2009) and financial time series forecasting (Dhamija and Bhalla, 2010) (shown in Table 1). The result all of the researches show that ANN performed better than traditional forecasting.

Table 1: Examples of Papers in Comparison of Neural Network and Regression Analysis

Authors	Year	Titles	Methodology	Contributions to research
I.Pulido-Calvo, P.Montesinos, J.Roldan and F.Ruiz-Navarro	2007	Linear regression and neural approaches to water demand forecasting in irrigation districts with telemetry systems	Linear multiple regression and feed-forward computational neural network (CNNs)	-CNNs performed better than the regressions when water demand and climatic variables were considered as input data.
G.B. Sahoo, S.G. Schladow and J.E.Reuter	2009	Forecasting stream water temperature using regression analysis, artificial neural network, and Chaotic non-linear dynamic models	Artificial Neural Network (ANN), Multiple regression analysis (MRA) and Chaotic non-linear dynamic	-Micro Genetic Algorithm and Back propagation neural network (uGA-4 BPNN) is the one of ANN method, is the highest prediction performance among all techniques.

Authors	Year	Titles	Methodology	Contributions to research
			algorithm (CNDA)	
N.M.A.Baker and I.M.Tahir	2009	Applying Multiple Linear Regression and Neural Network to Predict Bank	Multiple linear regression, MLP	-MLP is more accuracy and more complex than regression, while regression is quite simple.
R.Noori,A.Kha kpour, B.Omidvar and A.Farokhnia	2010	Comparison of ANN and principle component analysis-multivariate linear regression models for predicting the river flow based on developed discrepancy ratio statistics	Multiple linear regression, MLP	-MLP model is the satisfactory predicting performance.

3. Research Methodology

This section focuses on the process of this research. The research methodology is divided into four steps as follows:

3.1 Study factors influencing container throughput

The factors are selected from the results of researches as Greenway and Nam (1988), Ram (1985) and Chou et al. (2008). The others are Thailand's Economic indicators and both of importing and exporting factors.

3.2 Collect data from Yr 2001-2011

3.2.1 Dependent factors:

A Number of Container Throughput in Bangkok Port, Private Wharves along the Chao Phraya River, Laem Chabang Port, and Songkhla Port.

3.2.2 Independent factors:

GDP, world GDP, exchange rate (compare to U.S. dollar), population, inflation rate, interest rate and fuel price.

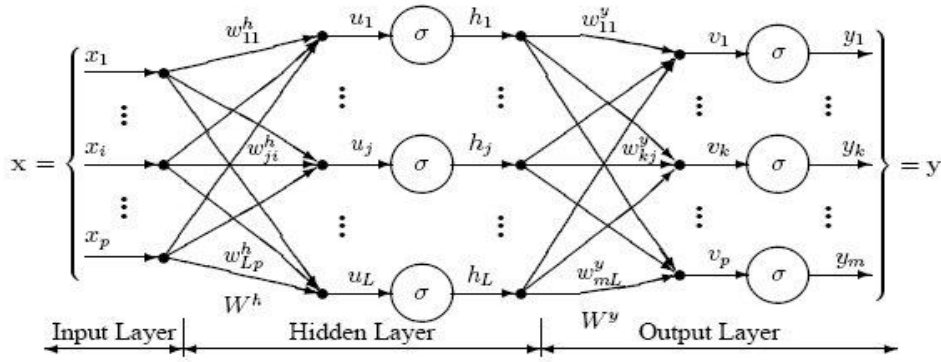
The data are collected in 11 years (132 months or 132 sets). The sources of data are from the Bank of Thailand, Office of the National Economic and Social Development Board, World Bank, Ministry

3.3 Analyze and select the appropriate method for forecasting the container volume

3.3.1 MLP

Multilayer perceptron (MLP) is the most common type of neural network used for supervised prediction. The basic unit (neuron) of the network is a perceptron. This is a computation unit, which produces its output by taking a linear combination of the input signals and by transforming this by a function called activity function.

Figure 1: The Multilayer Perceptron Neural Network Model



Parameter of MLP

Input node: 7 nodes (7 inputs)

Hidden: 4 nodes, following as $(\text{input} + \text{output}) / 2$

Output: 1 node

Epoch = 500

Learning rate = 0.3

Momentum = 0.2

Activation function = Sigmoid

3.3.2 Linear Regression

Linear regression analysis is a technique for modeling the linear relationship between two or more variables. It is one of the most widely used of all statistical methods. In banking and finance literature, regression analysis is a very common method used to find the determinants of bank performance. The general linear regression model, with normal error terms, simply in terms of X variables, is shown in Equation 1.

$$Y_i = \beta_0 + \beta_1 X_{i1} + \beta_2 X_{i2} + \dots + \beta_{p-1} X_{i,p-1} + \varepsilon_i \quad (1)$$

Where $\beta_0, \beta_1, \dots, \beta_{p-1}$ are parameters, $X_{i1}, \dots, X_{i,p-1}$ are unknown constants, ε_i are independent $N(0, \sigma^2)$, $i = 1, \dots, n$

Then, the data and parameters were set in software, called Weka 3.7.3. This software was created by researchers at the University of Waikato in New Zealand. Weka contains tools for data pre-processing, classification, regression, clustering, association rules, and visualization. A neural network model for forecasting is included training or learning and testing mode. The training set is used to build the network model by historical data and then the forecasting ability of the network is evaluated from the test set. During the training process, an overall error measure is minimized to get the estimates of the parameters of the models which are the connecting weights of the network. This research has used 132 data sets which are appropriate to build a concrete neural network model. The reliability of variables can be increased by using the updated variables to run the model for container throughput prediction. Furthermore, time horizon may be divided into quarters or months for higher accuracy.

3.4 Evaluate of the Accuracy Measurement and Correlation Coefficient

There are several statistical methods available to evaluate forecast performance. The commonly used forecast accuracy measures are; Mean Error (ME), MSE (Mean squared error), RMSE (Root mean squared error), MAPE (Mean absolute percentage error) and so on.

The scope of this work is forecasting the container throughput at Bangkok Port, Private Wharves along the Chao Phraya River, Laem Chabang Port and Songkhla Port. Two techniques were selected to apply in this research: the root mean squared error (RMSE) and the mean absolute error (MAE). These accuracy measurements techniques can be used to determine how well the output fits the desired output, but it doesn't necessarily reflect whether the two sets of data move in the same direction. For instance, by simply scaling the network output, the MSE can be changed without changing the directionality of the data. The equations of root mean squared error (RMSE) and mean absolute error (MAE) are shown as follows:

$$MAE = \frac{\sum_{i=1}^n |y_i - \hat{y}_i|}{n} \quad (2)$$

$$RMSE = \sqrt{\frac{\sum_{i=1}^n (y_i - \hat{y}_i)^2}{n}} \quad (3)$$

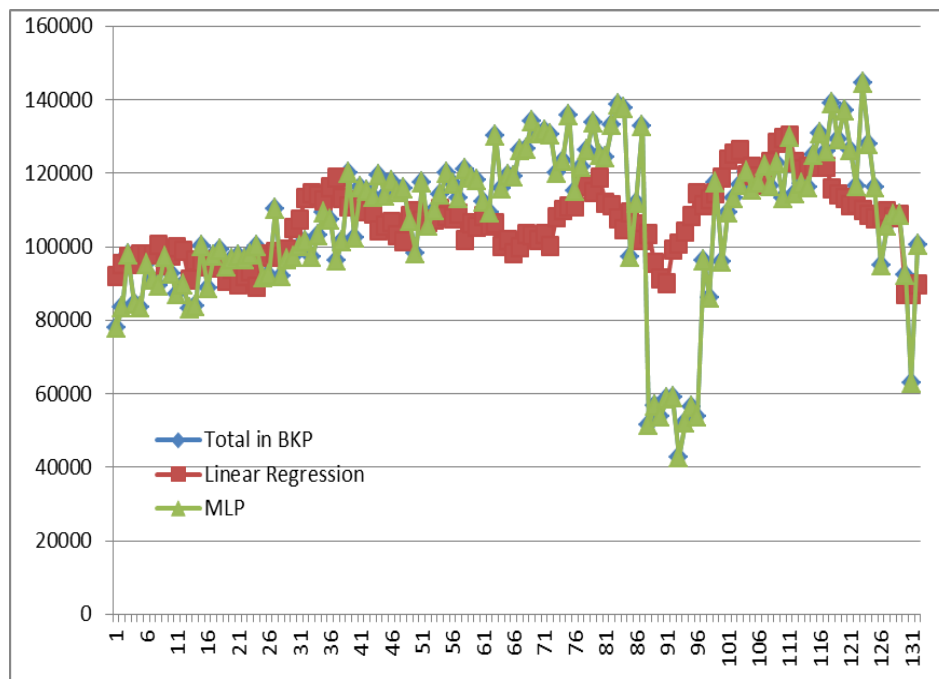
Note, y and \hat{y} are the actual and the predicted values of the time series in period i respectively. Obviously, both of measures are positive in value and the smaller the value obtained for each of the measures calculated, the better the performance of the forecasting method. The correlation coefficient measures the strength and the direction of a linear relationship between two variables.

The quantity r , called the linear correlation coefficient, measures the strength of the analysis. The value of r is between $-1 \leq r \leq +1$. The $+$ and $-$ signs are used for positive correlations and negative correlations respectively.

4. Results and Discussion

This section presents the results of the multilayer perceptron model and linear regression for forecasting container throughput and gives the discussion of the results. The results from the model are shown in Figure 2 illustrating the actual and predicted number of container throughput volumes in monthly order. The trend of the container throughput had gone up since 2001 until the year 2011 the trend seems to go down because of the effect of the world's economic crisis.

Figure 2: The Comparison of Actual and Predicted Container Throughput Volumes of Bangkok Port (Unit: TEU)



When using the both of MLP and Linear Regression technique to predict container throughput volumes, the factors discussed in Section III were analyzed to find the relationship of the factors to the number of exporting and importing. From the analysis, the world's GDP, interest rate, exchange rate, population and interest rate affect to the export volumes. On the other hand, fuel price and interest rate affect to the cost of productions which mean the factors give impact to the volumes of import including interest rate, exchange rate, population, inflation rate, fuel price and GDP. Applying these factors in the neural networks for predicting import and export container volumes, the predicted container throughput volumes are presented in Table 2.

Table 2: Performance of Forecasting the Number of Container in Thailand

Item	Bangkok Port		Laem Chabang Port		Private Wharves		Songkhla Port	
	MLP	Regression	MLP	Regression	MLP	Regression	MLP	Regression
Correlation Coefficient	0.94	0.85	0.98	0.97	0.96	0.82	0.85	0.72
MAE	6820.69	8028.55	8820.67	10612.98	1237.75	2241.7	376.89	434.87
RMSE	8430.47	9832.65	9430.46	12087.56	1628.88	2861.32	492.08	538.37
Total Number	132	132	132	132	132	132	132	132

5. Conclusion

It is very important for the government offices and private organizations to predict the volumes of container throughput at the important ports in Thailand such as Bangkok Port, Private Wharves along the Chao Phraya River, Laem Chabang Port and Songkhla Port. The forecast number will enable Port Authority of Thailand and Harbour Department to manage and develop the main infrastructures and equipments for supporting the country's competitiveness. Moreover, the Port Authority of Thailand and Harbour Department will be able to cooperate with the government and private sectors to invest for port business in order to serve transportation system and facilities for customer satisfactions, to ensure optimum efficiency and fairness of port services. The result of this study contributes to the knowledge of what factors are important and affect to the container volumes which forecasting technique is the most appropriate technique for predicting container throughput at Bangkok Port, Private Wharves along the Chao Phraya River, Laem Chabang Port and Songkhla Port. The forecasting accuracies from MAE and RMSE are satisfactory, and the values of correlation coefficients are more than 75%, but only Linear Regression method at Songkhla port is less than 75%. In this research, MLP is the most valuable tool for forecasting. MLP uses the information contained in the input data but it needs lots of input data and training is too slow. Setting parameters for MLPs is complex, while linear regression is easy and simple explanation on the estimated parameters. However, the accuracy of linear regression technique is less than MLP.

This paper has made a significant contribution to the knowledge for a new forecasting technique which provides the most accurate prediction for container throughput at Bangkok Port, Private Wharves along Chao Phraya River, Laem Chabang Port and Songkhla Port. The paper has worked on the literature gap by comparing neural network and linear regression for forecasting container throughput.

The finding of this research will assist officers at Bangkok Port and the others dealing with the future number of containers throughput as well as coping with yard planning and management. It would be interesting to extend the present study to investigate container throughput volumes of other international ports in further research. In the future, it may be worthwhile to extend or combine the power of earlier forecasting algorithms and methods such as various causal techniques or hybrid forecasting methods to improve the accuracy of forecasting.

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Statistical Reasoning in Judicial Contexts

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Abstract

This paper discusses the statistical reasoning in judicial contexts. Courts in modern world encounter complex cases that require the proof by statistical evidences, and the interpretations of such evidences need a sound statistical reasoning. Judge Oliver Holmes opined in 1897 that the man of the future is the man of statistics and the master of economics, and that future time has entered the judicial scene in the 20th century. Starting from allowing statistical evidence into court by classifying it as one of the hearsay rule exceptions, the courts formulate more and more principles on guiding how lawyers exercise their statistical reasoning. In the recent case of *Matrixx* (2011), the U.S. Supreme Court took a long discussion on the proper statistical reasoning approach on interpreting test of significance result when *p-value* less than 0.05.

The authors submit that with the advance in technologies, the use of statistical evidences as means of judicial proof will become more and more common. Statistician seems to become the required expert witness in cases related to discrimination, antitrust, and pharmaceutical torts, statistical reasoning becomes a new way to prove a complicated case by lawyers. It is no wonder that when one search the phrase “conference on forensic statistics”, the google search will list about 3,620 results.

Keywords: Anecdotal evidence, Hypothesis testing, *Matrixx v. Siracusano* (2011), Statistical evidence, Statistical reasoning, Statistical significance at 5 percent, Type I error, Type II error.

1. Introduction

The fields of law and statistics have interacted for many years. Judge Oliver Wendell Holmes published his famous article *The Path of the Law* in 1897. Holmes distinguished the nature of legal reasoning with that of statistical reasoning:

“The rational study of law is still to a large extent the study of history. History must be a part of the study, because without it we cannot know the precise scope of rules which it is our business to know. It is a part of the rational study, because it is the first step toward an enlightened skepticism, that is, towards a deliberate reconsideration of the worth of those rules. When you get the dragon out of his cave on to the plain and in the daylight, you can count his teeth and claws, and see just what is his strength. But to get him out is only the first step. The next is either to kill him, or to tame him and make him a useful animal. For the rational study of the law the blackletter man may be the man of the present, but the man of the future is the man of statistics and the master of economics” (Holmes, 1897).

Before conducting an analysis on a concept, one has to first define it. Statistical reasoning is a term that could be defined differently in different context. From pedagogical perspective, statistical reasoning can be seen as a data-driven approach with an emphasis on data production and the measurement of its variability (Moore,

1997). From the perspective of empirical enquiry, some researchers, such as Chamber (1993), focuses on the three components of statistical reasoning: (a) preparing data, (b) analyzing data, and (c) communicating the results. While other researchers, such as MacKay and Oldfield (1994), describe it as a five-stage cycle with each one deals with a specific task. The five stages are: (a) identify the statistical problem, (b) design a plan to tackle the statistical problem, (c) collect the relevant statistical data, (d) analysis of the statistical data, and (e) communicate the conclusion. In this article, the authors adopt a broad overview on the concept of statistical reasoning to include all methods and concepts used in presenting statistical evidence in court. Therefore, this article will emphasize conceptual interpretations in the legal context rather than calculations or mathematical details.

This article is divided into three major discussions. The section on literature review briefly outlines a historical account on how the courts and law professors' views on the use of statistical evidences to prove a legal case. Then, the first major discussion will be devoted to admission of statistical evidences. In this section, the authors will also discuss about the relationship between hearsay rule and statistical evidence, whether the lawyer owes a duty to disclose the process of deriving the statistical results, and the method of present statistical evidence. The second discussion focuses on determining the appropriate population of a sample, and this article deals with the courts' different treatments on this issue in medical and commercial cases. The final discussion concentrates on how the court views about statistical significance. The authors spent most of the writing on this section because the US Supreme Court in the *Matrixx* case (2011) settled on the idea that statistical insignificant (a *p-value* less than 0.05) does not mean the studied events are insignificant or non-material. The authors concluded that the US Supreme Court in *Matrixx* case essentially declares the judicial view in favor of Student (William Sealy Gosset) approach to test of significance over that of Fisher.

2. Literature Review

Statistics and the law share some common interests, such as interpretation of evidence, hypothesis testing and decision-making under uncertainty. For example, starting from the beginning of the 20th century, statistical techniques were being used to forecast the behaviors for offenders under parole (Borden, 1928; Burgess, 1928). During early 60s, an article about using statistical techniques in trademark litigation was published in *American Bar Association Journal* (Bonyne, 1962). Starting from the 60s, statistical professors started to publish in top journals on topic related to statistical concepts and law, such as, probability and crime (Mode, 1963), and statistician as expert witness in court (Matre, 1976) ; and law professors also published articles on statistical related areas on top law journals, such as *Harvard Law Review* (Finklestein, 1966).

Outside of academic world, practicing lawyers have voiced the misgivings about the statistical evidences used in courts. A trial lawyer observed that the abuse use of statistical techniques to “bolster sagging cases by applying the law of probability” on the forensic field (Houts, 1956). Negative comments can be found on probability theory as a model of proof (Tillers and Green, 1988; Thompson, 1986; Jaffee, 1985) and on particular applications of probability of statistics to legal proof (e.g., Kaye, 1986; Walker and Monahan, 1988; Sugrue and Fairley, 1983) have multiplied to the point of distraction.

Some law professors shared such view, for example, Laurence Tribe warned the legal profession about the evils of using statistical techniques to quantify the probative value of certain forms of evidence. He showed there existed some inherent limitations in the linking of mathematics to procedural rule making. Wrote professor Tribe in *Harvard Law Review* (Tribe, 1971):

“Reluctant as I am to make confident pronouncements about the final limits of mathematics in the fact-finding process of a civil or criminal trial, I am more reluctant still to attempt any definitive assessment of how far mathematical methods and models can acceptably be exploited in the rulemaking process that determines how trials are conducted. I have examined in some detail one simple model proposed by Kaplan and Cullison to assist in the determination of standards of proof, and have concluded that their approach, like that of Finkelstein and Fairley in the context of mathematical evidence, is more misleading than helpful. ... Surely the time has come for someone to suggest that the union would be more dangerous than fruitful.”

Nevertheless, with the advance in technologies, the call of statistical reasoning in judicial proof has been irresistible. In recent decades, the use of statisticians as expert witnesses, especially in cases relating to shipping accidents, shipment rejection on the grounds of defects in samples, discrimination, and pharmaceutical torts has swelled. What demonstrative evidence was to the 1960s and early 1970s, “statistics have become to the 1980s—the hottest way to prove a complicated case” (Lauter, 1984). And the trend continues to the 1990s, for example, the Royal Statistical Society organized its first conference on forensic statistics in 1991 (Royal Statistical Society, 1991).

3. Admission of Statistical Evidences

The issue of whether statistical reasoning should be used in contract implementation was discussed in courts as early as 1920s. Even before Sir Ronald Fisher published his famous work *Statistical Methods for Research Workers* in 1925, the US court has already admitted statistical evidence in making decision. During 1920s, agreements of international sales of goods started to incorporate contractual provisions calling for the acceptance or rejection of an entire shipment based on tests of a small sample thereof. In *Andersen & Co. v. U.S.* (1922), the US government condemned an entire shipment of salmon (a total of 1974 cases) on the basis of two small random samples (each sample consisted only 192 cans). The government inspectors pointed to the court that in sample #1, they found 55 cans contained rotten and decayed salmons (about 29 percent). The second sample showed that 47 cans released offensive odor and at the beginning of decomposition (about 25 percent). Based on the findings of the two random samples, the government inspectors made an inference that the entire shipment of salmons was defective. The Court of Appeals upheld the condemnation.

About 24 years later, in *U.S. v. 431/2 Gross Rubber Prophylactics* (1946), the government condemned a shipment of prophylactics as adulterated and misbranded. There were two brands in the shipment. The government only randomly tested 82 items in the first brand and found 6 were defective; and for the 108 items tested in the second brand, 8 items were defective. The manufacturer made two arguments (a) it was unfair to condemn the entire shipment based on the results of two defective random samples; (b) the tests were destructive in nature. The court referred to the *Andersen* decision to confirm the use of random sampling technique, and the court further held that the manufacturer should bear the obligation to provide samples for testing even the process is inherently destructive. By the mid twentieth century, the use of random samples as court evidences in estimating the characteristics of the population was well established in law.

3.1 Hearsay Rule and its Exceptions

Hearsay evidence refers to those statements a witness have heard from others, which was made out of court, and the lawyer introduces it for the purpose to prove the truth of the matter asserted. As a general rule, hearsay evidence of a fact is not admissible in courts. For example, a witness who came to the scene 20 minutes after a traffic accident happened, testifies in the court that: “I heard the passenger said the light was red when the accident was happened”, the statement is hearsay when it is offered to show that the light was red. It satisfies all the elements of a hearsay statement because the statement was made by passenger (not witness), and passenger made the statement out of the court. The statement is introduced to prove the light was red (the truth of the statement). In theory, if we look to the nature of statistical evidence, it fits perfectly within the definition of hearsay evidence. The data were provided by survey respondents (other than the statistician) and were communicated to the statistician out of court. The results of the analysis were introduced to prove the truth of the matter asserted. However, the hearsay rule does not create a serious barrier to the admission of statistical evidence.

The reason is that because the lawyers are allowed to offer statistical studies to explain the basis of an expert’s opinion, and not for proving the truth of the matter asserted. For example in *United States v. Esquivel* (1996), a Hispanic criminal convicted made an appeal by arguing that the procedure to select the juries to hear his case was unfair because the procedure led to a substantial underrepresentation of the race he belongs.” The court admitted the 1990 census data for showing the number of Hispanics eligible for jury service, not to prove the procedure is fair or unfair, but to explain an alternative method of comparison: whether to use the total population of Hispanics in the counties or the number of Hispanics eligible to serve as jurors as the base of comparison.

Besides, lawyers can bring in statistical studies under the learned treatise exception to the hearsay rule. For example, under Section 803 (18) of the US Federal Rules of Evidence, either party can introduce a learned treatise as evidence, irrespective of whether it is being used to rebut the opposing party. Such texts are now considered an exception to hearsay, so long as its introduction be complied with two conditions:

Condition #1: When the learned treatise being introduced, there must be an expert witness on the stand, and

Condition #2: The actual learned treatise itself does not go to the jury. It comes into evidence only by being read to the jury.

Therefore, the battle over statistical evidences concerns more on weight rather than their admissibility.

3.2 *Duty to Disclosing other Analyses*

In Malautea v. Suzuki Motor Co.(1993), the court held that all attorneys, as ‘officers of the court,’ owe duties of complete candor and primary loyalty to the court before which they practice. When statisticians conduct data analysis, there are variety ways to discover the pattern of the data. To permit a fair evaluation of the analysis, some commentators argue that counsel who knows other data sets or analyses that do not support his client’s position should reveal this fact to the court. He should not mislead the court by presenting only favorable results. In other words, they proposed that lawyers should owe a duty to the court for making disclosure of core information (Schwarzer, 1993), and an attorney's duty to his client should never outweigh his responsibility of keeping the smooth functioning of the judicial system.¹

3.3 *Method of presenting Statistical Evidence*

Most courts adopt a sequential format for the presentation of evidence. The plaintiff’s witnesses are called first, one by one, without interruption. The witnesses make their testimonies in response to specific questions. Testimony will not take the form of an extended narration.

However, on presenting statistical evidence, the courts may allow more narrative testimony, and the expert might be permitted to give a brief tutorial on statistics as a preliminary to some testimony. The judge may call the experts of the opposing sides to testify at about the same time. In bench trials, the judge may have both experts placed under oath and permit them to engage in a dialogue, so that experts are able to say whether they agree or disagree on specific points. The judge and counsel can interject questions. Such practices can help the judge to understand the statistical evidence and the theories behind them (Fienberg, 1989).

4. **Appropriate Population**

After the court settled on the issue of allowing statistical evidences into judicial consideration, it faced the problem of how to determine the appropriate population of the samples. In other words, the issue in this stage is how to use sample data to characterize a population. The population is the whole class of units that are of interest, and the sample is a set of units chosen for detailed study. In theory, inferences from the part to the whole are justified only when the sample is representative, there are many literatures on discussing how large a sample should be (Altman, 1980). For example, when samples are being collected to form “Anecdotal evidence”, the courts would believe that it cannot infer event A causes event B by simply pointing out the event A occurs before event B.²

4.1 *Appropriate Population in Medical case*

In Daubert v. Merrell Dow Pharmaceuticals, Inc. (1993), the court opined that any attempt to infer causation from anecdotal report shall be inadmissible as unsound methodology. To illustrate, Sir Norman McAlister

¹ Malautea v. Suzuki Motor Co., 987 F.2d 1536, at 1546 (11th Cir.1993).

² “Anecdotal evidence” means reports of one kind of event following another. Typically, the reports are obtained haphazardly or selectively

Gregg, the Australian ophthalmologist, who published his medical research results that for mothers who received exposure to German measles during pregnancy, would be followed by blindness in their babies (Gregg, 1941). A lawyer simply could not use Dr. Gregg's article to infer German measles inflicted by mother during pregnancy would cause blindness in babies, it is because blindness in new born babies also occurs among mothers who did not subject exposure to German measles during pregnancy.

To reach a valid conclusion in causation, it is necessary to compare the rates of having blindness babies among those mothers who are exposed and those who are not exposed to German measles. However, it is possible that the two groups of mothers may differ in other important ways beside the exposure. For example, vaccination has effectively interrupted the transmission of German measles for those who were born in US or in UK, and studies on the outbreaks of German measles occurred in the UK during 1996 indicated that pregnant women who were immigrants tended to suffer a high rate of the infection, and these mothers could come from poorer families and be exposed to other environmental hazards. These differences could create the appearance of a cause-and-effect relationship that mask the real cause. Therefore, most courts view anecdotal case reports in medical literature could only be used for generating hypotheses about causation, but not the conclusion of causation.

Another classic example on the limited use of anecdotal medical case reports is about the cause of lung cancer. At one time, it was thought that lung cancer was caused by fumes from tarring the roads. The logic of the anecdotal evidence is: Roads that had recently been paved, many lung cancer patients lived near those roads. But a counter-fact attacks such a conclusion on causation – many people without lung cancer were exposed to asphalt fumes. After the necessary comparison of rates, a better research design brings out the facts that lung cancer patients had similar rates of exposure to tar fumes as other people; the real difference was in exposure to cigarette smoke (Doll and Hill, 1952).

The position was summed up in *Haggerty v. Upjohn Co.* (1996), the court held that “scientifically valid cause and effect determinations” should depend on controlled clinical trials and epidemiological studies.

4.2 *Appropriate Population in commercial case*

In commercial fields, where controlled clinical trials were impossible to conduct, the courts would face more difficulty in determining the correct population that the samples drawing from, the problem is illustrated in following two court cases:

In *Amstar Corp. v. Domino's Pizza* (1980), Amstar sued Domino's Pizza for trademark infringement. Amstar owned the trademark “Domino” for selling sugar, while the defendant has used “Domino's Pizza” in connection with its sale of hot pizza pies. The legal question is whether there was a likelihood of confusion between the use of “Domino's Pizza” in selling pizza with the use of “Domino” by Amstar in selling in sugar. If the answer is yes, then Amstar will have a valid ground for its trademark suit.

Amstar conducted surveys to collect statistical evidences to support its assertions. Amstar conducted surveys on heads of households in ten cities. However, Domino's Pizza had no stores in eight of these ten cities. Besides, Amstar only interview women who were at home during daylight hours. The statistical implication of such survey design is that Amstar tends to collect the views of women who were grocery shoppers rather than young and single women. While young and single women comprise the majority of pizza eaters. In collecting counter-evidences, Domino Pizza conducted surveys only in its pizza parlors. The Court of Appeals decided that neither Amstar nor Domino Pizza had sampled properly from a sufficiently complete population.

In *Marisco v. Evans Chemetics* (1992), when two offices are consolidated as a result of corporate downsizing, the court faced the statistical question of: Which group should the terminated employees be compared with - those retained or those transferred?

Maresco was hired by Evans in 1967 as a senior clerk, and the company was located in New York City. In 1970, Evans relocated to Connecticut, and Maresco moved to Connecticut. He was promoted to staff accountant. In 1978, Grace acquired Evans, and became one part of Grace's Division, which had offices in

Massachusetts and Connecticut.

In 1986, Grace decided to shut down the Connecticut office. The accounting functions of the Connecticut office were transferred to Massachusetts. This relocation of functions entailed cost-saving consolidations, so that the move resulted in a reduction in total employment within the Division. The Connecticut office had 3 accounting and 9 non-accounting employees. Of the 3 accounting employees, Maresco and one other worker were over the age of 40. Employee of age 40 is within the class of employees protected by the US discrimination law. All of the non-accounting personnels were also in the protected age group. On the other hand, there were 20 persons in the Massachusetts office, and all were not in the protected class.

Maresco's performance was considered satisfactory. The justification for his termination was the shutdown of the Connecticut office. Four Connecticut employees were offered the opportunity to transfer to the Massachusetts office. Of this group, 3 were non-accounting employees over age 40. One was Mr. K, an accountant who was age 36. Unlike Maresco, Mr. K declined the transfer and was terminated. The remaining 2 accounting employees, including Maresco, and 6 non-accounting employees were terminated. No employees at the Massachusetts office were terminated in the downsizing process.

In the trial level, the judge focused on the facts that the age distribution of those transferred (3 of 4 were in the protected class) was approximately the same as the distribution of those being terminated. And Evans further argued that when only a single office was closed, there should be no inference of discrimination. The trial judge supported this view and dismissed Marisco's case.

During appeal, Marisco argued that when the two offices were consolidated, the accounting employees should be distinguished from non-accounting employees. Thus the appropriate population for comparison should be the accounting employees – therefore, there were 23 accounting employees at the two offices before the consolidation, 3 were in the protected class. However, after the consolidation, there were 20 employed accounting personnels, and none of whom were in the protected class. Marisco argued that such statistical figures showed clear evidence of discrimination. The Court of Appeals supported this view and reversed the lower court decision.

4.3 Values of Different Studies on Populations related to a Single Phenomenon

Courts acknowledge the values of different studies conducted on a single phenomenon. For example, the courts believe that although largely come from observational studies (the subjects choose to smoke rather than randomly assigned to smoke by the researcher), the evidence that smoking causes lung cancer in humans is compelling under the following conditions:

First, the association between smoking and lung cancer is seen in different studies (by different researchers in different time and places) among different populations. It is because the results from different studies would reduce the chance that the association is due to a defect in one type of study or a peculiarity in one group of subjects.

Second, if the different studies describe the association, and also taking the effects of plausible confounding variables into account by appropriate statistical techniques, such as comparing smaller groups that are relatively homogeneous with respect to the factor. In other words, courts will assign greater weight to studies which have designed control upon the influence of a confounder variable. For example, smokers are more likely to get lung cancer than non-smokers. Age, gender, social class, and region of residence are all confounders, but controlling for such variables does not really change the relationship between smoking and cancer rates. Furthermore, many different studies - of different types and on different populations – can help to confirm the causal link.

5. The Idea of Statistical Significance in Court³

³ The Reference Manual on Scientific Evidence (2d ed.2000) published by the Federal Judicial Center defines that when a study is statistically significant, it would produce results that are unlikely to be the result of random error. To test for

In *Matrixx Initiatives, Inc. v. Siracusano* (2011), the stock investors claimed that a drug manufacturer (*Matrixx*) that produces Zicam cold remedies, who failed to disclose adverse events linking certain Zicam products with anosmia (the loss of the sense of smell). The legal issue is: whether stock investors can claim securities fraud a under Rule 10b–5 action⁴ against the wrongful corporation under the SEC (Securities and Exchange Commission) Rules? The company argued that the report do not disclose a statistically significant number of adverse events, so that the company bears no duty to disclose.

The District Court dismissed the investors' complaint, and held that the number of adverse events was not statistically significant. The District Court's decision was overturned by the Court of Appeals, which found that the District Court committed an error in applying a strict, bright-line standard of statistical significance to determine materiality.⁵ After losing in the Court of Appeals, the drug manufacturer made an appeal to the United States Supreme Court. The US Supreme Court confirmed the Court of Appeals decision. Supreme Court Justice Sotomayor decided that it should not reduce to a bright-line rule to determine materiality of adverse event contained in a report. Accordingly, the Supreme Court ruled against the drug manufacturer. In other words, after the *Matrixx* decision, future drug manufacturers must disclose even statistically insignificant side effects.

Stephen Ziliak, a professor from Roosevelt University saw the court case *Matrixx Initiatives v. Siracusano* in essence a battle between Student v. Fisher in the statistical world.

“Student” is the pen name of William Sealy Gosset (1876–1937). Gosset made the discovery leading to what scientists now call Student's t-distribution and test of significance. He expressed such idea to his managing director at Guinness's Brewery sometime around 1904. More importantly, Gosset went on to proclaim the other side of that insight: “Similarly, a lack of statistical significance – statistical *insignificance* – is easily though often mistakenly said to show a lack of cause and effect when in fact there is one” (Ziliak, 2008). In other words, statistical significance is easily mistaken for evidence of a causal effect, when there is none.

When the London economist and statistician Francis Y. Edgeworth first used the word “significance”, in an 1885 article he prepared for the Royal Statistical Society (Edgeworth, 1885), his investigative mindset was largely economics in nature. He tried to estimate the *practical* importance of coefficients by using the wasp migration data collected in Ireland. In his economic equation, Edgeworth thought to control the variance of wasp “exports + imports”. Ziliak commented the positive aspects of Edgeworth's method - unlike today's hypothesis testing (significant at $P < .05$), Edgeworth did not give undue weight to the denominator, that is, to the amount of probable dispersion around magnitudes of economic interest. In other words, careful researchers, like Edgeworth or Gosset, did not make a fixed level of probability his sole criterion (Ziliak and McCloskey, 2008).

However, most statisticians now tend to compute a test statistic, comparing its value with the tabulated critical values, and reporting the result only as “significant” or “not significant”, and unfortunately, that mechanical approach is retained by editors of some top academic journals. For example, the American Psychological Association publication manual still claims that “if results do not meet the 0.05 level of significance, then they are to be interpreted as chance findings”.

significance, a researcher develops a “null hypothesis”, for example, the assertion that there is no relationship between the use of a drug and a side effect. The researcher then calculates the probability of obtaining the observed data if the null hypothesis is true (called the p-value). Small p-values are evidence that the null hypothesis is incorrect. Finally, the researcher compares the p-value to a pre-selected value called the significance level. If the p-value is below the pre-selected value, the difference is deemed “significant.”

⁴ In a Rule 10b–5 action, the claimant must prove:

- (1) a material misrepresentation or omission by the defendant;
- (2) scienter;
- (3) a connection between the misrepresentation or omission and the purchase or sale of a security;
- (4) reliance upon the misrepresentation or omission; (5) economic loss; and (6) loss causation.”

Stoneridge Investment Partners, LLC v. Scientific–Atlanta, Inc., (2008).

⁵ 585 F.3d 1167 (C.A.9 2009).

If one looks back in history to reexamine the origins of significance testing, and asks why the most commonly held benchmark of statistical significance is five percent. It was an initial suggestion of preference by Ronald Fisher. Fisher preferred the 5% rule because at a critical value of 1.96 (the critical value for a normally distributed test statistic using the 5% rule), one would reject the null hypothesis if the result is more than 1.96 standard deviations from the mean. In other words, Fisher prefers to categorize results as significant when they were more than two standard deviations from expectation under the null hypothesis (Lisse et al., 2003). Just because an early developer of the test deemed it appropriate would not make such 5% rule be the proper standard in all contexts.

In *Matrixx*, the executives from the drug manufacturer adopted the approach of significant at $P < .05$ in hypothesis testing, and concluded that the adverse events does not build up to a statistically significant number that require disclosure. Let us go to the facts of the *Matrixx* case to see why the resolve of it requires a choice of proper statistical reasoning:

5.1 Facts of *Matrixx*

Drug manufacturer produces Zicam Cold Remedy, which accounted for approximately 70% of its sales. Drug manufacturer's securities were traded on the NASDAQ. Those investors purchased stocks from drug manufacturer between October 2003 and February 2004 started a Rule 10b-5 action on the ground that drug manufacturer made some misrepresentation about its revenues and product safety during the period.

As illustrated in *Stoneridge Investment Partners v. Scientific-Atlanta* (2008), in a Rule 10b-5 action, the claimant must prove:

- (1) a material misrepresentation or omission by the defendant
- (2) scienter
- (3) a connection between the misrepresentation or omission and the purchase or sale of a security
- (4) reliance upon the misrepresentation or omission
- (5) economic loss, and
- (6) causation

The investors made the following points:

1. About four years before this lawsuit, Dr. Hirsch called drug manufacturer's customer service line in 1999 about his discovering of a possible link between Zicam and a loss of smell "in a cluster of his patients." Dr. Hirsch informed drug manufacturer that "previous studies had demonstrated that intranasal application of zinc could be problematic", and the active ingredient in Zicam was zinc gluconate. He showed drug manufacturer that at least one of his patients who did not have a cold, and who developed anosmia after using Zicam. The investors successfully used these findings to prove the element of scienter – drug manufacturer knows about the true facts.
2. In September 2002, after receiving a complaint from a customer who had lost her sense of smell after using Zicam, the vice president of the R&D department of drug manufacturer called Health Sciences Center from University of Colorado for information. The Center drew the vice president's attention to "previous studies linking zinc sulfate to loss of smell." The Center asked vice president whether the drug manufacturer had done any studies of its own; the vice president responded that it had not. In following up, the Center sent the mentioned abstracts of the studies to drug manufacturer. These findings help investors to prove the element of scienter.
3. A year later, in September 2003, Dr. Jafek at the University of Colorado had observed 10 patients suffering from anosmia after Zicam use. The findings were presented in a meeting of the American Rhinologic Society with the title "Zicam Induced Anosmia." The American Rhinologic Society posted their abstract in advance of the meeting. The presentation described in detail a 55-year-old man with previously normal smell, who experienced severe burning in his nose, followed immediately by a loss of smell, after using Zicam. It also reported 10 other Zicam users with similar symptoms.

4. Drug manufacturer sent a letter to Dr. Jafek warning him that he did not have permission to use drug manufacturer's name or the names of its products. Dr. Jafek deleted the references to Zicam in the title before presenting it to the American Rhinologic Society.
5. In October 2003, after Dr. Jafek had presented his findings to the American Rhinologic Society, drug manufacturer still announced to the public that Zicam was "poised for growth in the upcoming cough and cold season" and that the company had "a very strong momentum". Drug manufacturer further expressed that revenue would be expected 'be up in excess of 50% and that earnings per share for the full year would be in the 25 to 30 cent range.'
6. By November 2003, two plaintiffs commenced a product liability lawsuit against Matrixx alleging that Zicam had damaged their sense of smell.
7. In its Form 10-Q filed with the Stock Exchange Commission (SEC) in November 2003, it did not disclose that two lawsuits from Zicam users were commenced for lose their sense of smell.
8. In January 2004, Matrixx raised its revenue guidance, predicting an increase in revenues of 80% and earnings per share in the 33-to-38-cent range.
9. On January 30, 2004, Dow Jones Newswires reported that the Food and Drug Administration (FDA) was looking into complaints about drug manufacturer and Zicam users' loss of smell in light of at least three product liability lawsuits. Stock price of drug manufacturer fell from \$13.55 to \$11.97 per share after the report.
10. In response, on February 2, drug manufacturer issued a press release that stated that Zicam products caused anosmia are completely unfounded and misleading, with a conclusion that: "*The overall incidence of adverse events associated with zinc gluconate was extremely low, with no statistically significant difference between the adverse event rates for the treated and placebo subsets*". The day after Matrixx issued this press release, its stock price bounced back to \$13.40 per share. The findings help investors to prove causation – stock price was sensitive to the statements made by drug manufacturer.
11. By February 6, 2004, nine plaintiffs had filed four lawsuits.

Drug manufacturer accepts its duty to report adverse events to FDA, but urges the Court to adopt a bright-line rule for reporting adverse events to investors.

The US Federal law requires pharmaceutical manufacturers to report adverse events to the FDA. In 2006, US Congress enacted legislation to require manufacturers of over-the-counter drugs to report any "serious adverse event" to the FDA within 15 business days. [21 U.S.C. §§ 379aa(b), (c)]

Absent statistical significance, drug manufacturer argues, adverse event reports provide only "anecdotal" evidence that the user of a drug experienced an adverse event at some point during or following the use of that drug. Accordingly, drug manufacturer contends that only reports of statistically significant can establish a reliable basis for inferring a causal link between product use and the adverse event. Drug manufacturer's argument rests on the premise that statistical significance is the only reliable indication of causation. The Supreme Court Justice Sotomayor held that this premise is flawed because medical researchers would consider multiple factors in assessing causation, his reasoning is in line with that of the Student approach of test of significance.

Opined Justice Sotomayor that statistically significant data may not be always available; for example, when an adverse event is rare, then the inability to obtain a data set of appropriate quantity may preclude a finding of statistical significance. Therefore, a lack of statistically significant data does not mean that medical experts have no reliable basis for inferring a causal link between a drug and adverse events. Prior cases have recognized that medical researchers consider evidences other than the results of randomized clinical trials or

to statistically significant dataset.⁶

5.2 Discussion

To better understand why the Supreme Court opinion, it is important to have a basic understanding of hypothesis testing. In this section, we explain what a hypothesis test is, the way the results can be interpreted after such a test is performed, and the two types of errors that a researcher can make when performing a hypothesis test.

The aim of conducting a hypothesis test is to determine whether the data being investigated are consistent with a null hypothesis. A hypothesis test is first performed by posing a null hypothesis, which is the hypothesis that the statistician wishes to test. Then, the researcher calculates a test statistic, assuming that the "null" hypothesis is true. Subsequently, the researcher determines whether the test statistic falls into one of two subsets of values: a region under which the null hypothesis is rejected and one under which the null hypothesis cannot be rejected.

It seems the hypothesis testing is a simple dichotomous procedure of either rejecting or failing to reject a hypothesis. In fact, this is a wrong impression of hypothesis testing. It is because a failure to reject a null hypothesis does not mean that one then accepts it as the truth.

In other words, failing to reject the null hypothesis does not indicate that the effect of interest is meaningless or unimportant. Confusion often occurs, not during, but after a significance test is performed – in other words, the disputes surround the correct interpretation of the data. The principle is: A rejection of the null hypothesis does not necessarily mean that one accepts the alternate hypothesis. Similarly, failing to reject the null hypothesis does not mean that one should then accept it. (Anderson, Sweeney & Williams, 2006). For example, in economics research, a researcher builds a simple consumption function which presumes that consumer spending is a function of national income measured by gross domestic product (GDP). The researcher uses the estimated parameter on the *GDP* variable to derive the marginal propensity to consume. If he estimates that the marginal propensity to consume is 0.7, which means that an average social member would spend 70 cents when there is a one dollar increase in GDP. If this parameter has a *p-value* less than 0.05, which means that it is "statistically insignificant at 5 percent." Then, there are two options of conclusion open for the researcher:

Option #1: based on the result of statistical testing, he should assume that the marginal propensity to consume is zero.

Option #2: based on economic observations, the marginal propensity to consume is still 0.7.

Any reasonable economic researcher would choose option #2. Put it simply, the best estimate of an effect is the one derived from a model build upon empirical evidence, regardless of whether a particular level of statistical significance is achieved. In medical research, the FDA adopts the approach based on empirical evidence rather than merely statistical evidence, for example, it would act on the basis of empirical evidence that suggests, but does not prove, causation. For example, the FDA frequently exercises its regulatory power to require all over-the-counter drugs manufacturers to include a warning as soon as there is reasonable evidence of an association of a serious hazard with a drug, and a causal relationship need not have been proved [21 CFR § 201.80(e)]. Therefore, regulatory decisions are based upon empirical evidences that suggest a strong degree of suspicion. If a drug on the market may pose a significant health risk to consumers, to determine what actions should be taken, the FDA will weigh the effect of the adverse events against the benefit of the drug. This decision-making process will not be reduced to a mere statistical test of significance, but encompasses many empirical factors⁷, such as:

⁶ FDA - The Clinical Impact of Adverse Event Reporting (1996), available from: [http://www.fda.gov/downloads/safety/Med Watch/UCM168505.pdf](http://www.fda.gov/downloads/safety/Med%20Watch/UCM168505.pdf).

⁷ <http://www.gao.gov/new.items/d06402.pdf>

- the medical importance and utility of the drug
- the drug's extent of usage
- the severity of the disease being treated
- the drug's efficacy in treating this disease, and
- the availability of other drugs to treat the same disorder

When assessing causation, the FDA does not limit its consideration solely to the evidence build on statistically significant data. Based on relevant FDA Guidance⁸, when assessing the safety risk, FDA would rely on a wide range of empirical evidence to assess causation, and the factors be considered are:

- strength of the association
- temporal relationship of product use and the event
- consistency of findings across available data sources
- evidence of a dose-response for the effect
- biologic plausibility
- seriousness of the event relative to the disease being treated
- potential to mitigate the risk in the population
- feasibility of further study using observational or controlled clinical study designs, and
- degree of benefit the product provides, including availability of other therapies

Finally, even a hypothesis test is properly done, the result of it will be subject to two types of errors, namely, the Type I and Type II errors. Type I error occurs when one rejects the null hypothesis when the null hypothesis is true. Type II occurs when one does not reject the null hypothesis when it is false. Type I error occurs when the researcher rejects the null hypothesis accidentally. Alternatively, Type II error occurs when the researcher fails to reject the null hypothesis, when in fact he should. When one identifies the level of significance in a hypothesis test, one has also identified the probability of making a Type I error. For example, when a medical researcher wants to determine whether a particular medication would reduce cholesterol relative to a placebo, then he would construct the following null and alternate hypotheses.

Null hypothesis: the medication has effect on subject cholesterol equivalent to that of a placebo.

Alternate hypothesis: Effect on subjects' cholesterol from the medication is different than the effect from a placebo.

If the medical researcher performs this test at a 5 percent level of significance, the probability of *incorrectly* rejecting the null hypothesis would be 5 percent. However, a Type I error is not the only "bad" outcome when performing the above test. From a testing perspective, another poor outcome may be: he fails to reject the null hypothesis when in fact the experimental medication works. This is Type II error.

When analyzing the probability of a Type II error, statisticians will sometimes refer to the "power of the statistical test, which is the probability of correctly rejecting the null hypothesis. In other words, the cost of decreasing Type I error is to increase the Type II error. Therefore, balance must be struck between these two types of error.

6. Conclusion

Statistical significance testing shall not be merely calculating whether a 5 percent standard has been met. In fact, the adoption of a bright-line test of statistical significance would fail to capture important nuances of applied significance testing. At the minimum, cost consideration should come within the equation. When performing a test of statistical significance, a researcher must weigh the costs of accepting hypotheses that are false, against the costs of rejecting hypotheses that are true. To reduce the chance of a "Type I" error (rejecting hypotheses that are true), researchers can lower their standards of statistical significance. However, the researcher must bear in mind that when he lowers the standard of statistical significance, the result will bring

⁸ FDA Guidance for Industry - Good Pharmacovigilance Practices and Pharmacoeconomic Assessment (2005), available from: <http://www.fda.gov/downloads/RegulatingInformation/Guidances/UCM126834.pdf>

an increase in the "Type II" error (accepting hypotheses that are false).

Secondly, researchers should not analyze statistical significance at the expense of practical importance. One has to decide who is the proper party to undertake the test of significance, for example, if a society gives the responsibility to the drug manufacturers, then when faced with a particularly important set of undisclosed adverse events, a drug manufacturer may have incentive to avoid disclosing these events until it has received data sufficient to meet a particular standard. A researcher must strike the correct balance between statistical significance and practical importance. In short, there is an obvious ethical dilemma exists when the entity conducting the significance test has a vested interest in the outcome of the test.

In addition, how to deal with adverse events would be a challenging aspect of significance testing. Since adverse events may gradually accumulate in over time, and it may be very difficult to determine the number of individuals actively taking a medication within a given time period, hypothesis tests can be subject to error. This is why courts tend to trust clinical tests rather than significance testing based on observable data when answering whether the adverse events are indeed drug related.

In conclusion, the traditional a bright-line standard of statistical significance at 5 percent standard makes little practical sense when determining whether undisclosed adverse events are material.

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Continuous Improvement of Supply Chain Service: A Case Study

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Abstract

In this paper, we study the continuous improvement of supply chain service based on a case study from Shenzhen-DC Company. First, it analyses the current status of the Digital supply chain headquarters systematically. Then, it presents two key factors for continuous improvement of supply chain service, i.e., operational efficiency and customer satisfaction. With the application of the two key factors, cost reduction and efficiency improvement is obtained obviously. Finally, systematical comparisons are given based on the real data from the case study.

Keywords: Six Sigma, Process management, quality Management, Continuous improvement, Operational efficiency, Customer satisfaction

1. Background

So far, process improvement project management based on the Six Sigma is mainly used in manufacturing enterprises, and it is not widely used in the IT service-oriented enterprise. Part of the SM supply chain is the first time to promote CPI project in the field of business logistics and hope that through the establishment of process management system and continuous process improvement to improve the efficiency of business processes, reach the purpose of enhancing the operational efficiency and accumulation of knowledge.

Opportunities for improvement: the customers have higher demands of transportation on-time rate and transportation cost, which requires us to improve processes to meet customers' needs.

Quality management (QM) has developed into a mature field with sound definitional and conceptual foundations (Sousa and Voss, 2002), but new QM methods continue to grow. For example, Six Sigma, which is "an organized and systematic method for strategic process improvement and new product and service development that relies on statistical methods and the scientific method to make dramatic reductions in customer defined defect rates" (Linderman et al., 2003), generates intense interest in industry. Since its initiation at Motorola in the 1980s, many companies including GE, Honeywell, Sony, Caterpillar, and Johnson Controls have adopted Six Sigma and obtained substantial benefits ([Pande et al., 2000] and [Snee and Hoerl, 2003]). However, Six Sigma is criticized as offering nothing new and simply repackaging traditional QM practices ([Dalglish, 2003]). It is argued that the large returns from Six Sigma at some companies were due to the initial quality level of these companies being so low that anything would have drastically improved their quality (Stamatis, 2000). Although there have been numerous case studies, comprehensive discussions, books and websites addressing Six Sigma, very little scholarly research has been done on Six Sigma and its influence on quality management theory and application ([Goffnett, 2004] and [Schroeder et al., 2005]). Xingxing Zu reviewed both the traditional quality management and Six Sigma literatures and identified three

new practices that are critical for implementing Six Sigma's concept and method in an organization.([Xingxing Zu et al.,2008]). Zhang Yuan etc. introduced the Six-Sigma quality process's operation pattern, and the differences between Six-Sigma quality process and the traditional management method. They revealed the application prospect of Six-Sigma management in supply chain by using abundant cases and detail data. ([Zhang Yuan et al.,2010]).

2. Case Study based on Six Sigma Process Management

2.1. Define

The goal of the project is defined by two factors:

- 1) Commitments reached (time rate) $\geq 90\%$.
- 2) Transport efficiency - the expense ratio decreased by 11.5% to 0.71 RMB / ton / km.

The scope of the project is given by Fig. 1.

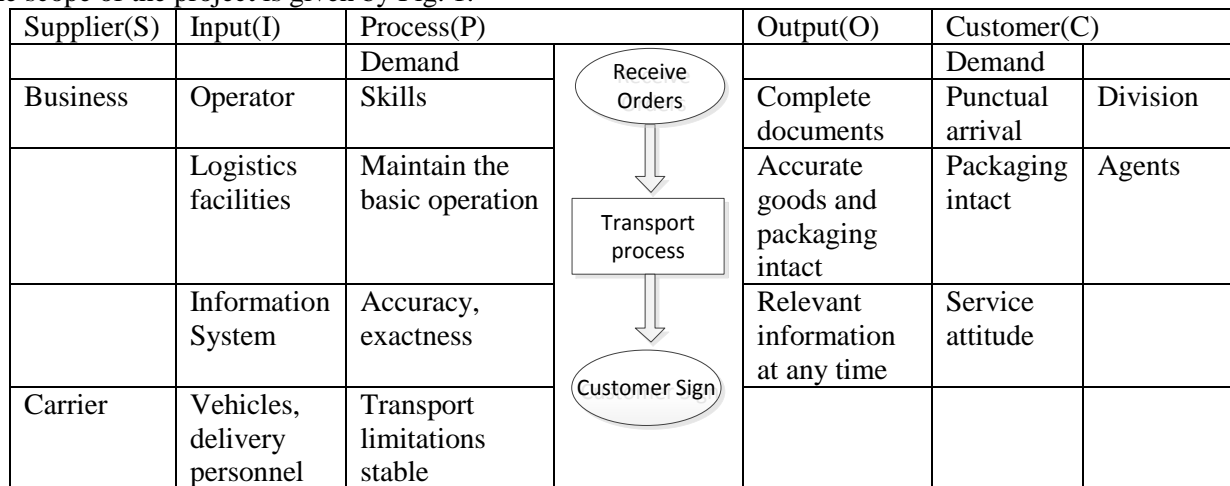


Figure 1: The Scope of the Project

Team members and organization of work is given by Fig. 2:

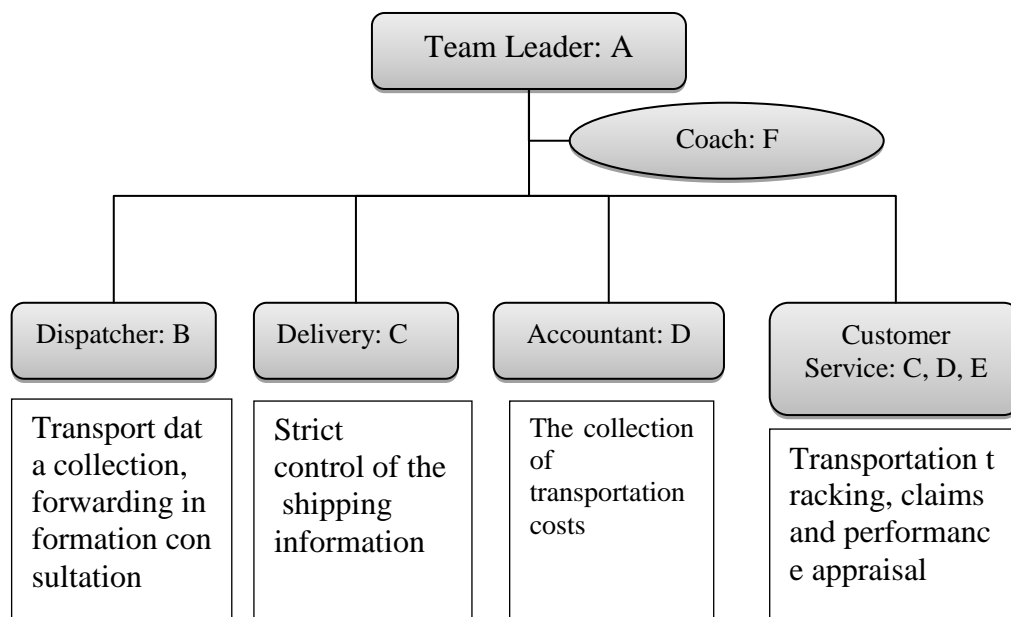


Figure 2: Team Members and Organization

These are the team members and organization of work, the personnel involved in the project and each be responsible for the work of the introduction.

The project task document details the implementation of the project person in charge, project manager and project leader, the scope of the project, the project target beneficiaries of the project and project plan to make a more detailed explanation, the project staff to do their jobs.

2.2. Measurement

Punctuality Data Measurement

Serial Number	Factors for Unpunctuality	Volume	Percentage
4	Unable to distribution in weekends and holidays	254	35.62%
1	Carrier distribution delay	150	21.04%
6	System can not bring out a commitment to aging	70	9.82%
7	System with a commitment to timeliness is incorrect	67	9.40%
3	Transit platform after receiving failed to turn out	65	9.12%
15	Indoor documents	30	4.21%
2	Terminal sign maintenance error	29	4.07%
11	Operation and maintenance errors	18	2.52%
5	In-transit abnormalities such as wating or address change	17	2.38%
8	Division is not shipped the same day	13	1.82%
9	Time of delivery delay	0	0.00%
10	Not shipped empty single	0	0.00%
12	Platform delayed delivery	0	0.00%
13	Orders after 5-20 days	0	0.00%
In Total		713	100.00%

The main factors for unpunctuality in May is clearly given in Fig.4, which can be summed up to lay the foundation behind the accurate implementation of the plan and the corresponding change in mid-May.

2.3. Analysis

1) Analysis of Punctuality

In the analysis phase, the punctuality rate analysis for the five aspects of the descriptive analysis, in order to understand the factors affecting facilitate the subsequent improvement work.

May data comparison chart can be seen by visual observation, the difference between the headquarters on time rate and the actual time rate is conducive to the improvement of the follow-up.

(May)

Serial Number	Factors for Unpunctuality	Volume	Percentage
4	Unable to distribution in weekends and holidays	254	35.62%
1	Carrier distribution delay	150	21.04%
6	System can not bring out a commitment to aging	70	9.82%
7	System with a commitment to timeliness is incorrect	67	9.40%
3	Transit platform after receiving failed to turn out	65	9.12%
15	Indoor documents	30	4.21%

2	Terminal sign maintenance error	29	4.07%
11	Operation and maintenance errors	18	2.52%
5	In-transit abnormalities such as waiting or address change	17	2.38%
8	Division is not shipped the same day	13	1.82%
9	Time of delivery delay	0	0.00%
10	Not shipped empty single	0	0.00%
12	Platform delayed delivery	0	0.00%
13	Orders after 5-20 days	0	0.00%
In Total		713	100.00%

(June)

Serial Number	Factors for Unpunctuality	Volume	Percentage
4	Unable to distribution in weekends and holidays	260	35.33%
1	Carrier distribution delay	170	23.10%
6	System can not bring out a commitment to aging	119	16.17%
14	Indoor documents	68	9.24%
3	Transit platform after receiving failed to turn out	49	6.66%
5	In-transit abnormalities such as waiting or address change	22	2.99%
7	System with a commitment to timeliness is incorrect	21	2.85%
2	Terminal sign maintenance error	14	1.90%
13	Division is not shipped the same day	8	1.09%
11	Operation and maintenance errors	4	0.54%
9	Time of delivery delay	1	0.14%
8	Does not maintain a receipt time	0	0.00%
10	Not shipped empty single	0	0.00%
12	Platform delayed delivery	0	0.00%
In Total		736	100.00%

Figure 10: Main Factors for Unpunctuality

Figure 10 is not allowed when the reasons for division, lists are not allowed when the reason, as well as the corresponding number and the percentage.

Summary for punctuality analyses

1. Weekend impact documents-----35.48%

Improvement: Shenzhen as distribution platform of factory goods and customs sub-goods, weekend receipts impact is relatively large. For arrival of the documents on weekends, it's necessary to calls to the customer to make an appointment to keep people receiving before delivery (Recommend additional weekend whether shipped in the system option) ,In addition the delivery of customer requirements, maintenance of information exceptions, and e-mail to notify the relevant person in charge

2. Carrier distribution delay-----22.07%

Improvement: Major improvements of the actual operation of, Rational allocation of resources, Increase carriers assessment efforts, Delay the documents given to this single freight 20% -80% reduction in, Embodied from the month freight.

3. System can not bring out a commitment to timeliness is wrong-----11.16%

4. The transit platform is not timely transferred—9.18%

Improvement: Early due to the platform was not accept the goods in the weekend, which affected the transit efficiency, has been adjusted upon receipt transit time, and improved

5. Timely delivery

Improvement: Carriers sign system, to the library on the carriers, delivery is completed, the time point from the library and other records, and included in the assessment. Late more than three times a month to give a fine of 100 Yuan per time.

6. Batches delivery

Improvement: Requirements of carriers to multi-batch delivery to ensure the same day at 18:30 before the documents were issued to (the BYD delivery back to the library, late sub goods).

The two graphs above are for the on-time rate analysis summary, a summary of each step can help a project always in control.

2) Cost Analysis

Transportation Costs Analysis

1. According to the cost analysis, the transportation cost is 9425625.74 Yuan from March 21st 2008 to March 20th 2009.

2. According to the task document, the whole cost reduces 11.5%.

3. The transportation cost is 8341678.78 Yuan under the premises of the same weight.

4. The expected benefit is 1083947 Yuan.

5. Divided by paths: Shenzhen-Beijing:29.05%, Shenzhen-Shanghai:10.08%, Shenzhen-Nanjing:7.17%, Shenzhen-Chengdu:6.88%, Shenzhen-Shenyang:5.51%, the sum is 63.69% of the whole cost which need to be emphatically analyzed.

In the analysis phase, the cost has been carefully observed and controlled.

It contributes to the analysis and the reality of the situation accurately connected. We will list the transportation cost analysis summary.

2.4. Improvement

Improvement program:

Improved Content	Specific Measures	Completion Time	Completion	Unfinished Reason
Reduce unit cost	focus on unit cost adjustment in Common Aerial and expedited aerial	09.04.01		
Expand transportation channels	lines whose Freight is more than 50,000 Yuan must be carried by two carriers, formulate healthy competitions about quality and price	09.04.02	Report Cang Airlines Shenzhen Airlines	

Choose reasonable transportation mode	under the premier of more than 300kg, take highway express and railway express into account instead of airline express	09.04.03		
Reduce the rental business	integrate own resources, control the cost of rental	09.04.04	own vehicles are given priority	
Integrate transportation lines	lines whose Freight is less than 30,000 Yuan, introduce third-party companies to achieve decentralized, and help to reduce the cost of delivery, improve the operator's ability to control	09.09.12	introduced Guo'ou, Susuda	
Promote small parcel courier	orders sent directly to customers whose weight is less than 5kg, use the small parcel courier to replace current transportation mode		Contracted with EMS, Jialidatong, SF express	Contract pending
Control damage	Appropriate inputs to packaging costs, and Cisco products, for example, by customizing the special shipping container	09.07.20	Damage has been effectively controlled, a slight increase in finance costs, the opportunity to greatly reduce the cost, and significantly improve customer satisfaction	

The figure above lists the specific measures the project team taken to save cost. The figure below shows about reduces unit cost.

Reduce unit cost

Path	Transportation Mode	Transportation Volume/Weight	Original Price		Current Price		Expected Benefits
			Unit Cost	Total Cost	Unit Cost	Total Cost	
Shenzhen-Beijing	Highway	10414.38	160	1666301	150	1562157	104143.8
	Common Aerial	175641.55	3.5	614745.4	3.5	614745.4	0
	Expedited Aerial	58547.185	4.8	281026.5	4.5	263462.3	17564.16
							121708
Shenzhen-Shanghai	Highway	4699.23	120	563907.6	120	405417.6	0
	Common Aerial	92358.225	2.8	258603	2.6	112656.3	18471.65

	Expedited Aerial	30786.075	3	92358.23	3	42916.32	0
							18417.65
Shenzhen-Nanjing	Highway	3378.48	125	422310	120	405417.6	16892.4
	Common Aerial	40234.39	3.5	140820.4	2.8	112656.3	28164.07
	Expedited Aerial	13411.35	4.3	57668.81	3.2	42916.32	14752.49
							59808.96
Shenzhen-Chengdu	Highway	1924.36	195	375250.2	190	365628.4	9621.8
	Common Aerial	42145.62	4.2	177011.6	4	168582.5	8429.124
	Expedited Aerial	14048.54	4.8	67432.99	4.2	59003.87	8429.124
							26480.05
Shenzhen-Shenyang	Highway	1410.75	195	275096.3	195	275096.3	0
	Common Aerial	23784.19	7.5	178381.4	5.4	128434.6	49946.8
	Expedited Aerial	7928.06	8.9	70559.73	8.2	65010.09	5549.642
							55496.44
	Sum						281965

Data interval (08.3.20-09.3.20), the five key lines, for the charging unit in 2008, the expected benefit will be 281965 Yuan when reduces unit costs.

Adjust the transportation mode

List

Data interval (09.04-09.07), the benefit is 93551 Yuan; the expected benefit in 2009 will be 280653 Yuan after adjusting transportation mode.

Transportation on-time Rate

Improved content	Specific Measures	Completion Time	Completion	Unfinished Reason
Betimes of carries' sign on behalf	Enhance the understanding of carrier SMS receipt to realize that the shipments which aims at maintaining	09.09.01	Originating direct billing, carriers SMS receipt has been implemented	
Delays on weekends	For the weekend arrival of documents, bring forward to make calls to make an appointment to keep people receiving (additional options recommended for	09.05.15	Weekend receipts, Friday Service reservation to delivery	

	weekend receipt in the system)			
Carriers' delays	Increase the assessment efforts, delay receipts will be given a reduction of 20% -80% reduction in the freight, and started in that month	09.05.20	In 2009, focus on promoting the carriers assessment, reduced delays	
System cannot bring out a commitment to timeliness is wrong	check receipts the next day, in a timely manner to modify, and timely feedback	09.06.12	improve the system gradually	
Delivery in time	Carriers sign system, to the library on the carriers, delivery is completed, the time point from the library and other records, and included in the assessment. Late more than three times per month to give a fine of 100 Yuan per time.	09.01.01	In 2009, focus on promoting the carriers assessment, make the delivery point to get in control in time	
Batches delivery	carriers are required to multi-batch delivery and make sure at the same day before 18:30 the receipts were issued (the BYD delivery back to the library, the time for subbing goods is very late)	09.07.20	18:00 receipts issued the same day	

Overview

List

Month	Total Orders	Punctuality	Unpunctuality	On-time Rate	Note
April	3501	2743	758	78.40%	
May	4417	3733	684	84.00%	
June	4711	4038	673	84.40%	
July	5238	4395	843	83.90%	
August	5261	4513	748	85.80%	

Data interval (09.04-09.07) under the guidance of the various policies, transportation on-time rate has an upward trend monthly.

The diagrams above depict the measures the project team taken to improve transportation on-time rate, and the results.

2.5. Control

Control method: improve the stage of effective methods and processes to form a system file, such as: "carriers to pick up the sign system", "carriers in batches delivery approach", "SMS sign appraisal system" etc.

Control effect

Headquarters Assessment Indicators

Unit Business Cost in 2008	Indicators of Reduced in 2009	Unit Business Cost after Reducing	Decline Percentage in Q1	Cost Indicators in Q1	Decline Percentage in Q2	Cost Indicators in Q2
0.8	11.50%	0.71	2.88%	0.78	5.75%	0.76

Archiving indicator in first half year

Month	Orders	Total Transportation Cost	Weight*Kilometer	Unit Business Cost
3.21-4.20	3737	806190.77	1147074.37	0.70
4.21-5.20	4724	948065.78	1254971.02	0.76
5.21-6.20	4804	932019.5	1442664.24	0.63
6.21-7.20	5479	1065163.64	1465963.52	0.73
7.21-8.20	5632	1135852.17	1637278.4	0.69
8.21-9.20	6313	1355078.77	1975487.123	0.69
Average				0.70

Combine DMAIC with four steps of PDCA project control, which formulate a long-term mechanism for continuous improvement.

3. Summary and Analysis based on Six Sigma Process Improvement Project Examples

1. Project benefits

Calculation formula:

Transportation Benefits=Unit Cost Decline * Estimated Total Cost (2009) = [(Cumulative Unit Cost until December – FY08 Annual Unit Transportation Cost)/ FY08 Annual Unit Transportation Cost] * [(Total Cost from April to December / 9 Months) * 12 Months]

Unit: RMB

Transportation Benefits = Unit Cost Decline * Estimated Total Cost (2009) = [(0.61-0.8)/0.8] * [(10270521.22/9)* 12] = 3252331.71

2. Problems and solutions (or the next work plan)

For transportation on-time rate, we need to focus on solving delivery delay on weekends, and remove the delays caused by customers not receiving goods on weekends.

For transportation cost control, we need to focus on the introduction of a small parcel courier, eliminate the higher cost outliers found by the analysis phase, in addition, adjust the proportion of air transport and other modes of transport is the key to reducing costs.

Acknowledgements

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The Main Changes on Container Terminals Located in Baltic Sea Region with Specific Scope on Poland

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Abstract

The financial global crisis of 2007–2010 that converted quickly to economical crises took its toll across almost all sectors, including some far away from Wall Street. The global financial crisis, brewing for a while, really started to show its effects in the middle of 2007 and into 2009. Around the world stock markets have fallen, large financial institutions have collapsed or been bought out, and governments in even the wealthiest nations have had to come up with rescue packages to bail out their financial systems. The global ocean container trade has lost speed in the face of a major financial crisis. The slowdown has been greatest in the advanced economies then developing ones.

Consequently, container terminals were suddenly hurt as bad as any industry since shipping demand substantially softens. This paper investigates the impact of the global financial crises on the container terminals located in Baltic Sea Region and the expected changes that could force terminal operators to find solutions that could minimize the impact of such crisis on their activities. The major container ports of Poland include: Gdansk port, Gdynia port, and Szczecin – Świnoujście port.

Moreover, this paper explores the current state of container terminals in BSR and reviews it in the context of a past history of Grate Reform followed by radical macro-economic adjustment, and more recent concerns and debates around the deregulation and privatization of the port industry (De Monie, 2009). It reveals that the situation in BSR ports is a product of both local and global pressures, mounded by economic and political forces. The financial crises overcome consequently depend on local participation and broader social, economic and transport infrastructure.

Keywords: container terminals, financial crisis, market share, container turnovers, Baltic Sea Container market

1. Introduction Macroeconomic Situation of BSR

The underlying purpose of this paper is to look at the situation of container terminals located in Baltic Sea Region. It is an attempt to take stock of where we are at that moment, and where it may be useful to focus our attentions in the future. The Baltic Sea Region economy underwent a major transformation during the 1990s as a result of liberalization policies, macroeconomic changes and a major public (administration) sector reform (Breitzmann K, Von Seck, 1994; Cottam, Roe 2004). As a result, both Gross Domestic Product (GDP) and investments increased rapidly until 2007. Even between 2009 – 2010 years, during international financial crisis, Poland had positive increase of GDP in European Union. For example, Poland has achieved 0,8% [Central Statistical Office, 2009], of economic growth. Table 1 illustrates the in GDP every country located in Baltic Sea Region (BSR) from 2005 to 2011 period.

In the Baltic Sea Region we had a two different growth dimensions in container terminals. There were well developed container terminals of capital states such as: Denmark, Germany, Finland and Sweden. Moreover we had not well – developed container terminals in such countries as: Estonia, Latvia, Lithuania, Russia and Poland. Although in Poland we had a Baltic Sea Container Terminal which was a window on the container global market. Anyway in that time, we had economy of BSR countries of two speeds. From one side, north – western countries have developed very well container terminals and accompanying infra and superstructure.

And from the second side, the south – eastern countries have had poor container terminals and accompanying infra and superstructure. The large gap between two sides was until process of state economy transformation (privatization) had not begun. As a consequence, states of south – eastern BSR had to make up for the lost time in development of container terminals and it's infra and superstructures. The backwardness in south - eastern states has created a higher dynamic of GDP growth then in north – western countries of Baltic Sea Region.

As we can see from table 1, between periods 2005 – 2007 we had a great development of countries located in BSR. But during financial crises only Poland had a positive GDP in 2009. In 2011 we could see that all states located in the BSR received a positive increase of GDP.

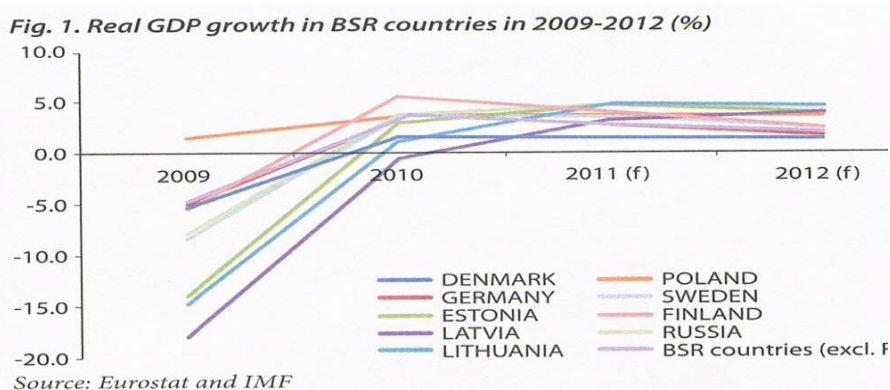
Table 1: The Growth of GDP in Baltic Sea Region

<i>Country/year</i>	<i>2005</i>	<i>2006</i>	<i>2007</i>	<i>2008</i>	<i>2009</i>	<i>2010</i>	<i>2011</i>
Denmark	2,4	3,4	1,6	-1,1	-5,2	2,1	1,3
Germany	0,8	3,4	2,7	1	-4,7	3,6	2,9
Estonia	9,4	10,6	6,9	-5,1	-13,9	3,1	3,2
Latvia	10,6	12,2	10	-4,2	-18	1	4,2
Lithuania	7,8	7,8	9,8	2,9	-14,7	-0,3	6,3
Poland	3,6	6,2	6,8	5,1	1,7	3,8	3,7
Finland	2,9	4,4	5,3	0,9	-8,2	3,1	2,8
Sweden	3,2	4,3	3,3	-0,6	-5,3	5,5	3,9
<i>Russia</i>	<i>6,7</i>	<i>6,4</i>	<i>6,7</i>	<i>8,1</i>	<i>-7,9</i>	<i>3,8</i>	<i>4,5</i>

Source: Authors' study based on Eurostat database

The biggest collapse in GDP was in 2009. In this year we had an apogee in decrease in nearly all countries. The most countries, except Lithuania, have overcome economic problems, which achieved in that year still a soft decrease – 0,3% in 2010.

The forecast for Baltic Sea Region are optimistic, nearly for whole states, see figure 1. For this region the real GDP growth in BSR countries in 2009 – 2012 (%) has had a similar level of increase. The structure, of course, of the GDP some states has changed but currently is stable.



The Baltic Sea Region has been regarded as one of the fastest developing areas in the European Union from some years. This development is directly connected with its economic growth, trade development, and high level of direct or indirect foreign investments as well as transport market. Therefore, container traffic in the Baltic Sea Region is developing faster then the global average. During the years 2000 and 2007 the average growth for container traffic in the Baltic seaports achieved the level of 14%, while an average global container growth was approximately 10%. Unfortunately, the very high economical growth has caused a very large public debt and market instability in such countries as Lithuania, Latvia and Estonia.

The growth rates of development across the region are mostly high in post- communist's countries: Lithuania, Latvia, Estonia, Russia and Poland.

In BSR countries increased of GDP is stimulated by domestic consumption more than in countries of old European Union. According some opinion it's the result of a more positive labour market situation and more vivid growth perspective. As we can see in Table 2 in 2011 there is a growing a gap between public and private sector, but in a smaller amount.

Table 2: Growth Rates of GDP Components in Selected Regions

	BSR		EU - 27		OECD	
	2010	2011	2010	2011	2010	2011
Consumption						
Private	1,80%	2,10%	0,80%	0,80%	1,70%	1,70%
Public	0,60%	0,50%	0,70%	0,20%	1,20%	0,60%
Investment	0,20%	4,70%	4,00%	3,60%	8,40%	3,80%
Trade						
Export	7,80%	7,70%	10,40%	7,00%	11,50%	6,30%
Import	10,30%	8,30%	9,40%	5,70%	11,10%	5,60%

Source: State of the Region Report 2011

As we can see the economic situation of BSR countries was improved rapidly in 2011. In 2010 trade of BSR countries looked very optimistic. Imports proceed to grow more intensively than exports, albeit the blank in growth rate is decreasing. Export's increase in the UE-27 and the OECD countries is very optimistic because of its increase domestic demand for foreign goods. This situation better describe table. 2.

It should be emphasized that there are optimistic forecasts of container turnovers in the Baltic Sea Region. Relying on materials furnished by "Ocean Shipping Consultants Ltd.", the growth of container turnover shall increase from 8,6 m in 2011 to 24,2 m TEU in 2025 for fallowing states: Poland, Belarus, Ukraine, Slovakia, Czech, Austria, Hungary, Russia – Baltic, Finland, Estonia, Latvia and Lithuania, table 3.

Table 3: Total Base Case Market Demand Expected to Grow to 18, 221m TEU Pa from 6, 126m in 2011
Forecasts based on IMF Regional GDP Combined with Container Trade Demand Multipliers

Country demand in '000 TEU	2011	2012	2013	2014	2015	2020	2025
Poland	1 682	1 809	1 994	2 198	2 424	3 763	5 530
Russia - Baltic	2 562	2 824	3 092	3 386	3 708	5 837	8 458
Finland	1 077	1 127	1 178	1 231	1 286	1 576	1 867
Estonia	150	165	179	195	212	311	447
Latvia	287	308	334	363	393	585	869
Lithuania	368	399	433	470	510	732	1050
Total	6126	6632	7210	7843	8533	12804	18221

Source: Own study based on: Ocean Shipping Consultants Ltd „Market Study Analysis” November 2011

Though, if we take into account only countries located in BSR the increase also is very optimistic, because the scope extend from 6,126 m to 18,221m in 2025, with excluding such countries as: Sweden, Norway, Denmark

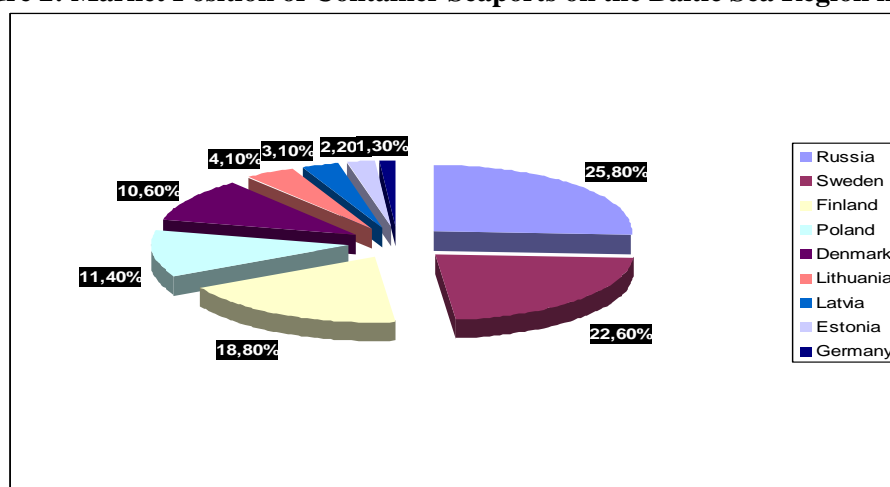
and Germany – Baltic. As a result container turnover in BSR shall be higher.

As we can see there is a great potential of growth of container demand. Anyway during 2011 – 2025 periods there shall be increase of about 228%¹ in Poland. Nearly the similar level of increase will be in Russia around 235%². So large value of increase brings a good perspective for all participants involved in container business in Baltic Sea Region.

2. Impact of Economic Crisis on Baltic Sea Port Turnovers

The container traffic in the Baltic Sea region has been estimated as follows: in the 2008 there were approximately 8 m TEU, but in 2009 less then 6 m TEU. In consequence the market lost around one year 2 m TEU. Market position of container seaports on the Baltic Sea in 2009 is presented on the figure 2.

Figure 2: Market Position of Container Seaports on the Baltic Sea Region in 2009



Source: Author's study based on website seaports

The figure 2 shows that the situation of container seaports in the Baltic Sea Region has been nearly stable. The first position has belonged to Russia container seaports and the second position had Sweden seaports. Between those seaports was a small market gap. That is why they were fighting for the first position on Baltic container market. The next group of container seaports has created: Finland, Poland and Denmark. Those container seaports also were fighting for better position in the region. However there was short difference in container turnover between Poland and Denmark. Probably the third position of Finland container seaports will be not threat by many years for the next containers players. The last group of container seaports has created the others container seaports. Of course between them was still strong position but for them will be very hard to force one's way.

Anyway St. Petersburg has remained the leader container terminal in the Baltic Sea Region, even though a high drop in 2009. St. Petersburg container seaport turnover above 1m TEU was unique in this region. The next position in the container market has belonged to Port of Gothenburg with traffic of 824 000 TEU. It is worth mentioned that the drop in the biggest Swedish container seaport was quite small, with the number - 4.4% in 2009. The deepest rate of decreased was observed in such container seaports as: Kaliningrad (-55,7%), Kotka (-48,1%), Hamina (-39,5%), Gdynia (-38,0%) and Klaipeda (-33,6%). In that time, only some container seaports have experienced the increase: port of Gdansk (+ 55 000 TEU), Gavle (+4,700 TEU) and Norrkoping (300 TEU). The large increase in container turnover was noticed in Gdansk in estimated time by authors. It was caused by Maersk decision to move all its container operation from Gdynia seaport to Gdansk seaport in 2008.

¹ Source: Ocean Shipping Consultants Ltd „Market Study Analysis” November 2011

² Ibidem.

The radical changes in seaport traffic structure of the 10 Baltic container seaports presents table 4. The highest rate of change was achieved by the port of Gdansk (the fourth position). The Polish container seaports have had a quite good position in the Baltic Sea Region.

Table 4: The 20 Top Baltic Container Seaports in 2009

No.	Seaports	2008	2009	Annual change 2008/2009 (%)
1	St. Petersburg	1983110	1343675	-32,24
2	Göteborg	862595	824218	-4,45
3	Aarhus	453503	385000	-15,11
4	Gdynia	610502	378340	-38,03
5	Helsinki	419809	357200	-14,91
6	Kotka	666356	345939	-48,08
7	Klaipėda	373263	247982	-33,56
8	Gdansk	185651	240623	29,61
9	Riga	210900	182980	-13,24
10	Copenhagen/Malmö	194000	156159	-19,51
11	Rauma	172155	143269	-16,78
12	Tallinn	180972	130939	-27,65
13	Helsingborg	135934	111981	-17,62
14	Gävle	103811	108522	4,54
15	Hamina	178804	108133	-39,52
16	Kaliningrad	213210	94516	-55,67
17	Lubeck	96122	79441	-17,35
18	Szczecin-Świnoujście	62913	52589	-16,41
19	Hanko	45772	38071	-16,82
20	Norrköping	30662	34254	11,71

Source: Authors' study based on website seaports.

From the table 4, we can see that, most container terminals achieved a negative turnover in 2009. Only such sea container terminals have reached the positive growth: Gdansk (+29,61), Gävle (+ 4,54) and Norrköping (+11,71).

As we can see from table 4, the trunk of the top 20 container seaports in 2009 and 2010 was nearly the same. In the 2009 in the region we had a great decreased in container turnover except the Polish container market. But in 2010 most container terminals achieved a positive increase but there were some leaders which reached a very high dynamic of growth such as: Lübeck (+145), Gdansk (+113), ADP (Fredericia) (+49%) and St. Petersburg (+ 44).

Table 5: The 20 Top Baltic Container Seaports in 2010

No.	Seaports	2009	2010	Annual change 2008/2009 (%)
1	St. Petersburg	1343675	1931	+44
2	Göteborg	824218	891	8
3	Aarhus	385000	447	16
4	Gdynia	378340	485	28
5	Helsinki	357200	400	12
6	Kotka	345939	397	15

7	Klajpeda	247982	295	19
8	Gdansk	240623	512	113
9	Riga	182980	254	39
10	Copenhagen/Malmo	156159	153	1
11	Rauma	143269	165	15
12	Tallinn	130939	152	16
13	Helsingborg	111981	149	33
14	Gavle	108522	100	-7
15	Hamina	108133	115	7
16	Kaliningrad	94516	231	145
17	Lubeck	79441	126	6
18	Szczecin-Świnoujście	52589	57	7
19	Alborg		64	6
20	ADP (Fredericia)		56	49

Source: Authors' study based on website

In turn in 2010 most sea container terminals in BSR achieved a positive dynamics of growth, except Gävle terminal. A confirmation that the financial crises has gone in the BSR as regards sea container turnover were positive dynamic growth in all states in 2011. The table 6 shows that most important sea container terminals catch up with losses of the financial crises.

Table 6: The Main Turnover Eastern Baltic Countries: Container Ports (TEU)

No.	Seaports	2011 % Annual change
1	St. Petersburg	23
2	Gothenburg	-
3	Aarhus	-
4	Gdynia	27
5	Helsinki	19
6	Hamina Kotka	-
7	Klajpeda	30
8	Gdansk	34
9	Riga	19
10	Copenhagen/Malmo	-
11	Rauma	35
12	Tallinn	30
13	Helsingborg	-
14	Gavle	-
16	Kaliningrad	38
17	Lubeck	-
18	Szczecin-Świnoujście	-
19	Hanko	-
20	Norrköping	-

Source: Authors' study based on website

The main Eastern Europe – top ten container terminals owning/operating companies are: NCC/ Eurogate (Ust Luga, St. Petersburg), GPI (St. Petersburg), NCSP (Baltiysk), DP World, Port of Ilvchevsk, ICTSI (BCT Gdynia), HHLA, HPH (GCT Gdynia), Macquarie (DCT Gdansk), MCT, UCLH (St. Petersburg).

In 2010 container terminals operation in the area was very profitable market GPI. Container sector archived EBIDTA in the BSR sector between 60 and 62% in 2010 and 2011 (Vanaale 2012).

The important factor for the investments made by seaports was the development container traffic in Baltic Sea region. The global financial crunch solved temporarily problem of insufficient container capacity in the Baltic seaports but it will be back if situation will return together with market recovery. This is the reason for seaports have made some infrastructure and superstructure investments the more they were much cheaper than during the peak of the market. For example, such a huge investment was run by the National Container Company (NCC) in the BSR seaports. The company has started building a new container terminal in Ust-Luga (Russia). The investment has been run by two main companies: FESCO (a Russian ship – owner and logistics provider) and First Quantum.³ The both companies have had equal share in NCC. Ust-Luga Container Terminal's first stage will be commissioned in September 2011⁴ and it is expected to have turnover approximately 440 000 of TEU. Moreover the next new container terminal was going to be built in Nynashamn by the seaport of Stockholm and will be operated by Hutchison Port Holdings.

This market situation has encouraged also other seaports to undertake infrastructure and superstructure investments in 2011 but its scale in comparison with above mentioned investments will be lower.

3. Expected Changes in the Container Business in Baltic Sea Region

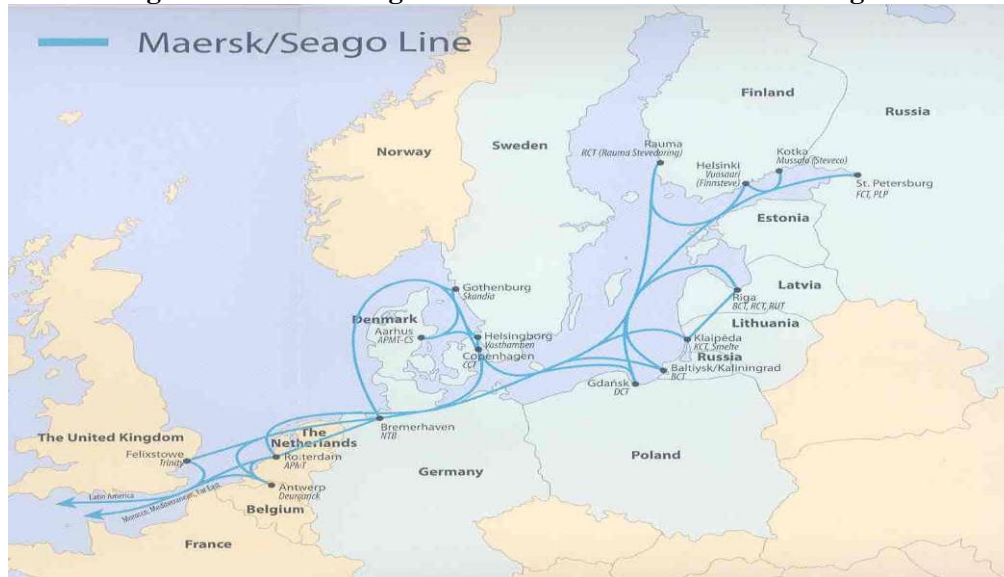
In the Baltic Sea Region has been observed a very specific situation especially in container shipping and terminals business. Some ship-owners have introduced larger vessels even to 14 000 TEU. When demand for containers turnover collapsed because of the financial crisis ship-owners introduced the vessels' slow steaming. Nowadays slow steaming of vessels is directly connected with high price of fuel oil on the international petroleum markets. Ocean – going vessels calls at the same number of deep seaports or even more. Moreover shipping lines have opened new links especially in feeder operation. Ship-owners put into the operation more vessels, but create smaller cascading to other/ new services, and consequently from 9 to 10 vessels are operated in one rotation. It is a standard of vessels operation nowadays. Indeed with 9 to 10 vessels in an Asia – Europe service, the roundtrip takes approximately 70 days, but in good weather condition and political stability the trip may be shorter.

The important issue of recent development in the Baltic container activity was the establishment of the first ocean connections between Asia, South America and the Baltic Sea. The new connection was performed by the Maersk Shipping Line which founded new opportunity for this very quickly developing region. The first direct deep-sea liner service was created by extending the Asia – Europe Maersk AE10 service, which previously ended its service in Gothenburg and Aarhus. The deep-sea vessel called at port of Gdansk on 4 January 2010. The new service AE10 has the following port rotation: Ningbao (China) – Shanghai (China) – Kaohsiung (Taiwan) – Yantian (China) – Hong Kong (China) – Tanjung Pelepas (Malaysia) – Le Havre (France) – Felixstowe (UK) – Zeebrugge (Belgium) – Gdansk (Poland) – Gothenburg (Sweden) – Aarhus (Denmark) – Bremerhaven (Germany)- Rotterdam (Netherlands) – Singapore (Singapore) – Hong Kong (China) – Kobe (Japan) – Nagoya (Japan) – Shmizu (Japan) – Yokohama (Japan). Moreover, Maersk Shipping Line served the Baltic Sea Container Terminals by Seago Line. Nowadays we have had direct ocean connection in Gdansk Port but also Seago line used its feeder service. In this way, containers of Maersk have come to all countries located in BSR.

³ http://www.container.ru/en/press/ncc/news_detail.php?ID=1159

⁴ <http://www.container.ru/en/terminals/ustluga/>

Figure 2. Maersk/Seago Line Connections in Baltic Sea Region



Source: Baltic Transport Journal

The Maersk Shipping Line has employed 10 vessels with a tonnage of over 8'000 TUE each, in order to ensure a weekly regular service. Furthermore Maersk has opened new feeder connections from Gdansk to St. Petersburg. In turn, during that time also Unifeeder Shipping Line has opened new feeder connections from Gdansk to Kotka and Helsinki. Another deep sea links, established by Maersk Shipping Line was launched between Ecuador and Russia (St. Petersburg) on 15 February 2010. The new weekly regular service Ecuador – Banana – Express (ECUBE) has called at the following seaports Guayaquil – Balboa – Rotterdam – St Petersburg – Bremerhaven – Manzanillo – Balboa – Guayaquil.

Furthermore in 2011 a high increase of competition between container ship-owners caused that other mega carriers created new alliances which are instable in the market. So the followed ship-owners created new alliance called “G6”: Hapag-Lloyd, MOL, APL, OOCL, NYK and Hyundai MM. The members of alliance “G6” also existing on the Baltic Sea Container Market. They had to enter into the Polish largest sea container terminals, such as: BCT, GCT and DCT, but they hadn't. Furthermore some mega carries have still been the main clients of the abovementioned container terminals.

The second direct ocean line existing in BSR may create new solution in the whole BSR. The new direct ocean link may cause decrease of feeder service connections between Polish market and western seaports countries such as: Germany, Denmark, and Dutch. So such changes may influence on sea container feeder service in Baltic pattern, because the new direct container line will carry also container units into the other sea ports located in BSR. By the new opportunities the Polish sea ports and container terminals may improve its market position in the region (Klimek, 2003; Klimek, 2006; Klimek 2010; Marek 2009; Marek, 2009).

The companies assess its economic situation and expect its further improvement in the near years, in spied off increasing competition and increasing costs of activities. The accumulative requirements of clients cause, that companies systematically broaden its offers on new markets segments and intensify range of its services. In the nearly future will be put an infancies on logistics consultants, quality control, manage of multimodal transport, management of load and empty containers by using communication systems which allow to directly connects with clients by Internet using. Planed investments (except means of transport) have embraced first of all informatics systems and modern technologies. The necessity of permanent broaden of a range of activity and increasing completion in BSR region influenced on further container market consolidation.

By entrance ocean direct connections in the BSR may change current pattern of feeder services because some companies may collapse. Currently the Baltic Sea Region is served by the fallowing feeder container companies: Unifeeder, Atlanitc Container Line, FESCO ESF, Swan Container Line, Delta Shipping Line, Hacklin Seatrans, K-Line, Mann Lines, OOCL, X-Press Feeders, MSC, Maersk/Seago Line, SCA Transforest,

Sea Connect, Tschudi Lines, Team Lines, Containerships, Samskip, Eimskip, TransAtlantic, Green Feeder, Merilinja. Perhaps, some of feeder companies may drop out from the container market. How the pattern change we will see probably in the near future.

The direct service between Poland (DCT Gdansk) and Asia, has opened up new markets and opportunities for all seaports located in the BSR. More direct access to those markets enhances the attractiveness of the terminal and may also create benefits from the growth of transshipment in all container terminals in Poland.

On the other hand, the clients demand a reliable, cheap logistic container solution. Slow steaming means more floating inventory, so also more containers needed that is why ship-owners want to optimize the rotation of container: so quicker container flow logistics. Economical models are adjusting: following the 'crisis' stakeholders of container's business and consumers create new solutions - green versus cheap, quick versus expensive. Anyway the all business players must find an optimal solution between these two once. Especially, nowadays there is a strong pressure in BSR container terminals on efficiency, throughput and accessibility.

4. Conclusion

As we have seen, the global financial crunch has hit into the BSR container traffic but not as strong as in other container seaports located all over the world (Elsayeh, Mohi-Eldin, Elkolla 2008). For example, if we take a Poland container market into consideration, there were positive level of GDP and very high level of internal demand. In the analyzed period, the changes of the Polish container market had two dimensions. One of them was strong competition struggle with existing container terminals. The second one was entrance of new container terminal (DCT in Gdansk) into operation. In consequence these two elements had the strongest impact on the Polish container market.

Even though, in 2010 – 2011 period, we have had a positive dynamic of growth in all container terminals located in Baltic Sea Region. Moreover there is still a forecasting that development of the market will be still much larger in numbers than average level of a container global growth.

Taking into the account so large increase of container turnover in the nearly future, all seaports and terminals make new investments and connections with its hinterland and of course new international solutions within and outside the European Union. For example, Port Gdynia improved its port channel and dredged port's basins and way (Borkowski, 2009; Borkowski, 2010) Thus, Port Gdynia may serve a bigger size ocean and feeder container vessels (Gromadowski, 2001). Such investments enable Port Gdynia to compete with port of Gdansk and other container sea ports located in Baltic Sea Region.

Many investments have had an international character because they focused on improvement of transport infrastructure and connections. The main barrier of container turnover increase was increasing costs of activity (employment and oil). From the other hands bad condition of transport infrastructure has had a negative impact upon the development of container market in BSR

New deep-sea links opened by Maersk Shipping Line, reopened the discussion on establishment a Baltic container hub. This concept has had benefits and threats for both main and smaller players in the container market. By many years, businessmen and researchers experienced the opinion that ultra large container vessels could not call at Baltic seaports but economical and technological progress changed the market completely. The economic growth has developed very quickly the international seaborne trade between seaports located in the BSR and in other overseas countries. In consequence some sea container terminals in the Baltic Sea Region have had ambitions to become a Baltic hub. For example port Aarhus has developed the concept of AARHUB. A similar approach has had port of Gothenburg. Both ports want to service the largest container vessels and may serve as a gateway for the Baltic container seaborne trade.

Anyway expansion of deepwater container terminal in Gdansk formed an opportunity to attract ocean-going vessels and creates bigger competition for container transshipment for smaller feeder companies. From theoretical point of view, port of Gdansk with their terminals has had a good opportunity for becoming a container hub, but in the long run time.

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Pricing Joint Products in Liner Shipping

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Abstract

Fronthaul and backhaul shipping trips share the same round-trip voyage costs. The pricing strategies for the two trips are critical to the performance of liner operators, as well as the trade volume. This paper analyzes the pricing strategies for the two trips in liner shipping based on different levels of demand imbalance. The critical condition is found when demand imbalance causes trade imbalance, and the optimal pricing strategies and the relationship between fronthaul and backhaul prices in both balanced trade and imbalanced trade are identified. Using the properties derived from theoretical analysis and employing Johansen's Vector Error Correction Model, the relationships between fronthaul and backhaul container freight rates for the Trans-Pacific, Trans-Atlantic and Euro-Asia routes were tested, and the critical trade imbalance ratios that disintegrate the freight rates for both directions were identified. The paper develops a theoretical model for pricing joint products under the demand imbalance in liner shipping. Practically, our model provides different pricing strategies for fronthaul and backhaul routes with different imbalance ratios, and explains price movements on the three major trade routes using demand imbalance.

Keywords: Container trade, backhaul, cointegration, joint product

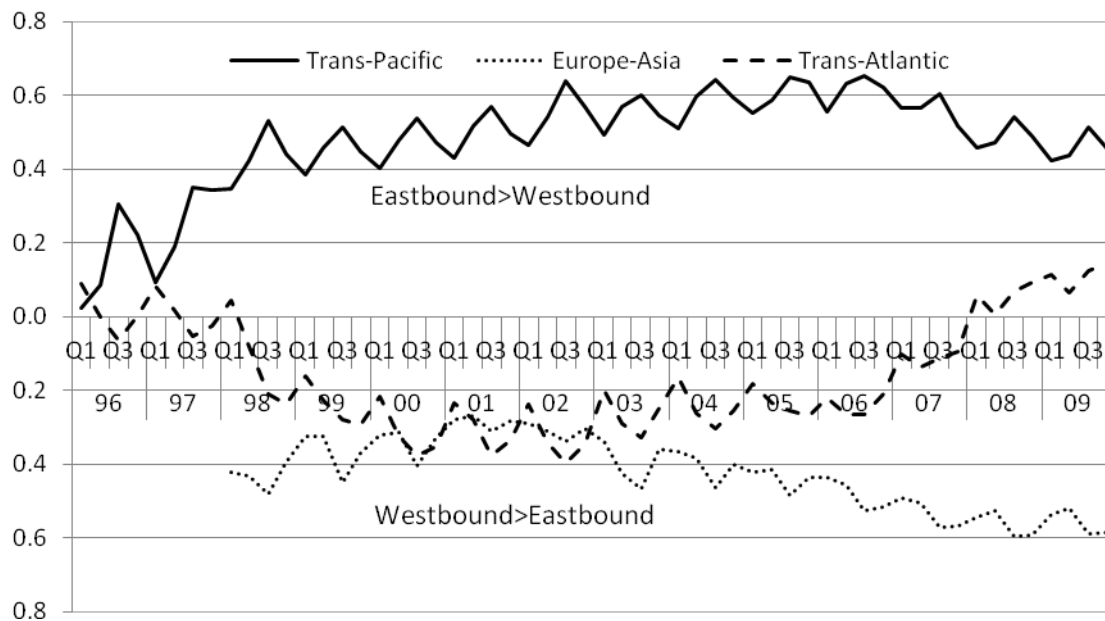
1. Introduction

Container liner shipping provides reliable and efficient logistic services for global businesses and handles the majority of seaborne trade in manufactured goods. In most such services, carriers have to move in both directions between selected ports in different regions. The costs for providing services in one direction (e.g. from Asia to North America) cannot be separated from the costs for bringing the ship back. Hence, the services for the two directions can be looked upon as a joint production process. If a company provides a service in one direction, it will have to provide the service in the opposite direction.

Due to the inherent nature of joint products, allocation of total production costs and pricing of individual products to maximize total profits become important issues in a firm's production decisions and pricing strategies. Joint products have been well studied in economics (Nicholson, 1958; Mohring, 1976) and transportation economics (Wilson, 1987) due to their importance to both producers' profits and social welfare. They are especially important to shipping because different countries have their own natural and human resources, comparative advantages in skills and specializations, which often leads to different shipping demands. However, demand imbalance among different regions may not necessarily result in trade imbalance if prices for different directions can be charged differently. Therefore, it is critical for liner shipping companies to charge right prices when there are different levels of demand imbalance among their trade partners.

Liner shipping routes can be divided into three groups - East-West, North-South and intraregional. Among them, East-West group has the largest trade volume, which is about 42% of global containerized trade (Drewry, 2010). This group includes Trans-Pacific, Trans-Atlantic and Euro-Asia routes—the major long-haul routes on which the biggest container ships are deployed to link the industrial centers in North America, Europe and Asia. Figure 1 shows the actual imbalance between eastbound and westbound trade on these three routes from the first quarter of 1996 to the year 2009. On the upper part (above the horizontal axis in the middle) are the Trans-Pacific routes where eastbound trade is usually 40% more than westbound one. On the lower part (below the zero axis) are Trans-Atlantic and Euro-Asia trade, where westbound trade is larger than eastbound one. Among them, the Trans-Atlantic routes have much smaller trade imbalance, while Euro-Asia trade imbalance has been constantly increasing since 2001, and, in 2009, the westbound volume was almost 60% more than the eastbound one. The figure also displays seasonal variations in trade imbalance which is always at its lowest in first quarters.

Figure 1: Trade Imbalance on Different Routes



Note: Imbalance is defined as $1 - \text{Westbound}/\text{Eastbound}$ if the eastbound volume is larger than the westbound one; otherwise, it is $1 - \text{Eastbound}/\text{Westbound}$. For Euro-Asia trade, data before 1998 is not available.

Trade imbalance on major trading routes and its impacts on liner operation make important the study of best pricing strategies for fronthaul and backhaul routes. However, due to the nature of joint products, the fronthaul price cannot be separated from the backhaul price. Dependent on differences in potential demand, these two prices may be correlated with each other, and jointly determine trade imbalance on a route. This study extends the market access model by Wilson & Dooley (1993), Wilson (1994) and Wilson & Beilock's (1994), theoretically analyzes pricing strategies and price relationships when there are different demands for seaborne trade, when demand imbalance induces trade and price imbalance, and when freight rates for the same route in both directions should be cointegrated or not related. Through applying the cointegration test to time-series data about container freight rates for the three major east-west trade routes in both directions as well as their sub-samples, price relations among the major routes and their relations with different annual trade imbalance ratios are found. The statistical results show that the trade imbalance ratio which disintegrates is higher in Trans-Pacific route than that in Trans-Atlantic route. This study is the first one applying the cointegration method to trade imbalance in liner shipping, which can help liner operators price front/backhaul services when there is an imbalanced demand for both directions.

The structure of this paper is as follows. Section 2 reviews the relevant literature on shipping and transportation in terms of backhaul. Section 3 presents the conceptual work on the operation of fronthaul and backhaul trips. Section 4 describes the method, data, and data properties. Section 5 reports the empirical results and discussions. Finally, section 6 gives the conclusions.

2. Literature Review

Many studies on trade imbalance in shipping focus on repositioning of empty containers due to its importance to the operation of liner shipping companies (Cheung & Chen, 1998; Song, 2007; Shintani et al., 2007). Very few researchers have studied pricing strategies for transportation services. Zhou and Lee (2009) once studied strategic pricing for monopoly and duopoly in terms of trade imbalance, and used numerical simulation to show how profits are affected by loaded equipment movement costs, unit empty equipment reposition costs, price sensitivity and competition intensity. In comparing the above study, our study focuses on the relationship between market prices in the two directions where demand is imbalanced and major costs for providing shipping services in the two directions are inseparable.

Regarding transportation studies, the most common topic of joint production is pricing of backhaul trips due to the fact that fronthaul and backhaul share the non-allocable joint (Taussig, 1913; Pigou & Taussig, 1913a; Pigou & Taussig, 1913b; Felton, 1981). Pederson et al. (1979) suggested that empty backhaul is a *pervasive and dominant* characteristic of trucking and causes problems to both carriers and shippers. Shippers using fronthaul have to pay high freight rates, which can reduce transportation demand, lead to excessive capacity, and restrict competition. Since pricing for fronthaul usually happens before backhaul, Wilson (1987) argued that there are negative correlations between fronthaul prices and backhaul probabilities. In terms of the relationship between the costs of the whole trip and freight rates, Mohring (1976) found that greater demand for fronthaul relative to backhaul makes fronthaul prices closer to round-trip costs. If demand imbalance is sufficiently large, the fronthaul trip may bear the entire costs of round trips, while backhaul can only cover pickup and delivery costs. Felton (1981) explored the formation of fronthaul and backhaul rates under different relative demands. Above a certain level of imbalance, all joint costs are borne by fronthaul, and backhaul covers the separable marginal costs only. Below that level, joint costs are borne by both rates in different proportions. In our study, similar patterns are found in liner shipping.

Although there are numerous studies on empty container repositioning in liner shipping and backhaul pricing for trucking, there is no study investigating pricing strategies and price relationships between the two directions in the liner market facing different levels of demand imbalance, which results in this study.

3. Conceptual Framework

The market access model for trucking operation (Wilson & Dooley, 1993; Wilson, 1994; Wilson & Beilock, 1994) are extended to liner shipping, in which liners have to decide the number of round trips (N) in a time period facing an imbalanced demand for fronthaul (f) and backhaul (b). For simplicity, it is assumed that fronthaul is always fully loaded while backhaul may or may not be fully loaded dependent on the backhaul demand imbalance. The capacity of a ship is assumed to be T TEUs, and the fixed, non-separable round-trip costs are b , which includes all financial and capital costs of a ship, as well as operation costs and voyage costs. The only costs excluded from b are the separable marginal/average costs of handling one container, which are equal to h_f in fronthaul or h_b in backhaul.

Regarding demand, it is assumed that demand functions for fronthaul and backhaul are $q_f = Q_f - k_f p_f$ and $q_b = Q_b - k_b p_b$, where p_f and p_b are freight rates for fronthaul and backhaul, q_f and q_b are quantities demanded (or realized demands), Q_f and Q_b are potential demands, and k_f and k_b are price sensitivities. Liners are price takers, and their operation mechanism is to maximize profits for given market freight rates.

The profit function for a competitive firm facing demand functions is:

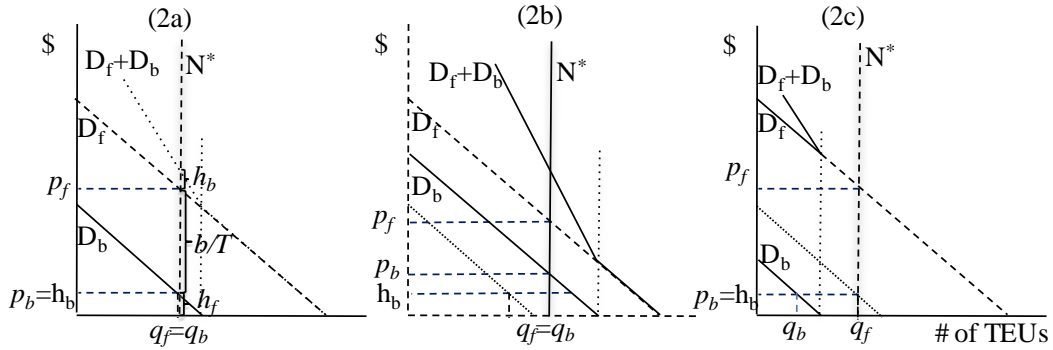
$$\begin{aligned} \pi &= p_f NT + p_b NT\delta - bN - h_f NT - h_b NT\delta \\ \text{s.t. } 0 &< \delta \leq 1, p_b - h_b \geq 0 \end{aligned} \tag{1}$$

where δ is the load factor in backhaul. The liner operator has to determine the optimal number of trips (N) to maximize profits, the solution to which can be considered in the following cases:

$$\begin{cases} \delta = 1, p_b = h_b & (2a) \\ \delta = 1, p_b > h_b & (2b) \\ \delta < 1, p_b = h_b & (2c) \end{cases}$$

The optimal prices with respect to different levels of demand imbalance corresponding to these three cases are shown in the graphs below.

Figure 2: Fronthaul and Backhaul Prices at Three Levels of Demand Imbalance



When $\delta=1$ (cases 2a and 2b), there is no trade imbalance between fronthaul and backhaul in spite of imbalanced demands for the two directions. In (2c), backhaul containers are less than fronthaul ones because of empty containers.

In case (2a), the fronthaul freight rate $p_f = b/T + h_f$ covers the average fixed round-trip costs and the separable marginal costs for fronthaul. The backhaul price $p_b = h_b$ just covers the separable marginal costs for backhaul. In theory, backhaul has the same number of containers as fronthaul.

In using the demand function of backhaul $q_b = N \times T = Q_b - k_b p_b$, the optimal number of trips $N^* = (Q_b - k_b h_b)/T$ can be calculated. Obviously, N^* can also be calculated by substituting p_f in the fronthaul demand function, which is $N^* = (Q_f T - k_f b - k_f h_f T)/T^2$. Since these two are equal to each other, the condition for (2a) is $(Q_f - k_f h_f) - (Q_b - k_b h_b) = b k_f / T$. The left-hand side is the difference in potential demands when taking into account the marginal container handling costs. On the right-hand side, b/T is the average fixed round-trip costs, and k_f is the price sensitivity in fronthaul. The right-hand side is the impact of the average fixed costs on fronthaul demand. There will be two different cases dependent on whether the left-hand side is larger or smaller than the right-hand side.

When demand imbalance is less than that in case (2a) (i.e. backhaul demand closer to that fronthaul demand), case (2b) is obtained, where $p_f + p_b = b/T + h_f + h_b$. Fronthaul and backhaul prices not only cover their respective separable marginal costs, but also share fixed round-trip costs. In comparing case (2a), fronthaul prices are lower, while backhaul prices are higher. Although there is demand imbalance, there should be no trade imbalance theoretically, and prices for the two directions should be interdependent. If this situation lasts for a long period, the time-series of fronthaul and backhaul prices should show a statistical association. That is, they should be cointegrated.

Using demand functions for fronthaul and backhaul, the equilibrium number of round-trips and equilibrium prices can be obtained:

$$N^* = \frac{\frac{Q_f - k_f h_f}{k_f} + \frac{Q_b - k_b h_b}{k_b} - \frac{b}{T}}{T(1/k_b + 1/k_f)} \quad (3a)$$

$$p_f^* = \frac{Q_f - Q_b + k_b(b/T + h_f + h_b)}{k_f + k_b} \quad (3b)$$

$$p_b^* = \frac{-(Q_f - Q_b) + k_f(b/T + h_f + h_b)}{k_f + k_b} \quad (3c)$$

It is obvious that the ratio of fronthaul and backhaul prices is

$$\frac{p_f^*}{p_b^*} = \frac{k_b(b/T + h_f + h_b) + Q_f - Q_b}{k_f(b/T + h_f + h_b) - (Q_f - Q_b)} \quad (4)$$

In case (2c), backhaul demand is much lower than fronthaul demand. The price for backhaul only covers its separable marginal costs, i.e., $p_b = h_b$. The price for fronthaul has to cover the average fixed round-trip costs and its own marginal costs (i.e. $p_f = b/T + h_f$), and it is independent of backhaul price. There is trade imbalance, and the load factor in backhaul is $\delta = (Q_b - k_b h_b) / (Q_f - k_f h_f - k_f b/T)$.

The above three situations can occur over time depending on different levels of trade imbalance. For example case (2b), freight rates for both directions are cointegrated. If demands for fronthaul and backhaul shift in or out by the same amount, the two rates will move in the same direction. However, if backhaul demand shifts in, the two rates will remain cointegrated but in opposite directions (i.e. decrease in backhaul prices and increase in fronthaul prices). Further shift-in in backhaul demand can anchor backhaul rates at its separable marginal costs, which disintegrate the two rates. Therefore, although the model is static, it can be used to explain the dynamic relationship between the time-series if the multi-period pricing behavior is not considered.

This section explains theoretically how demand imbalance can lead to trade imbalance, demonstrates the optimal pricing strategies with or without trade imbalance, and points out the possibility of using the model to explain the dynamic relationship between different time-series data about fronthaul and backhaul rates on the same route. In practice, trade imbalance is observed, instead of demand imbalance. In addition, due to practical limitation, freight rates may not become disintegrated whenever trade imbalance is observed. Therefore, finding the threshold that disintegrates the two prices can point to practical guidance on pricing joint round-trips in liner shipping.

4. Empirical Analysis of the Relationship between Fronthaul and Backhaul Prices

4.1. Method

One of the problems in analyzing long-term time-series data, such as container freight rates in the past fifteen years, is non-stationarity, which can lead to important issues in econometric analysis such as autocorrelation, multicollinearity and heteroscedasticity. Many times-series models are designed specifically to solve these problems (Kavussanos, 1996; 1997; Veenstra, 1999; Glen, 1997), especially in evaluating the dynamic relationship between different time-series data.

The first step in analyzing the dynamic relationship among different variables is to determine the integration order of each variable. A non-stationary time-series is integrated of order d , denoted as $I(d)$, if it becomes stationary after being differentiated d times. If two or more time-series variables are integrated of order d (i.e. $I(d)$), and there is a stationary linear combination of these variables, they are said to be cointegrated. In this study, the cointegration test of Johansen's VAR (Vector Autoregressive) approach 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).

4.2. Data source

The study uses quarterly average freight rates (on TEU basis) for three major liner routes, Trans-Pacific, Euro-Asia and Trans-Atlantic, in both directions provided by United Nations Conference on Trade and Development annual reports (UNCTAD, 1997-2010), which spans from the last quarter of 1995 to the last quarter of 2009. There are six time-series variables. $ASUS_t$ and $USAS_t$ are freight rates for the Trans-Pacific route which are from Asia to the U.S. and the U.S. to Asia. $ASEU_t$ and $EUAS_t$ are for the Euro-Asia route. Finally, $USEU_t$ and $EUUS_t$ are for the Trans-Atlantic route.

Table 1 summarizes the descriptive statistics for the logarithm of the above six variables. The differences in mean values of each pair of freight rates on the same route shown in parenthesis indicate that the Trans-Atlantic route has smaller differences in the two directions. 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 freight rates for the U.S. to Asia and Europe to Asia are not normally distributed. These two rates are on the backhaul routes with large trade imbalances. One possible explanation is that freight rates cannot be lower than its no-separable marginal costs.

Table 1: Descriptive Statistics of Average Freight Rates for Different Routes

Time series	Mean(Δ)	Std. Dev.	Skewness	Kurtosis	Jarque-Bera	Probability
$ASUS_t$	7.440	0.134	-0.302	2.463	1.550	0.461
$USAS_t$	6.813 (0.626)	0.207	1.226	3.183	14.364	0.001
$ASEU_t$	7.283	0.200	-0.421	2.583	2.099	0.350
$EUAS_t$	6.739 (0.559)	0.197	0.790	2.679	6.169	0.046
$USEU_t$	7.015	0.241	0.244	1.641	4.951	0.084
$EUUS_t$	7.221 (0.206)	0.157	0.407	2.055	3.696	0.158

Figure 3 plots all the quarterly freight rates over the sample period. Each panel contains one route. The fronthaul and backhaul freight rates were very close before 1998 in the first two panels (Trans-Pacific and Euro-Asia routes). After 1998, the fronthaul rates for from Asia were significantly higher than backhaul rates for from the U.S. or Europe. In addition, the volatility of freight rates for fronthaul is much higher than that for backhaul, and there is no obvious co-movement between the freight rates on the same routes. For Trans-Atlantic trade, the freight rates exhibit some co-movement when the U.S. outbound freight rates were higher before 2000 and after 2008, which implies reverting of relative demand between these two regions.

For the six time-series variables, the ADF (Augmented Dickey-Fuller)(Dickey & Fuller, 1981) and PP (Phillips and Perron) (Phillips & Perron, 1988) methods are used to perform unit root tests. The test results (Table 2) show that the logarithm of freight rates is non-stationary for all the routes, while their first differences are stationary, indicating that variables are integrated of order one, $I(1)$. Since they have the same order of integration, it is possible to apply a cointegration test to these variables.

5. Results and Discussion

5.1. Cointegration test results

After identifying all freight rates as $I(1)$ variables, cointegration techniques are used to examine whether a long-run relationship exists between freight rates on the same route. According to Johansen (1988; 1991), the VAR model can be written in the following equation,

$$\Delta y_t = \Pi y_{t-1} + \sum_{i=1}^{p-1} \Gamma \Delta y_{t-i} + \varepsilon_t \quad (5)$$

where y_t is the vector of directional freight rates on each route, which is equal to $(ASUS_t, USAS_t)'$ on the Trans-Pacific route, $(ASEU_t, EUAS_t)'$ on the Euro-Asia route, and $(USEU_t, EUUS_t)'$ on the Trans-Atlantic route. The last term ε_t is an error term. The lag length (p) is set to 2 based on the Akaike Information Criterion (AIC) (Akaike, 1973) and the Schwartz Bayesian Information Criterion (SIC) (Schwarz, 1978). The Δy_{t-1} in the second terms is stationary because y_t is $I(1)$. The stationarity of the model is determined by the rank of Π , a 2 by 2 coefficient matrix for y_{t-1} . If cointegration exists, the rank must be between zero and two. If the rank is 0, the directional rates are independent of each other and no integration exists. If the matrix has full rank, the two variables must be stationary, which contradicts the assumption that all data series are $I(1)$. In this study, cointegration exists between fronthaul and backhaul rates only when the rank is one. The commonly used methods to assess rank (R) of coefficients matrix Π , which is also the number of cointegration relations, are the trace test (λ_{trace}) and maximum eigenvalue test (λ_{max}) (Johansen, 1991). The λ_{trace} tests the null hypothesis of r cointegration relations against the alternative hypothesis of full rank, while λ_{max} tests the null hypothesis of r cointegration relations against the alternative hypothesis of $r+1$ cointegration vectors.

Figure 3: Plot of Freight Rates for Different Routes

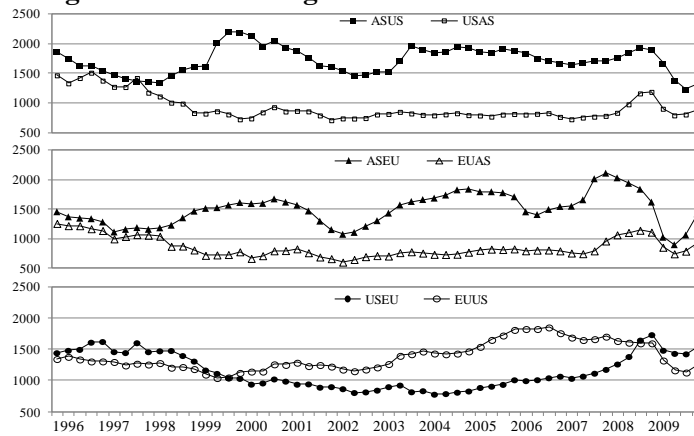


Table 2: Unit Root Tests

Time Series	Levels		First differences	
	ADF	PP	ADF	PP
$ASUS_t$	-3.135*	-2.262	-4.507**	-4.574**
$USAS_t$	-2.925	-2.517	-3.848**	-5.878**
$ASEU_t$	-2.200	-2.359	-3.188*	-3.636**
$EUAS_t$	-2.781	-2.495	-2.615	-5.159**
$USEU_t$	-1.124	-1.002	-5.734**	-5.734**
$EUUS_t$	-1.996	-1.460	-1.338	-4.672**

Note: * Rejection of hypotheses at 5% significance level.

** Rejection of hypotheses at 1% significance level.

The cointegration tests for directional freight rates are shown in Table 3. On the Trans-Atlantic route, both λ_{trace} and λ_{max} reject the null hypothesis of $R=0$ (no cointegration) and accept that there is one cointegration relation. However, both tests accept that there is no cointegration relationship on the Euro-Asia route. On the Trans-Pacific route, the λ_{max} test suggests that there is no cointegration relationship, while the λ_{trace} test shows the existence of one cointegration relationship. These controversial findings may be caused by the instability of cointegration in different time periods. This can be further examined using different sub-samples in the following sub-section.

Table 3: Results of Johansen's Reduced Rank Cointegration Tests

Pair of variables	Lags	λ_{max}		λ_{max} Value	λ_{max} 95% CVs	λ_{trace}		λ_{trace} Value	λ_{trace} 95% CVs
		H0	HA			H0	HA		
Trans-	2	R=0	R=1	14.811	15.892	R=0	R=2	24.225*	20.262

Pacific		R=1	R=2	9.414	9.165	R=1	R=2	9.414	9.165
Euro-Asia	2	R=0	R=1	12.000	15.892	R=0	R=2	18.976	20.262
		R=1	R=2	6.976	9.165	R=1	R=2	6.976	9.165
Trans-Atlantic	2	R=0	R=1	16.982*	15.892	R=0	R=2	22.070*	20.262
		R=1	R=2	5.088	9.165	R=1	R=2	5.088	9.165

Note: * Rejection of hypotheses at 5% significance level. CVs represent the critical values from Mackinnon-Haug-Michelis (1999).

The trade imbalance is relatively higher on the Trans-Pacific and Euro-Asia routes than on the Trans-Atlantic route. The findings about no cointegration on the Trans-Pacific and Euro-Asia routes are consistent with the non-cointegration scenario introduced in Section 3 when demand imbalance is large enough to result in trade imbalance. In this case, fronthaul has to cover the common inseparable fixed costs of round trips, while backhaul only pays the separable marginal costs. For the Trans-Atlantic route, the demand imbalance rate is relatively low. In theory, such level of demand imbalance may not result in trade imbalance, although in practice there is still trade imbalance due to many practical reasons. However, the fronthaul and backhaul freight rates are cointegrated, and fronthaul and backhaul share the common inseparable fixed costs of round trips.

After testing the consistency in the theoretical results of the price relationship between fronthaul and backhaul, and the cointegration relations between different time-series data about the fronthaul and backhaul freight rates for the three major routes, it is natural to examine the stability of the cointegration relations during the study period. Then the cointegration relationship is further tested between the directional freight rates for each route according to the trade imbalance level, which can help identify the critical trade imbalance that may result in non-cointegration between fronthaul and backhaul freight rates.

5.2. Cointegration stability tests

During the study period, there are structural changes in demand imbalance on the three major routes, which can be found in Figure 1. This structural change can lead to the change in the nature of cointegration. Identifying the critical trade imbalance that can lead to such a change can help decide freight rates for fronthaul and backhaul when there is trade imbalance.

Based on the trade imbalance and freight rates in Figures 1 and 3, the whole sample of the Trans-Pacific is divided into two in the year 2000 when the annual trade imbalance (α) was higher than 0.5. For the Euro-Asia route, the sample is divided into three sections: before the second quarter of 1999 ($\alpha > 0.4$), from the second quarter of 1999 to the fourth quarter of 2003 ($\alpha < 0.4$), and after 2003 ($\alpha > 0.4$). For the Trans-Atlantic route, the sample is divided into three parts by $\alpha = 0.2$: before 1999 ($\alpha < 0.2$), between 1999 and 2006 ($\alpha > 0.2$), and after 2006 ($\alpha < 0.2$). The results for each pair of freight rates are shown in Table 4.

For the Trans-Pacific route, the fronthaul and backhaul freight rates are cointegrated when the trade imbalance rate is lower than 0.5. They are not cointegrated when the trade imbalance ratio is higher than 0.5. For the Euro-Asia route, cointegration is identified when the trade imbalance rate is lower than 0.4; when it is higher than 0.4, cointegration disappears. Regarding the Trans-Atlantic route, when the trade imbalance rate is below 0.2, the two freight rates are cointegrated; when the rate is higher than 0.2, no cointegration exists.

The above results show that in practice the freight rates for the same route in both directions are not disintegrated immediately when there is trade imbalance. In addition, the critical value of trade imbalance that can disintegrate the two freight rates for a route increases with the route length. The critical value for the Trans-Atlantic route is 0.2, while the value for the Trans-Pacific route is 0.5. This difference in critical imbalance ratio also provides a pricing principle for different routes. For the Trans-Atlantic route, fronthaul may need to pay the whole round-trip fixed costs even when there is little trade imbalance; while for the Trans-Pacific route, backhaul can also pay some round-trip costs as long as trade imbalance is less than 50%.

Table 4: Cointegration Tests for Sub-Samples on Each Route

Trans-Pacific			Euro-Asia			Trans-Atlantic		
α	Period	Cointegrated	α	Period	Cointegrated	α	Period	Cointegrated
<0.5	1995.Q4-2000.Q4	Yes	>0.4	1995.Q4-1999.Q1	No	<0.2	1995.Q4-1999.Q1	Yes
>0.5	2001.Q1-2009.Q4	No	<0.4	1999.Q2-2003.Q4	Yes	>0.2	1999.Q2-2006.Q4	No
			>0.4	2004.Q1-2009.Q4	No	<0.2	2007.Q1-2009.Q4	Yes

6. Conclusions

In this study, how demand imbalance induces trade imbalance and the relationship between freight rates for both trade directions are theoretically analyzed. Three cases are identified according to relative demands for the two round-trip directions and the optimal pricing strategies are demonstrated in different situations. Theoretically, when trade is balanced, freight rates for both directions are closely related and combine to cover the fixed round-trip costs in addition to their respective marginal costs. When trade is imbalanced, the two freight rates are no longer related. While fronthaul prices change according to market demand, backhaul is fixed at its marginal costs.

Empirically, a new approach, the cointegration test, is used to explain the dynamic relationship between different time-series data about fronthaul and backhaul rates for the same trade routes. The cointegration between freight rates is tested both for the whole time-series and sub-samples to examine the relationship between cointegration and the trade imbalance ratio. For the test on the whole sample, no cointegration is found on the Trans-Pacific and Euro-Asia routes, which can be explained by the high trade imbalance on the two routes. Cointegration exists on the Trans-Atlantic route, which may reflect the overall effects of the study period.

To test the change in a trade relationship over time, the stability of cointegration on the three main routes is tested on the sub-sample of the time-series data according to the imbalance ratio. Both cointegrated and disintegrated time periods are found on all three routes, and the critical values of the trade imbalance ratio that makes freight rates disintegrated are different on different routes. For the Trans-Atlantic route, a trade imbalance ratio higher than 0.2 can make the freight rates disintegrated. However, that ratio should be higher than 0.4 for the Euro-Asia route and 0.5 for the Trans-Pacific route.

This paper contributes on how to price joint products where there are common fixed costs and separable marginal costs when demands for two products are different through an example in liner shipping. It identifies different pricing strategies for different levels of demand imbalance. Practically, it helps liner shipping companies make pricing decisions when trade is imbalanced, which suggests that fronthaul needs to cover round-trip costs only when the trade imbalance ratio is higher than its critical value which is different for different routes at different times. Finally, it points out the existence of cross subsidies from net-exporting countries to net-import countries through shipping rates. For example the Trans-Pacific route, the trade volume from Asia to the U.S. is much higher than that from the U.S. to Asia. Consequently, the freight rate from Asia to the U.S. is almost twice as much as the way back. Therefore, it can be seen that Asian shippers pay much more than their U.S. counterparts, which is a voluntary subsidy of Asian countries to U.S. exporters.

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Considering Substitution in Green Perishable Products' Joint Pricing

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Abstract

Green products are favored by consumers, however, the substitutability between the two products and higher price of green products affect consumer green purchase behavior. This paper mainly took agricultural products as objects to study perishable green products pricing, provide strategy for the oligopoly retailer. In the paper, supposed that green products demand correlate to green degree, took advantages of pricing strategy to guide consumers to purchase and use green products. Besides, this paper made use of linear function to describe the relations between the prices and demands and took advantages of price-driven substitution to study joint-pricing when green and ordinary products coexist, with this to analyze the effects which green degree have on optimal joint-pricing, and how the retailer make can better decisions by green market capacity. So as to make this study plays a guiding and coordinating role in the green consumption and green production.

Keywords: perishable product, green degree, green product, price-drive substitution, joint pricing

1. Introduction

Implementing sustainable social economic development strategies requires change traditional producing and consuming patterns, and green consumption concept gradually becomes mainstreams and roots deeply in people's mind. However, In terms of the green consumption level in China, low level green agricultural products (China Agricultural Products Market Association defined green agricultural products as the products that follow the principles of sustainable development, accord with the specific production way, certificate by specialized agencies and permit to use green food logo, pollution-free, safety, high quality and nutritious agricultural products) consumption is dominant. Most green agricultural products in the existing market have short life cycle, which were defined as perishable products. Weatherford and Bodily (1992) defined perishable products as easy metamorphic, ageing or seasonal products which have long production period, short life cycle and low salvage value. From the perspective of both traditional consumer demand and enterprises' long-term strategy, enterprises should change from the traditional produce (sale) to green produce (sale), so as to realize the green economy transformation. Besides, Jin M and Lin X (2006), Wen Q X and Hu F X (2003) pointed out in their paper that the main factors impact green spending powers are the substitutability between green and ordinary products and the green products positive externality.

In the relevant study about green consumption, Andrew et al. (2005) from the perspective of how to identify sustainable green consumer studied green consumption and the way of sustainable life; (Zhang, 2008) proposed that green products pricing should consider the factors make product price raise, such as the cost of "green"; Guo and Li (2007) made use of the competition model of different green degree to make corresponding competitive price. In the previous articles, most authors from the perspective of pricing studied green products consumption. But this paper still is on the basis of green product pricing to study green consumption, meanwhile, the pricing should be considered the substitutability between green and ordinary products. Demand substitutions are generally classified into two forms: price-driven and inventory-driven substitution. This paper mainly study on price-driven substitution and takes perishable agricultural products as objects. The domestic and overseas existed literatures relevant to perishable product's dynamic pricing, Dou and Tian (2011) studied the impact of perishable products' value attenuation on dynamic pricing; Shen and Zhang (2011) studied the mixed consumer perishable products dynamic pricing. Bitran and Caldentey (2005) studied perishable products substitution pricing, studied pricing strategy from the view of both price driven and inventory driven substitution; (Levis, 2007) take use of optimal pricing to manage quick-selling substitution products. (Ferguson, 2007) use two-stage pricing to study perishable dynamic pricing, Si et al. (2010) and (Mu, 2011) use linear function to describe the demand substitution and product prices of 2 products. Bolt et al. (2008) from the perspective of users' price elasticity of demand considered market joint pricing problems within externality and complex demand, stated add lower cost-plus for the users who have higher price elasticity of demand can obtain more participants, besides, joint pricing applies to set high cost-plus price to the users who have lower demand price elasticity can obtain more profit. (He, 2010) under information symmetry take use of the green pork pricing model proposed that concentrated pricing strategy can make enterprises gain maximizing profit. Yang and Song (2008) studied single cycle substitute joint pricing strategy.

From the literature review, it's known that many of the authors used two periods pricing to study perishable products pricing and use joint pricing to study the optimal pricing strategy. But the studies considered both demand substitution and perishable product joint pricing are insufficient, or the objects almost never in terms of products of green supply chain. Therefore, this paper on the basis of former researches, take use of the two-stage joint-pricing strategy to study substitution on green supply chain, so as to analyze the factor of green degree in green consumption and in some extent to break through the traditional research view of green supply chain product pricing.

2. Problem Description and Hypothesis

This paper studies the problem that traditional perishable agricultural products oligopoly retailer, which decides to order green products for sale besides normal products. So the retailer is ability to re-price the two products. However, while selling the green products, the retailer should consider the following situations: The one is green demand greater than the supply because special requirements in the green production process and the restriction of green products amount that suppliers provide for the retailer; the other is insufficient green demand form the positive externality of green products leading to higher green price. The both above is defined as supply constraint market and demand restraint market of green products , and use high and low market capacity to describe the two situations respectively. The two-stage pricing is described as: When the products can't sale out in the 1st sales period then re-price them in the 2nd sales period.

Introducing the following assumptions:

Hypothesis 1, green products demand correlate to green degree (green degree is defined as "green degree standard" products comply with which the higher of the product green degree, the better of product environmental protection performance), besides, use green degree to describe the difference between green and ordinary products. Green products consumers buy green product according to the green preferences, and the average preferences and purchase probability is same.

Hypothesis 2, due to perishability of products, green degree declines over time, but green degree keeps the same within a certain period. The salvage values of both green and ordinary products are 0.

Hypothesis 3, Green product market capacity is proportional to the green degree; the ordinary product market capacity is inversely proportional to green degree.

Hypothesis 4, the price elasticity of demand, substitution coefficient and unit product cost are known, only discuss market capacity and green degree in a certain period.

The following are notations:

θ is green degree and $\theta \in (0, 1]$;

A is market capacity (market capacity is product or service number can be absorbed in a certain period which don't consider the product prices and suppliers strategy) , green product market capacity is donated as $A_{1j} = A\theta$; Ordinary product market capacity is donated as $A_{2j} = A(1 - \theta)$.

c_1, c_2 is green and ordinary products per unit cost;

Q_1, Q_2 is the ordering of green and ordinary products respectively;

p_1, p_2 is unit sales price for green and ordinary products respectively;

Subscript i indicates product type, $i = 1$ represents green products , $i = 2$ represents ordinary products ;

3. Model Description

3.1. Basic Model of Price Driven Substitution Joint Pricing

Make use of liner function, the product demands are indicated as:

$$D_1 = A_1 - b_1 p_1 + d_1 p_2; \quad (1)$$

$$D_2 = A_2 - b_2 p_2 + d_2 p_1; \quad (2)$$

$$D_1 + D_2 = A_1 + A_2 + (d_2 - b_1) p_1 + (d_1 - b_2) p_2 \quad (3)$$

$b_i = \frac{dD_i/D_i}{dp_i/p_i} > 0$; $d_1 = -\frac{\partial D_2/\partial p_1}{\partial D_1/\partial p_1} > 0$ represents the demand change of product 2 affected by the change product 1's price, $d_2 = -\frac{\partial D_1/\partial p_2}{\partial D_2/\partial p_2} > 0$ shows the demand change of product 1 affected by the change product 2's price; in that total demand is no more than the market total capacity in a certain period, therefore $d_2 - b_1 < 0$, $d_1 - b_2 < 0$, so $d_2 - b_1 < 0$, $d_1 - b_2 < 0$.

Set $D_i \leq Q_i$; profit function $R = D_1(p_1 - c_1) + D_2(p_2 - c_2)$; besides, in that

$\partial R^2/\partial p_1^2 = -2b_1 < 0$, $\partial R^2/\partial p_2^2 = -2b_2 < 0$, so then optimal prices exist and should obey the constraints

$\partial R/\partial p_1 = 0$, $\partial R/\partial p_2 = 0$, so the optimal joint prices now:

$$p_1^* = \frac{2b_2 A\theta + (d_1 + d_2)A(1-\theta) + 2b_2(b_1 c_1 - c_2 d_2) + (d_1 + d_2)(b_2 c_2 - d_1 c_1)}{4b_1 b_2 - (d_1 + d_2)^2} \quad (4)$$

$$p_2^* = \frac{2b_1 A(1-\theta) + (d_1 + d_2)A\theta + (d_1 + d_2)(b_1 c_1 - d_2 c_2) + 2b_1(b_2 c_2 - c_1 d_1)}{4b_1 b_2 - (d_1 + d_2)^2} \quad (5)$$

3.2. Modeling Green Products Price Driven Substitution Joint Pricing Model

Due to the basic model and the notations, the joint pricing model in the 1st and 2nd stage for green supply chain price-driven substitution present as:

$$D_{1j} = A_j \theta_j - b_1 p_{1j} + d_1 p_{2j}, \quad (6)$$

$$D_{2j} = A_j(1 - \theta_j) - b_2 p_{2j} + d_2 p_{1j} \quad (7)$$

Note that $b_1 < b_2$, represents that customers are more sensitive to the price of ordinary product than green product; $d_1 < d_2$, represents when green and ordinary product coexist the substitution between the two products presents some extent of downward substitutability, namely the impact of green product pricing has on ordinary product is greater than the influence of ordinary product pricing has to green product.

3.2.1. Joint Pricing Model for 1st Stage

Demand functions of the 1st stage:

$$D_{11} = A_1 \theta_1 - b_1 p_{11} + d_1 p_{21} \quad (8)$$

$$D_{21} = A_1(1 - \theta_1) - p_{21} + d_2 p_{11} \quad (9)$$

Optimal joint pricing in 1st stage now:

$$p_{11}^* = \frac{2b_2 A_1 \theta_1 + (d_1 + d_2) A_1 (1 - \theta_1) + 2b_2 (b_1 c_1 - c_2 d_2) + (d_1 + d_2) (b_2 c_2 - d_1 c_1)}{4b_1 b_2 - (d_1 + d_2)^2} \quad (10)$$

$$p_{21}^* = \frac{2b_1 A_1 (1 - \theta_1) + (d_1 + d_2) A_1 \theta_1 + (d_1 + d_2) (b_1 c_1 - d_2 c_2) + 2b_1 (b_2 c_2 - c_1 d_1)}{4b_1 b_2 - (d_1 + d_2)^2} \quad (11)$$

Proposition 1, under the price-driven substitution, green products optimal price is proportional to the green degree; and ordinary's is inversely proportional to the green degree.

Proof: simplify Eq. 10, $p_{11}^* = \frac{(2b_2 - (d_1 + d_2) - 1)A_1 \theta_1 + A_1 (1 - \theta_1) + 2b_2 (b_1 c_1 - c_2 d_2) + (d_1 + d_2) (b_2 c_2 - d_1 c_1)}{4b_1 b_2 - (d_1 + d_2)^2}$, due to $d_1 < b_2$, $d_2 < b_1$, $b_1 < b_2$, $d_1 < d_2$, then $2b_2 - (d_1 + d_2) > 0$, so p_{11}^* price is proportional to θ_1 ; simplify Eq. 11, $p_{21}^* = \frac{(-2b_1 + (d_1 + d_2))A_1 \theta_1 + 2b_1 A_1 (1 - \theta_1) + (d_1 + d_2) (b_1 c_1 - d_2 c_2) + 2b_1 (b_2 c_2 - c_1 d_1)}{4b_1 b_2 - (d_1 + d_2)^2}$, due to $d_1 < b_2$, $d_2 < b_1$, $b_1 < b_2$, $d_1 < d_2$, then $-2b_1 + (d_1 + d_2) < 0$, so p_{21}^* is inversely proportional to θ_1 . So, proved that green product price is proportional to the green degree and ordinary's is inversely proportional to the green degree.

Proposition 2, green product market capacity decided whether the optimal joint pricing can reveal the green products cost result from positive externality and if sale green products can be profitable.

Proof: green products positive externality result in higher price than ordinary products, compare the optimal prices Eq. 10 and Eq. 11, $p_{11}^* > p_{21}^*$ requires $(2b_2 - (d_1 + d_2))A_1 \theta_1 - (2b_1 - d_1 - d_2)A_1 (1 - \theta_1) > (d_1 + d_2 - 2b_2)(b_1 c_1 - d_2 c_2) + (2b_1 - (d_1 + d_2))(b_2 c_2 - c_1 d_1)$, $A_1 \theta_1$ represents green products market capacity, $A_1 (1 - \theta_1)$ represent ordinary products market capacity, if $p_{11}^* > p_{21}^*$, then $A_1 \theta_1 > \frac{(d_1 + d_2 - 2b_2)(b_1 c_1 - d_2 c_2) + (2b_1 - (d_1 + d_2))(b_2 c_2 - c_1 d_1) + (2b_1 - d_1 - d_2)A_1 (1 - \theta_1)}{(2b_2 - (d_1 + d_2))}$ so, green product market capacity decided whether the optimal joint pricing can show green products cost result from positive externality; the profit for sale green products expressed as $p_{11}^* - c_1$, to make sure gain profit requires $p_{11}^* - c_1 > 0$, namely $(2b_2 - 2(d_1 + d_2))A_1 \theta_1 > -(d_1 + d_2)A_1 - 2b_2(b_1 c_1 - c_2 d_2) - (d_1 + d_2)(b_2 c_2 - d_1 c_1) + c_1(4b_1 b_2 - (d_1 + d_2)^2)$, so green product market capacity decided whether sales green products can be profitable. From the above proves, green product market capacity decided whether the optimal joint pricing can reveal green products cost result from positive externality and if sale green products can be profitable.

3.2.2. Joint Pricing Model for 2nd Stage

Joint pricing model for 2nd stage is based on the 1st-stage, after the 1st sales stage, consider the inventory, there

are 4 situations: ① green and ordinary products are sold out in the 1st stage, namely $Q_1 \leq D_{11}(p_1^*, p_2^*)$, $Q_2 \leq D_{21}(p_1^*, p_2^*)$, then won't pricing in 2nd stage; ② green products are sold out but ordinary products are not, namely $Q_1 \leq D_{11}(p_1^*, p_2^*)$, $Q_2 > D_{21}(p_1^*, p_2^*)$, then just re-pricing green products; ③ ordinary products are sold out but green products are not, namely $Q_1 > D_{11}(p_1^*, p_2^*)$, $Q_2 \leq D_{21}(p_1^*, p_2^*)$ then just re-pricing green products; ④ both of the two products are not stock out in 1st stage, namely $Q_1 > D_{11}(p_1^*, p_2^*)$, $Q_2 > D_{21}(p_1^*, p_2^*)$. In terms of the 4 situations, discuss the situations ②③④ which re-price in the 2nd stage.

3.2.2.1. Only Re-pricing One Product in 2nd Stage

If ordinary products stock out, only sales green products in the 2nd stage, then the price of ordinary products can't influence green product demand. Now, the green products demand can be expressed as: $D_{12} = A_2\theta_2 - b_1p_{12}$, profit function:

$R = D_{12}(p_{12} - c_1) = (A_2\theta_2 - b_1p_{12})(p_{12} - c_1)$, $\partial R^2 / \partial p_{12}^2 = -2b_1 < 0$, therefore, there are maximum price; let $\partial R / \partial p_{12} = 0$, then optimal green price $p_{12}^* = \frac{A_2\theta_2 + b_1c_1}{2b_1}$.

Proposition 3, in the case of no substitution, the profits of green products determined by green product market capacity.

Proof: when ordinary products are out of stock, the optimal price of green products $p_{12}^* = \frac{A_2\theta_2 + b_1c_1}{2b_1}$, suppose unit green products cost c_1 and the elasticity of demand b_1 are known, then the green product market capacity $A_2\theta_2$ determine the optimal price of green products. Green products profit $p_{12}^* - c_1$, if the product unit profits is bigger than 0, namely $\frac{A_2\theta_2 + b_1c_1}{2b_1} - c_1 > 0$, requires $A_2\theta_2 > b_1c_1$, so only when $A_2\theta_2 > b_1c_1$, the retailer can make profit.

Same as the previous analysis, if green products stock out, only sales ordinary products in the 2nd stage, optimal ordinary products price $p_{22}^* = \frac{A_2(1-\theta_2) + b_2c_2}{2b_2}$.

3.2.2.2. Two products' Joint Pricing in 2nd Stage

The joint demand functions in 2nd stage:

$$D_{11} = A_1\theta_1 - b_1p_{11} + d_1p_{21} \quad (12)$$

$$D_{21} = A_1(1 - \theta_1) - p_{21} + d_2p_{11} \quad (13)$$

The optimal joint prices:

$$p_{12}^* = \frac{2b_2A_2\theta_2 + (d_1 + d_2)A_2(1 - \theta_2) + 2b_2(b_1c_1 - c_2d_2) + (d_1 + d_2)(b_2c_2 - d_1c_1)}{4b_1b_2 - (d_1 + d_2)^2} \quad (14)$$

$$p_{22}^* = \frac{2b_1A_2(1 - \theta_2) + (d_1 + d_2)A_2\theta_2 + (d_1 + d_2)(b_1c_1 - d_2c_2) + 2b_1(b_2c_2 - c_1d_1)}{4b_1b_2 - (d_1 + d_2)^2} \quad (15)$$

Compare Eq. 14 and Eq. 15, due to Proposition 3, when $A_2\theta_2 > \frac{(d_1 + d_2 - 2b_2)(b_1c_1 - d_2c_2) + (2b_1 - (d_1 + d_2))(b_2c_2 - c_1d_1) + (2b_1 - d_1 - d_2)A_2(1 - \theta_2)}{(2b_2 - (d_1 + d_2))}$ optimal joint pricing can reveal the green products cost which result from positive externality.

3.3. Model analysis and prospect

This paper used market capacity to describe supply constraint and demand constraint market, in the demand functions that green product demand constraint market was presented as low green products market capacity and green product supply constraint market was presented as high market capacity. Due to the proposition 2, green product market capacity decided whether the optimal joint pricing can reveal the green products cost result from positive externality and if sale green products can be profitable, besides product demand is not more than the market size. Therefore, via the market capacity, retailer can first decide whether introducing green products or not; and the total profit in both 1st and 2nd stage have those 4 cases: ① green and ordinary products are sold out in the 1st-stage, $R = \min(D_{11}, Q_1)(p_{11}^* - c_1) + \min(D_{21}, Q_2)(p_{21}^* - c_2)$; ② ordinary products are sold out but ordinary products are not, $R = D_{11}(p_{11}^* - c_1) + \min(D_{21}, Q_2)(p_{21}^* - c_2) + \min(D_{12}, Q_1 - D_{11})(p_{12}^* - c_1)$; ③ green products are sold out but green products are not, then $R = \min(D_{11}, Q_1)(p_{11}^* - c_1) + D_{21}(p_{21}^* - c_2) + \min(D_{22}, Q_2 - D_{21})(p_{21}^* - c_2)$; ④ $R = D_{11}(p_{11}^* - c_1) + D_{21}(p_{21}^* - c_2) + \min(D_{12}, Q_1 - D_{11})(p_{12}^* - c_1) + \min(D_{22}, Q_2 - D_{21})(p_{21}^* - c_2)$. Analyzing the 4 expressions conclude that the profit is relate to ordering quantity, so, consider the market capacity when make ordering quantity can and avoid too much stocks cost or shortage cost, compare the 4 profits, in some extent reduce loss or improve the total profit of retailers.

4. Conclusions

This paper based on the reasonable hypotheses to pricing green perishable products when faced with substitution. Via the optimal joint pricing model, this paper drew the following conclusions: under the market that green and ordinary products produce coexist, if only consider price-driven substitution, then green products optimal price is proportional to the green degree; ordinary product optimal price is inversely proportional to the green degree; besides, if green products market capacity is proportional to green degree, then green product market capacity determined whether the optimal joint pricing can reveal green products cost that result from positive externality and if sale green products can be profitable; when there's no substitution for green products, the optimal green price is related to market capacity. Through the model prospect, concluded that through analyzing green product market capacity retailer can decide whether to introduce green products for sale and make appropriate ordering strategy, in some extent reduce loss or improve the total profit for retailer. So, the joint-pricing strategy provided in this paper, in some extent can refine the market failure result from positive externality.

This paper just studied under oligopoly, in the further study, the research will focus on the competition environment and substitution degree on optimal pricing strategy; besides, based on the typical cases to testify the conclusions, so as to make the research on green supply chain perishable products substitution pricing more significant and practical.

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Pricing Policies for Green Supply Chain of Non-Perishable Product Considering Strategic Customer Behavior

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Abstract

Green supply chain management has emerged as an important organizational philosophy to reduce environmental risks. Suppose that a market is selling green non-perishable products which the demand is fixed and purchasing green non-perishable products at a certain quantity from a single supply channel. At the meantime, the consumers are strategic customers. Base on the above assumption this paper applied classic Stackelberg model to support that in considering strategic customers' behavior, retailers can obtain much more profit and stimulate green consumption through two stage pricing policy.

Keywords: Green supply chain, Non-perishable product, Strategic customer behavior, dynamic pricing

1. Introduction

Increasingly, companies are recognizing that green supply chain management is a strategic issue with the potential for a lasting impact on organizational performance. That is, appropriate pricing policies may attract more customers to purchase green product, and simultaneously bring the new profit growth for the companies. However, when consumers make a decision about purchase the green commodity, which normally have high value, they become more and more rational. The concrete manifestation is that they will make a choice which they purchase the product at a full fare or wait until the price went down based on their forecast on the storage and the future price of the product. Beyond all doubt, the appearance of the strategy consumer is bringing strong impact on the management of green commodities' producing, stock control and marketing strategy. Therefore, considering the consumer's strategic behavior, at the meantime confirm the retailers' best pricing policies, maximize the retailers' profit and adapt green and low-carbon consumption, has become the hot topic of this stage.

In the research about the green product pricing, (Jiao, 2006) adopt Rubinstein model analyzing the optimal pricing policies about the green non-perishable product and result in a Pareto optimal solution. (Liu, 2008) studies a supply chain system which consisted of manufactory and retailer. Then establish a model about them and conclude the advantages about the corporate pricing strategy. In the research of the strategic customer's

behavior, (Ronald,1972) has done it at the very beginning .In his research he concluded that the retailer had to adopt marginal cost pricing when they were facing the strategic consumer's waiting under the condition of assumption that there is a monopoly in the market. (Muth, 1961) has researched the strategic customer's behavior from the point view of economics. He has come a conclusion that economic result should be consistent with people's expectation to it under the rational expectation equilibrium assumption. (Su, 2008) has researched the optimal dynamic pricing strategy under the environment of limited sales cycle and limited quantity products. He got the result which strategic customers' estimate to the product and their patience degrees are closely related to pricing policies.(Huang,2010) has considered a two levels supply chain system consisted of a retailer and a customer group which can be indefinitely subdivided, and he apply the two-stage newsboy model and rational expectation equilibrium maximize the retailers' profit.

In conclusion, the research about green product pricing, mostly suppose that consumers in the market don't possess strategic customer behavior. Consumer will make his decision only based on the sale price and his expectation on the value of the product. On the other hand, the research about strategic customer behavior normally assumes that the category of the product is always ordinary goods. It ignores the green product has characteristic which can reduce the environmental pollution and consumption of energy. These short backs provided the space to research further. Considering the environment of the green supply chain, this paper analyses a game theory process between retailer and consumers who are far-sighted including the green degree factor. Then, establish the two-stage demand model and improve the retailer's profit in the sales cycle.

2. Descriptions and Basic Assumption

In a green non-perishable product market, there exist a potential consumer group consisted of N strategic customers. A single supply channel offers a certain number of green non-perishable products to consumers. Due to a long purchase leading time of the green non-perishable product, retailer has only one opportunity order product in the sales cycle. As the sales cycle ends, the remaining inventory will be disposed according to the scrap value. So the game process progress as follows:

- 1) Retailer will make sure the order's number and his own two-stage pricing policies before the first stage of sales time begins.
- 2) Strategic customer make the maximum by choosing the best time to buy, according to the utility they will get at different period.
- 3) Retailer will make the maximum profits by improving initial pricing strategy, which is based on the customers' optimal decision-making expectation .

This paper assumes that at different sales period, strategic customer will not change his mind, and both strategic customer and retailer realize optimal utility by accurate calculation. Meanwhile, prescribing a limit that every customer only purchases one product. To indicate briefly, the meanings of the symbols are as follows:

L —the whole length of the product sales cycle

T —the time point, that is between the end of the first stage and the beginning of the second stage in the sale cycle

Q —retailer's initial inventory

P —retailer's sale price of the green non-perishable product in the first stage.

θ —the green degree contained in the green durable product, the green degree of the green non-perishable product will not reduce as times pass by.

r —the salvage price of the unsold product in the second stage.

β —the discount factor introduced by retailer in the second stage, the selling price of the green non-perishable product in the second stage βP , and $\beta \in (0, 1]$.

\underline{e} —Strategic customer's lowest expectation about the green non-perishable product.

\bar{e} —Strategic customer's highest expectation to the green non-perishable product.

q —the possibility to purchase the product when the price went down, and $q \in (0, 1]$.

3. Modeling

Dynamic pricing model has attracted more and more attention of retailers due to strategic customer behavior which exists in the market. Retailer can get surplus profits through adopting two-stage pricing policy. The retailer should make sure two-stage pricing policy $[P, \beta]$ in the beginning of sales cycle, P is the full fare of the first stage, β is price discount factor of the second stage.

3.1 Strategic Customer Purchase Strategy

Customers could realize the dynamic pricing policy, and choose the best opportunity to purchase green non-perishable product according to the first stage price which is given by retailer and the possibility they can obtain the green non-perishable product in the second stage. In the first stage, strategic customers must acquire the goods and get utility as $a\theta - bP + h$. Letter a means positive effect factor about the green degrees, letter b means negative effect factor about the price and letter h means positive effect factor about other influence factor. In the second stage, strategic customers purchase the green durable goods under the risk q , they can get utility as $q(a\theta - b\beta P + h)$. Because the green degree of non-perishable goods is merely constant basis, and strategic customer's maximum expectation is:

$$\text{Max}[a\theta - bP + h, q(a\theta - b\beta P + h)]$$

There will be an P^* , in this point, strategic customers can get the same utility in the different stage, and it will affect the strategic customer's purchase decision.

Proposition1: Only when their maximum purchase willing is higher than P^* , the strategic customer will purchase in the first stage, or they will wait until the price went down.

Set no differences in purchasing from the first stage and the second stage, and get:

$$a\theta - bP + h = q(a\theta - b\beta P + h)$$

So,

$$P^* = \frac{(1-q)(a\theta + h)}{b(1-\beta q)}$$

3.2 Retailer's Optimal Two-stage Pricing Strategy

Stackelberg game model is a dynamic game of complete information, which could correctly describe every subject's decision making behavior. Therefore, this paper introduces this model to result in retailer's profit function. First, we can get strategic customer's maximum utility and his best purchasing time in the sales cycle. Then, retailer make two-stage pricing policy to maximize own profit when strategic customer get maximum utility. Considering every stage's sales volume is restrained by the inventory, we can conclude the retailer's profit function:

$$\max_P E[TR_{(P)}] = PE[\min[N \int_{P^*}^{\bar{e}} \frac{1}{\bar{e} - \underline{e}} d\theta, Q]] + \beta PE[\min[N \int_{\beta P}^{P^*} \frac{1}{\bar{e} - \underline{e}} d\theta, Q] + r(Q - N \int_{\beta P}^{\bar{e}} \frac{1}{\bar{e} - \underline{e}} d\theta)]$$

As q is given, there exists one point which makes the retailer's profit function maximum profit.

Theorem 1: Retailer can get maximum profit when his pricing policy is

$$\left[\frac{\beta P^* - r\beta + \bar{e} - P^*}{2\beta^2}, (\bar{e}q + 2r + \bar{e}) \frac{b}{2\bar{e}bq - 2\bar{e}q + qbr + 2\bar{e} + br} \right].$$

Demonstration: For partial derivatives in the profit function P and β , we can obtain the result:

$$\frac{\partial T}{\partial P} = \frac{N(\bar{e} - P^*) + N\beta P^* - 2N\beta^2 P - rN\beta}{\bar{e} - \underline{e}} \quad (1)$$

$$\frac{\partial T}{\partial \beta} = bN\beta P(1 - \beta P)^2 + NPb(1 - \beta P)^2 - 2bNP^2\beta(1 - \beta P)^2 + NP(1 - q)(a\theta + h) \quad (2)$$

Set formula(1) equals 0, $P = \frac{\beta P^* - r\beta + \bar{e} - P^*}{2\beta^2}$ is solved. Meanwhile, $\frac{-r\beta + \beta P^* + \bar{e} - P^*}{2\beta^2} - \bar{e} < 0$, $\frac{-r\beta + \beta P^* + \bar{e} - P^*}{2\beta^2} - \underline{e} > 0$ are proved by the former inequality $\bar{e} > P^* > \beta P > \underline{e} > r$. Set formula (2) equal to 0, attained that $\beta = (\bar{e}q + 2r + \bar{e}) \frac{b}{2\bar{e}bq - 2\bar{e}q + qbr + 2\bar{e} + br}$ after eliminating.

For derivatives in the profit function T , get $\frac{dT}{d\beta} = \bar{e}P + \beta^3 P^2 - \beta^2 P^2 + \bar{e} - 4\beta P^2 - 2\beta^3 P^3 + 4\beta^2 P^3$. When set $P = \underline{e}$, $P = \underline{e}$, get the maximum $TR_{max} = rQ$, when set $P = \bar{e}$, $\beta \in (0, 1]$, conclude the maximum $TR_{max} = N(\bar{e} - r) + rQ$.

For derivatives in the profit function T , get $\frac{dT}{dP} = \frac{N(\bar{e} - P^*) + N\beta P^* - 2N\beta^2 P - rN\beta}{\bar{e} - \underline{e}}$, because of

$\frac{d^2 T}{dP^2} < 0$, when $\beta = 1$, $P \in [\underline{e}, \bar{e}]$, get the maximum $\frac{2\bar{e} - \bar{e}^2 - 4r\underline{e} - r^2}{4(\bar{e} - \underline{e})} + rQ$. Put point

$M = \left(\frac{\beta P^* - r\beta + \bar{e} - P^*}{2\beta^2}, (\bar{e}q + 2r + \bar{e}) \frac{b}{2\bar{e}bq - 2\bar{e}q + qbr + 2\bar{e} + br} \right)$ into the retailer's profit function, receive

$TR_{max} = \frac{(P+r)\bar{e} - (1+\beta)P + (1+\beta)P^*}{\bar{e} - \underline{e}} N + rQ$. Because $\bar{e} > P^* > \beta P > \underline{e} > r$ and $\beta \in (0, 1]$, come the conclusion :when

retailer adopt the pricing policy $\left[\frac{\beta P^* - r\beta + \bar{e} - P^*}{2\beta^2}, (\bar{e}q + 2r + \bar{e}) \frac{b}{2\bar{e}bq - 2\bar{e}q + qbr + 2\bar{e} + br} \right]$, retailer receives the highest profit.

This paper obtains an equilibrium price polices which comes into being in the process of the game between retailer and strategic customer. If retailer's first stage pricing deviate the equilibrium solutions, consumers will keep waiting or retailer lose some profit. If retailer's second-stage pricing deviate the equilibrium solutions, retailer will lose some potential customers in the second stage or can't obtain the higher profit.

4. Conclusions

From the standpoint of the retailer, this research tries to working out the problem about how to make the dynamic pricing policy of the green non-perishable products considering the behavior of strategic customer. First, this paper analyses a game process between retailer and consumers who are far-sighted. Then, establish

a two-stage dynamic pricing model of the retailer and get the optimal pricing policy. But, this paper has some shortcomings. In the future, our research will focus to the two-stage pricing policy in perfect competitive situations and facing mixed type customers.

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Effects of Hinterland Accessibility on U.S. Container Port Efficiency

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Abstract

As the bottleneck of intermodal transportation system has shifted from the ship/port interface to the port/inland interface, container port productivity is likely to be constrained by the connection between ports and hinterland (Heave, 2006). This study empirically explores the impacts of hinterland accessibility on efficiency of U.S. container ports. In particular, a two-stage approach is implemented. First, the container port efficiency is measured by data envelopment analysis (DEA). Then, Tobit regression analysis is undertaken to explore the relationship between the DEA efficiency scores and the ground transportation condition, such as provision of on-dock rail facility, Class I rail services connecting to hinterland and road congestion around the ports. The empirical results suggest that provision of on-dock rail facility at container terminals is negatively correlated with container port efficiency whilst the impacts of class I rail services are ambiguous. In general, there is a negative association between road congestion around the port and port productivity. However, this relationship tends to be negligible or even positive for primary ports of entry which enjoy substantially larger container throughput volume.

Keywords: Container port productivity, Hinterland accessibility, Data envelopment analysis, Tobit

1. Introduction

The recent wave of globalization and the emergence of containerization have boosted international trade and maritime shipping of containerized general cargos (Rodrigue, 2009), imposing tremendous pressure on gateway ports and corresponding intermodal transportation systems. The bottleneck of such port-hinterland intermodal transportation system has shifted from the ship/port interface to the port/inland interface (Heave, 2006). It is argued that hinterland accessibility plays a crucial role in port competition (Notteboom, 1997; Kreukels and Wever, 1998; Fleming and Baird, 1999) and this argument is supported by a number of studies on factors affecting shippers' port selection process (Slack, 1985; Lirn et al, 2004; Ugbonma et al, 2006; Yuen et al, 2011).

This paper investigates the efficiency of a sample of U.S. container ports and empirically explores the impacts of hinterland access condition on port efficiency. Here hinterland accessibility is represented by rail services and road congestion around the port. The widely used two-stage approach is applied: in the first stage, the container port productivity is measured by data envelopment analysis (DEA). Then, Tobit regression analysis is undertaken to explore the relationship between the DEA efficiency scores and the connectedness of hinterland, such as provision of on-dock rail facility, Class I rail services linking the ports and hinterland and road congestion around the ports.

There is an abundant literature on seaport productivity with DEA (see Panayides et al, 2008, for a recent review), but studies on container ports in North America are rarely covered by previous studies. Empirical evidence on the impacts of hinterland connection on seaport productivity is also limited. The most relevant study we find is conducted by Turner et al (2004) who examined 26 North American ports from 1984 to 1997 and measured the impacts of rail services on these ports' productivity. The present paper takes the initial effort to consider the impacts of not only rail services but road transportation as well. Besides, it adds to the current literature in the following ways: (1) it uses a more recent dataset; (2) it examines the effects of road congestion on ports differentiated in sizes; and (3) it explores the impact of rival's road congestion.

This study has a few interesting findings. It is conform to historic literature that provision of on-dock rail facility at container terminals is negatively correlated with container port efficiency. The impacts of class I rail services, on the other hand, are ambiguous. In general, there is a negative association between road congestion around the port and port productivity. However, road congestion may have negligible or even positive relationship with DEA scores of ports which may be perceived as primary ports of entry to the U.S. hinterland and enjoy substantially larger container throughput volume. We also observe that the association between DEA score and rival's road congestion is much smaller than the association between DEA score and own road congestion.

The rest of the paper presents the research methods and Tobit regression models in Section 2, followed by a brief description of the data in Section 3. Section 4 presents empirical results and Section 5 makes concluding remarks.

2. Methodology

Twelve U.S. container ports over a ten-year period from 2000 to 2009 are studied in this paper. Table 1 lists the name of the ports and their corresponding rivals. Here the rival of a certain port is defined based on the physical distance between the ports in the sample. That is, the one located closest to the port in concern is considered to be the port's rival. For each port, only container terminals are of concern and terminals for other cargo categories, for instance breakbulk and ro/ro, are excluded from this study.

Table 1: List of ports studied and their corresponding rivals

Ports	Rival
Baltimore	NYNJ / Hampton Roads
Boston	NYNJ
Charleston	Jacksonville
Hampton Roads	Baltimore
Jacksonville	Charleston
Long Beach	Los Angeles
Los Angeles	Long Beach
New York/New Jersey (NYNJ)	Baltimore
Oakland	Long Beach / Los Angeles
Portland	Seattle / Tacoma
Seattle	Tacoma
Tacoma	Seattle

In the first stage, we measure the infrastructure efficiency among the container ports sampled by calculating DEA scores and denote DEA_{it} as the efficiency score for port i in year t . In the DEA model, we use container throughput as the only output and consider container terminal size, total length of berths and total number of cranes and gantries at container terminals as the inputs. As investment in port infrastructure is lumpy and port expansion projects usually take several years to complete, it is common that the amounts of these inputs may be constant over many years following or followed by a sudden addition of port capacity. Compared with low

variation in inputs, container throughput changes rapidly over the years. Thus, output-orientated DEA is more appropriate. In addition, following Turner et al (2004), we pool all the time periods and the ports together when fitting the efficiency frontier, so as to capture the dynamics of port efficiency over time. DEA scores are calculated by assuming constant return to scale (CCR model) as well as variable return to scale (BCC model).

In the second stage, we examine the impacts of hinterland accessibility and other factors on DEA scores calculated from the first stage by Tobit regression (Tobin, 1958). Since DEA scores must be less than or equal to one, OLS regression is no longer appropriate. In the context of DEA scores, Tobit regression instead assumes truncated normal distribution for the dependent variable. That is, assuming that port efficiency is an unobservable (i.e. latent) variable denoted as DEA_{it}^* , the observed DEA score is defined below:

$$DEA_{it} = \begin{cases} DEA_{it}^* & \text{if } DEA_{it}^* \leq 1 \\ 1 & \text{if } DEA_{it}^* > 1 \end{cases}. \quad (1)$$

We consider catchment area population, intra-port competition, rail service, on-dock facility, road congestion, and port operational scale as independent variables. The detailed construction of these variables is discussed below.

Catchment area population: To calculate the population of the catchment area of a port, we need to first identify the port's catchment area. Here taking the port as the center, area within the 250-mile circle around the port is considered as the catchment area. Summing up the county level populations within the catchment area, we can obtain the catchment area population, denoted as $POP250$.

Intra-port competition: Since more terminal operators serving the same port are likely to cause more intensive competition among these operators. Thus, we measure the level of intra-port competition by the number of container terminal operators serving the same port, denoted as $NOPEATOR$. However, the number of terminal operators is constrained by the sizes of the port and the demand. Smaller ports usually have only one or two container terminal(s) and hence the number of terminal operators at these ports tends to be small as well. Then, a small value of $NOPEATOR$ may not be a good indicator of low competition intensity. Larger ports instead usually have a number of container terminals operated by a few terminal operators, but some terminals may be operated by the same terminal operator, leading to a lower level of competition. Therefore, we also use the ratio between the number of operators and the number of container terminals, OP_TER , as another measure of intra-port competition for robust check.

Rail service: As one aspects of hinterland accessibility, higher level of rail service frequency and quality facilitates smoother and faster transfer of containers from port to inland destinations. As rail is the major mode of transportation to move long-haul container cargoes between port and inland, superior rail service and network will attract more long-haul container shippers to the port and raise container throughput, resulting in higher DEA scores. However, as detailed data of rail services are not available, we use the number of Class I railroads serving the port as a proxy (denoted by $NCLASSI$). In the U.S., large railroads with operating revenues exceeding USD 250 million are classified as Class I railroads. Large number of Class I railroads implies higher competitive among rail carrier and hence higher service quality, larger rail service capacity and higher service frequency.

On-dock facility: This is a dummy variable, denoted by $ONDOCK$. As long as at least one of the container terminals in the port provides on-dock rail facility, the value of this variable is one; otherwise, it is zero.

Road congestion: The theory about the relationship between port efficiency and road congestion has never been formally established. However, our hypothesis is that an increase in road congestion will reduce a container port's infrastructure efficiency. This hypothesis is based on the following rationale. First, road congestion increases the time cost of delay when the containers are transferred between the gateway port and intermodal transport facilities (such as rail terminals) or inland destinations. Consequently, shippers may divert to other ports and the container port output, such as throughput, will reduce, leading to a decrease in

port productivity given that the port's inputs are unchanged. This argument can be supported by Wan et al (2012) which empirically find that an increase in road congestion around the port is associated with a decrease in container throughput. Second, high level of road congestion may lead to lengthened time that containers have to wait in the port until being picked up by trucks. As a result, container terminals may have to increase their sizes and make extra investment in other relevant storage resources to accommodate more containers at the same time, which may further reduce port infrastructure productivity. Third, as road transportation around the port is one stage of the intermodal international shipping process, road congestion may lead to high probability for trucks to pick up and drop off containers at the port on time, amplifying the operational uncertainty at the port. Applying the tradeoffs heuristic between capacity utilization, inventory and variability or the so-called OM triangle (Lovejoy, 1998 and Schmidt, 2005), facing with increased level of uncertainty, to maintain the same level of throughput, container ports may either invest more on capacity or increase warehousing space to stack more containers. Both approaches require an increase in resource inputs at the container port while keeping output level constant, causing lower port productivity. We denote road congestion around the port in concern as *RCI* and road congestion around the rival port as *RCI_R*.

Port operational scale: We define two dummy variables, *LARGE* and *SMALL*. Ports with annual container throughput over 3 million TEUs are considered to be a large port. In this sample, Long Beach, Los Angeles and NYNJ belong to this category. All the other ports are considered to be small ports. *LARGE* equal to 1 for large ports and zero for small ports, while *SMALL* equals 1-*LARGE*.

We estimate three sets of Tobit models. The first set is the base case model which focuses on the relationship between port efficiency and includes $\ln(\text{POP250})$, *NOPEATOR* or $\ln(\text{OP_TER})$, *NCLASSI*, *ONDOCK*, $\ln(\text{RCI})$ and *LARGE* as explanatory variables. Note that we take natural log for catchment area population, operator-terminal ratio, and road congestion so as to reduce the impact of heteroskedasticity widely observed in cross-sectional data (Verbeek, 2005). The second set of models, the port difference models, examine how the impact of own road congestion on port efficiency differs between large and small ports. Therefore, we drop *LARGE* dummy and $\ln(\text{RCI})$ from the base case model and replace them with two interactive terms, *LARGE* × $\ln(\text{RCI})$ and *SMALL* × $\ln(\text{RCI})$. The third set of models, called the rival models, explore the impacts of own road congestion and the rival's road congestion at the same time. Thus, both $\ln(\text{RCI})$ and $\ln(\text{RCI_R})$ are included as independent variables.

3. Data

This study uses secondary data from various sources. The American Association of Port Authorities publishes annual port-level container throughput data which are used as the output variable for DEA models. The three input variables are obtained from various issues of Containerization International Yearbook (CIY, 2001~2010). This yearbook also provides information about infrastructure and facility at the container terminal-level for major ports in the U.S. However, since the terminal-level throughput data are not available we sum up the sizes of container terminals within a port as the measure of terminal size in DEA. Similarly, the numbers of ship-shore gantries, yard gantries and quay cranes are summed together to form another input variable, total number of gantries and cranes. The total length of berths in container terminals within a port is considered as the third input variable, total berth length.

Information about the names of terminal operators, on-dock rail facility and names of rail carriers serving the container terminals are also mostly available in CIY. However, rail carrier information is incomplete in CIY and so we double check this information with Port Series Reports published by the US Army Corps of Engineers. Based these pieces of information we obtain the number of Class I rail carriers for each port in our sample. The aforementioned data sources were used by Turner et al (2004) as well, but their sampling period is different. The data about catchment area population are compiled based on the county-level population data published from the U.S. Census Bureau. Another important source of data is the Annual Urban Mobility Report published by Texas Transportation Institute (TTI, 2010). This report provides annual updated measurements of selected metropolitan areas' road traffic condition. TTI constructs a Road Congestion Index (RCI) to measure the level of congestion on freeways and arterial streets. Lacking of road congestion data for roads around the port, we use RCI's of metropolitan areas of the ports in the sample to approximate.

4. Results

4.1. DEA scores

Tables 2 and 3 present the DEA scores for CCR and BCC models respectively. CRS_P stands for DEA scores from CCR model while VRS_P stands for DEA scores from BCC model. Efficiency varies over time, but not necessarily increasing. In general, the efficiency scores drop in 2008 and 2009, consistent with international trade reduction after the financial crisis. Smaller ports, such as Boston, Jacksonville and Portland, are quite sensitive to the assumption of scale efficiency. The three largest ports, Long Beach, Los Angeles and NYNJ, are relatively more efficient than the other ports.

Table 2: DEA scores assuming constant return to scale (CCR model)

CRS_P	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Baltimore	0.204	0.198	0.204	0.212	0.224	0.242	0.252	0.245	0.171	0.146
Boston	0.139	0.133	0.142	0.158	0.440	0.474	0.502	0.552	0.523	0.469
Charleston	0.606	0.568	0.592	0.565	0.603	0.643	0.617	0.550	0.431	0.311
Hampton Roads	0.375	0.363	0.401	0.459	0.504	0.552	0.570	0.593	0.422	0.353
Jacksonville	0.546	0.539	0.528	0.449	0.472	0.504	0.499	0.461	0.453	0.490
Long Beach	0.689	0.630	0.732	0.500	0.621	0.852	0.925	0.824	0.685	0.547
Los Angeles	0.848	0.722	0.851	1.000	0.914	0.679	0.768	0.735	0.691	0.588
NYNJ	0.746	0.811	0.917	0.716	0.651	0.552	0.580	0.604	0.565	0.489
Oakland	0.356	0.336	0.408	0.378	0.366	0.407	0.428	0.444	0.415	0.457
Portland	0.238	0.228	0.209	0.278	0.178	0.104	0.139	0.169	0.159	0.063
Seattle	0.574	0.507	0.577	0.596	0.712	0.838	0.797	0.761	0.551	0.513
Tacoma	0.657	0.631	0.641	0.726	0.751	0.864	0.715	0.804	0.778	0.646

Table 3: DEA scores assuming variable return to scale (BCC model)

VRS_P	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Baltimore	0.215	0.208	0.214	0.223	0.235	0.254	0.265	0.258	0.175	0.150
Boston	0.215	0.205	0.220	0.244	0.798	0.858	0.909	1.000	1.000	0.897
Charleston	0.634	0.594	0.619	0.587	0.625	0.666	0.638	0.569	0.454	0.328
Hampton Roads	0.386	0.373	0.411	0.471	0.518	0.567	0.586	0.609	0.433	0.363
Jacksonville	0.869	0.857	0.839	0.849	0.893	0.954	0.943	0.871	0.856	0.925
Long Beach	0.690	0.631	0.735	0.594	0.737	0.907	0.985	0.948	0.810	0.646
Los Angeles	0.876	0.722	0.851	1.000	1.000	0.884	1.000	0.986	0.927	0.797
NYNJ	0.761	0.828	0.936	0.721	0.652	0.625	0.660	0.687	0.666	0.577
Oakland	0.361	0.341	0.448	0.382	0.369	0.410	0.431	0.447	0.419	0.464
Portland	0.639	0.612	0.562	0.746	0.337	0.197	0.263	0.319	0.301	0.119
Seattle	0.602	0.532	0.607	0.627	0.750	0.881	0.839	0.798	0.571	0.531
Tacoma	0.941	0.902	0.684	0.767	0.834	0.958	0.744	0.849	0.821	0.682

4.2. Regression results

Tobit regression results for the base case models are provided in Table 4. The four models presented here produce consistent coefficient estimations. Container port efficiency is negatively correlated with catchment area population, but positively correlated with intensity of intra-port competition. On average, large ports have higher DEA scores than small ports and the difference is huge, ranging from 0.54 to 0.66.

Table 4: Regression results for the base case model

IV's	DV=CRS_P		DV=VRS_P	
	CP1-1	CP1-2	VP1-1	VP1-2
Ln (POP250)	-0.1618** (0.0275)	-0.1619** (0.0244)	-0.1927** (0.0292)	-0.2303** (0.0294)
Ln (OP_TER)	0.0985** (0.0409)		0.1829** (0.0524)	
NOOPERATOR		0.0409** (0.0094)		0.0075 (0.0129)
NCLASS1	-0.0710** (0.0207)	-0.1667** (0.0505)	-0.1370** (0.0478)	-0.1405* (0.0722)
ONDOCK	-0.0681** (0.0298)	-0.0393 (0.0365)	-0.1563** (0.0522)	-0.1551** (0.0614)
Ln(RCI)	-0.6712** (0.1225)	-1.2184** (0.2504)	-0.9565** (0.2001)	-0.9108** (0.3329)
LARGE	0.5417** (0.0400)	0.5982** (0.0610)	0.6176** (0.0722)	0.6626** (0.0802)
CONSTANT	2.3542** (0.2712)	2.4302** (0.2399)	3.0539** (0.2748)	3.3177** (0.2675)
N	120	120	120	120
F	51.36	45.16	55.76	44.13
Log pseudo-likelihood	56.061876	64.968912	31.314669	25.491722

* significant at $\alpha=0.10$; ** significant at $\alpha=0.05$; Values in the brackets are robust standard errors

The coefficients for *NCLASS1* are unexpectedly negative and statistically significant. Turner et al (2004), however, found that the number of Class I railroads is positively associated with DEA scores. Considering that our sample is different from Turner et al's and the variation of this variable is small as most of the ports in our study have two Class I railroads, our results may simply reflect the limitation of the dataset. The other two sets of regression models provide quite different estimations for this variable. We also find that ports providing on-dock facility tend to have lower DEA scores, consistent with Turner et al's (2004) finding. The magnitude of this negative effect is much larger for BCC DEA scores. Following our expectation, road congestion is negatively associated with DEA scores. In general, when road congestion in the urban area around the port increases by 0.1%, the DEA score of that port reduces by 0.07~0.12.

Table 5 shows the estimation for the second set of models. Note that this time the coefficients of *NCLASS1* tend to be positive or statistically insignificant, suggesting that a positive association between port efficiency and rail service levels may exist. More importantly, with the interaction terms, we find that road congestion affects large ports and small ports differently. Road congestion has a strong negative association with efficiency of small ports, but the relationship between road congestion and large ports' efficiency scores is either positive or statistically insignificant. One explanation is that large ports defined in our sample are in fact primary ports of entry to the Continental U.S. These ports usually have superior logistics service providers, such as forwarders, trucking firms and insurance companies, gather around, offering high quality services with competitive prices. Consequently, the benefits from those services and convenience at those primary ports may outweigh the cost of delay on the road and shippers may choose those ports even if roads surrounding those ports are highly congested. Smaller ports, on the other hand, do not possess the same advantage as those primary ports and hence when shippers are choosing among a set of small ports, traffic condition on roads connecting the smaller ports and the hinterland becomes an important criterion. Therefore, road congestion does not substantially affect large ports' throughput and efficiency scores but has a significant negative impact on small ports.

Table 5: Regression results for the port difference model

	DV=CRS_P	DV=VRS_P
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IV's	CP2-1	CP2-2	VP2-1	VP2-2
Ln (POP250)	-0.1138** (0.0255)	-0.1225** (0.0217)	-0.1378** (0.0287)	-0.1762** (0.0314)
Ln (OP_TER)	0.1956** (0.0392)		0.2929** (0.0544)	
NOOPERATOR		0.0649** (0.0084)		0.0283** (0.0129)
NCLASS1	0.0464** (0.0204)	-0.0807** (0.0277)	-0.0027 (0.0247)	-0.0254 (0.0437)
ONDOCK	-0.0607* (0.0333)	-0.0104 (0.0356)	-0.1484** (0.0494)	-0.1434** (0.0659)
SMALL×Ln (RCI)	-1.0595** (0.1597)	-2.0379** (0.2450)	-1.3879** (0.1889)	-1.4442** (0.3346)
LARGE×Ln (RCI)	0.3885** (0.1113)	-0.2340 (0.1681)	0.2569* (0.1472)	0.2727 (0.2239)
CONSTANT	1.7504** (0.2495)	1.8969** (0.2051)	2.3618** (0.2504)	2.5750** (0.2621)
N	120	120	120	120
F	40.54	38.04	49.78	28.01
Log pseudo-likelihood	56.394167	72.198982	31.259577	19.365668

* significant at $\alpha=0.10$; ** significant at $\alpha=0.05$; Values in the brackets are robust standard errors

To investigate the impacts of rival port's road congestion, we have to make sure that Ln(RCI_R) does not have the collinearity problem with Ln(RCI). In general, the Variance Inflation Factors (VIF) for these two variables exceed 10, suggesting serious collinearity problem exists. However, we find that after dropping observations of Long Beach and Los Angeles from the regression model, VIFs of all variables (including the road congestion variables) are below 6. That is, the collinearity problem is substantially mitigated by removing these two largest ports from the sample. Therefore, the third set of regression models are fitted with the rest ten ports (Table 6).

Table 6: Regression results for the impact of rival's road congestion

	DV=CRS_P		DV=VRS_P	
IV's	CP3-1	CP3-2	VP3-1	VP3-2
Ln (POP250)	-0.0919** (0.0279)	-0.1018** (0.0224)	-0.1181** (0.0337)	-0.1555** (0.0361)
Ln (OP_TER)	0.2144** (0.0382)		0.3265** (0.0582)	
NOOPERATOR		0.0902** (0.0111)		0.0640** (0.0201)
NCLASS1	0.0836** (0.0287)	-0.0491 (0.0317)	0.0592* (0.0350)	-0.0038 (0.0576)
ONDOCK	0.0215 (0.0639)	-0.0724 (0.0516)	-0.1720** (0.0717)	-0.2614** (0.0765)
Ln (RCI)	-2.0210** (0.4856)	-1.8094** (0.3424)	-1.2847** (0.5125)	-0.7533 (0.4569)
Ln (RCI_R)	0.7853** (0.2928)	-0.6107** (0.2540)	-0.1072 (0.3001)	-1.0991** (0.3606)
CONSTANT	1.4158** (0.2657)	1.6754** (0.2121)	2.0883** (0.2859)	2.4013 (0.2885)
N	100	100	100	100
F	27.11	32.87	33.97	16.45

Log pseudo-likelihood	52.372734	67.352134	24.779871	15.660785
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* significant at $\alpha=0.10$; ** significant at $\alpha=0.05$; Values in the brackets are robust standard errors

The coefficients of catchment area population and intra-port competition are consistent with those estimated in the previous two sets of models, implying that our estimations of the impacts of these factors are robust. Interestingly, the number of Class I railroads is positively correlated with DEA scores when intra-port competition is measured by operator-terminal ratio and has statistically insignificant coefficients when intra-port competition is measured by the number of terminal operators.

Again, own road congestion is negatively associated with port efficiency and the magnitude is quite large. The signs of the coefficients of Ln(RCI_R) vary across the models, but the magnitudes tend to be much smaller (sometimes statistically insignificant) than the coefficients of own road congestion. Note that we identify each port's rival arbitrarily based on the distance among ports in our sample. It remains a question that rivals identified with this method do compete fiercely. Ports located farther away can compete more fiercely than those located closer to each other. Container ports selected in our sample may also compete with rivals not covered in this study. Therefore, caution needs to be taken when interpreting the estimated coefficients of rival's road congestion.

Another possible explanation to the unstable coefficient of Ln(RCI_R) is that the pair of rivals, Seattle and Tacoma, belong to the same Metropolitan area and hence their road congestion indexes are the same. Thus, in terms of the impact road congestion, it may be more appropriate to merge these two ports into a conceptual port complex. The same argument applies to another pair of rivals, Long Beach and Los Angeles, as well. Therefore, we pool Seattle and Tacoma into one port by summing up the values of their input and output variables and treat Portland as the rival; we treat Long Beach and Los Angeles similarly and consider Oakland as the rival. We recalculate DEA scores and fit regression models similar to those in Table 6 with two dummy variables indicating these two "port complex" respectively. The resulting coefficient for rival's road congestion now tends to be positive or statistically insignificant, while the magnitude of this coefficient keeps to be much smaller than that of the own road congestion coefficient. This result suggests that rival's road congestion may have some slight positive impact on port efficiency.

5. Concluding Remarks

This paper takes a two-stage approach to examine the relationship between hinterland access condition and container port productivity. Consistent to the literature, as on-dock rail facility requires land space which could be used to load/unload and store containers, provision of such facility may lead to lower infrastructure efficiency scores. The estimated impact of Class I rail services is slightly different from the literature. The relationship between port efficiency and the number of Class I railroads varies across models, but in general a positive or statistically insignificant correlation between these two variables is more likely.

In various models, own road congestion is negatively correlated with DEA scores, especially for small ports. Efficiency of large ports is less sensitive to road congestion around them. The implication of this finding is that roads around the port are likely to be the bottleneck of the intermodal transport process. Controlling congestion of roads connecting to the ports may largely improve port efficiency and competitiveness for non-primary ports. The relationship between port efficiency and rival's road congestion is in general ambiguous, but compared with own road congestion, this link is much weaker.

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Competitive Factors of Global Ports in the New Economy: Implications for Theory and Practice

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Abstract

The new economy is changing the way global ports compete because of the excess capacity in the supply chain, and the imbalance in the movement of goods. Goods movements from Asia to the U.S. and Europe far exceed those to Asia from the West. This creates mode dead-heading, driving prices to all-time lows in some channels, and to highs in others. Ports are forced to compete in new ways to attract and retain customers and generate revenue to invest in infrastructure. Port managers recognize that the economy will eventually recover and they need to attract new investors to build the infrastructure to support the expected increase in demand. However, actions to attract customers can detract investors, and visa-versa. This study develops a model of port strategies that managers can use to evaluate their decisions for their impact on customers and investors. Using AHP, this pilot study empirically examines the new model. While the instrument and analysis appear to accurately represent the phenomenon of interest, the conclusions must be considered unsupported until the full study is performed with the proper sample size.

Keywords: AHP, port strategies, seaports, global studies

1. Introduction

In addressing how global ports will compete for container volume in the new economy, the literature uses traditional measures that focus on attracting new container volume and retaining existing volume. Totally separate measures address how well ports attract new investment to improve port infrastructure, superstructure, and facilities. The problem with these measures is that they fail to capture the interaction effects between capturing new business and new investment. This suggests that ports may indulge in activities to improve one factor while harming the other. This is important because ports need to develop strategies to compete in the new economy. The purpose of this study is to use a new scale that measures these interaction affects and becomes the first to predict the impacts of the decisions of port administrators on attracting customers and investors.

From the time of the first containership, from Newark, New Jersey, international trade and transport have been transformed through containerization. The result has been an alteration of the geography of production and distribution (CFP, 2006), with Asia becoming the global center for all types of manufacturing and service creation. Starting with Singapore, Hong Kong, and Busan, many Asian ports have taken full advantage of containerization and associated inter-modal transport methods to create some of the world's most efficient and competitive ports (Yap and Lam 2006).

In recent years, Asian merchandise trade has grown at a rate higher than the rate of growth of global trade in North America and Europe (see Table 1). Within Asia the main driver of merchandise trade is China where imports as well as export growth rates in recent years have hovered around 25 percent per year (see Table 1). While merchandise trade growth rates are high for Europe, trade among the European Union member states accounts for most of this growth. Asian trade, on the other hand, is directed significantly outside the region although intra-Asia trade is also growing. Table 2 further dramatizes the very high levels of North America and Europe-linked merchandise trade from China and Korea. In 2005, Asia's North America and Europe-linked trade was about \$1.1 trillion dollars while North America's and Europe's combined Asia-linked trade was about \$600 billion dollars.

Table 1: Share in Merchandise Trade by Global Regions or Countries

REGION	Exports 1990	2000	2005	% Change	Imports 1990	2000	2005	% Change
North America	\$16.6 B	\$19.5 B	\$14.5 B	4 %	\$19.6 B	\$25.8 B	\$21.7 B	6 %
Europe	49.6	42.0	43.0	11%	50.1	42.4	43.2	10%
Asia	21.8	26.4	27.4	11%	20.3	22.9	24.7	12%
China	1.8	4.0	7.5	25%	1.5	3.4	6.3	24%

Source: Based on World Trade Organization (WTO, 2006)

Table 2: Merchandise Trade among North America, Europe, Asia Regions

		Merchandise Trade with (\$billions, 2005):		
		<i>North America</i>	<i>Europe</i>	<i>Asia</i>
Merchandise Trade from (\$billions, 2005)	<i>North America</i>	824	238	270
	<i>Europe</i>	398	3201	332
	<i>Asia</i>	608	498	1424

Source: Based on WTO statistics (WTO, 2006)

Before the 2008 recession, Asia's merchandise trade with North America and Europe was increasing faster than the planned capacity expansion for ports located in those regions. This growth is expected to return quickly once the global economy recovers. Exacerbating the imbalance problem is the fact that for the first time in many centuries, new shipping channels are being created and the usefulness of existing channels are being expanded beyond normal operating seasons. For example, several shipping companies are considering using the Northwest Passage across the top of the world as an alternative to the traditional Pacific routes. Reportedly, this will cut shipping time from Asia to the US east coast by 10%. Global warming effects have allowed the Northeast channels and seaports to operate later in winter season. As new lanes open up the probability of supply chain interruptions increase. This is somewhat counter-intuitive since more channels and extended usefulness should logically translate into improved balance. Instead these changes have led to greater imbalance due to the future ability of the Panama Canal to handle container cargo that was once transshipped through Busan and Los Angeles/Long Beach, reducing the demand on those infrastructures and the associated need for existing capacity and return on premium investments. This activity then increases the business at US east coast ports such as Houston, New Orleans, and Savannah; as well as European ports such as Hull in Great Britain and LeHavre in France. Longer shipping seasons through northern-most channels also reduce the need for developed premium hinterland and seaport capacities, which investors relied on to earn returns. To mitigate these emerging imbalances and potential interruptions, several initiatives have been undertaken, or are being contemplated (Song & Yeo, 2004; Kerr 2006; Anderson et al, 2007, Grigalunas, et al, 2009, et al, 2007; Jacobs & Hall, 2007: G). They include:

- Extreme pressure on the Long Beach port in California is spawning initiatives to enhance East Coast and Gulf ports in USA, and to increase volumes to Canadian ports, with surface transport of some of the goods to US.
- China's development push in its own western region has shifted container volume to inland Yangtze ports - with Shanghai as a hub. This is necessary since 90% of China's international trade is handled through marine transport.

- The intense transshipment competition between major Asian ports such as Busan, Singapore, and Shanghai has led to major investments in port capacities.
- Middle East ports such as Dubai Jebel Ali, Jeddah, are making continuing efforts and Aqaba to upgrade and to become transshipment centers not just for Middle East/Africa but also for South Asia – capturing some of the expected growth through Busan and China.
- China has launched aggressive plans to upgrade the infrastructure of its remote western regions by building a major highway link from its western provinces to the Pakistan port of Gwadar.
- Busan has consistently increased its berth capacity among its five member ports to discourage competition and maintain competitive service levels. This includes the development of the Busan New Port into a super-hub as well as the planned renovation of the existing Busan port. As part of this initiative, aggressive plans to increase hinterland access to the ports through the Siberian Railway are in the concept stages.
- The European Union, with the support of agencies such as Geneva-based International Road Transport Union (IRU), is making concerted efforts to improve transportation infrastructure by developing regular road-rail, inter-modal links, via northern and southern routes, to western China.
- To mitigate the increased costs and decreased service levels at some US ports, the Panama Canal widening project has prompted private firms to invest in increasing capacities on the US Gulf and East Coast ports such as Houston, Savannah and Charleston. In addition, CMA-CGM has chosen the Port of Boston as a transshipment port in the Northeast US. This compliments its Southeast transshipment port in Jamaica.

2. Literature Review

The literature on how ports compete has primarily addressed port competition from the viewpoint of the customer (customer-facing) within a country or region (e.g., Song & Yeo, 2004). Other studies either do not specify the context for their findings (i.e., whether the findings apply within a specific region or on a global scale) or they address only a few of the competitive factors predicting volume (e.g., Grigalunas et al, 2009; Brooks, 2000; Foster, 1979; Malchow and Kanafani, 2001; Murphy et al, 1988, 1992; and Slack, 1985). Collectively, these studies identified five major factors affecting port competition from the viewpoint of a customer. These include *port location*, *cargo volume*, *service level*, *port facility*, and *port expenses* (port cost or price). In the Song & Yeo (2004) model, the authors expressly exclude port expenses because the accounting practices in the Chinese ports they studied were heterogeneous – making meaningful comparisons difficult. In this study, the variable ‘port costs’ were included as a subjective factor so that Port Competition can be measured in a more robust manner. In doing so, it is expressly assumed that the port experts, managers, and directors have knowledge of these factors in the absence of objective data. Based on these studies, we adapted general definitions for each of the five competitive factors. Greater levels of each of the following factors are considered to make a port more competitive:

- (1) Actual Cargo Volume (not capacity): Carriers and port users view major ports that handle large volumes of containers as preferable. Total volume combining import, export, and transshipment cargo appears to be more important than any single category of volume.
- (2) Port Facility Capacity: Port facilities are defined as all tangible assets that are used to service water-borne cargo. Capacities of these assets are of particular importance to liners and carriers since ports operate during peak and off-peak periods. They include infrastructure, superstructure, and labor assets.
- (3) Port Location: Location factors include geographical distance from production facilities, ease of port and berth entry, potential for expansion, and quality of inter-modal access.

- (4) Service Level: The percentage of cargo that will be off-loaded/loaded within the port management's promised time period (variance of time promised), as well as the average off-load/load time. This includes operation during peak periods and in adverse weather conditions.
- (5) Port Costs: The cost to the liner per TEU for load/off-load service as well as applicable port duties. From the viewpoint of a liner/user, Cost is a surrogate for port efficiency – so efficiency will not be measured separately (Song and Yeo, 2004).

Perhaps the most important issue with Asia-linked trade today entails the second factor listed above – Port Facility Capacity – because the existing 10,000, 14,000, and planned 18,000 TEU post-Panamax vessels require 16-21 meter, deep draft, multi-berth container ports (World Bank, 2007, Module 2, Pg. 41, Box 12). Currently, neither the US nor Busan (Korea) or China ports can handle all of these vessels when fully loaded (Haralambides and Behrens 2000). While these ports can handle these vessels when partially loaded, because the draft requirement is not as deep, they are appropriate for transshipment purposes. From the viewpoint of a customer/user, this could be especially problematic for developing countries because their fast growth and steady shift to world-class manufacturing will rely on developing reliable and efficient supply chains. The efficiencies created by these larger vessels will necessarily involve accommodating them when fully loaded. Not doing so will increase the probability of supply chain interruptions because of inadequate scale and efficiency of ports. Other well-known Asian-port rivalries (e.g., Busan-Shanghai, Singapore-Dubai) are motivating these mega-ports to improve their competitiveness for transshipment business by planning to build the capacity to handle the larger vessels. In addition, they are planning greater hinterland capacity to airports, roadways, and rail to improve the efficiencies of imports and exports.

In addition to the factors considered important to a customer (customer-facing competitiveness), the literature identifies factors affecting port competitiveness for resources (e.g. Foreign Direct Investment (FDI) and/or governmental funding). We group these factors under the label of Investment Competitiveness. These competitive factors are heavily influenced by public policy and could be used to shape public policy. [Source: World Bank Report, 2007] These factors are:

- (1) Legal Framework: This entails the degree of autonomy of port management, including its own judiciary, to work outside of political arenas (similar to US Administrative courts) and the specific agreement between central and local governments describing the powers of port officials.
- (2) Institutional Structure: The management structure should be conducive to investment (Private Sector ports), with proper autonomy and have a cooperative relationship with labor. The labor force should be sufficient and well trained. Table 3 demonstrates the four major port management structures and spells out how they differ with respect to the control over port assets and activities. They are Public Service Ports, Tool Ports, Landlord Ports, and Private Sector Ports. At the extremes, Public Service ports are operated as not-for-profit entities whose primary goal is public service; while Private Sector ports operate solely in the interest of the investors – with the government abdicating its rights for any public good.
- (3) Financial Resources: Autonomy to use port revenue for maintenance and expansion, maintain healthy cash flows, and the capacity to raise funds when needed.
- (4) Port Reputation: The use of a mechanism, such as a port sector regulator, to ensure fair competition among the various entities that compete in ports. This involves preventing anti-competitive practices that often take place with port monopolies.
- (5) Price: The price that ports charge for basic services including container handling, drayage services, premiums for peak periods, and storage fees.

The literature suggests that the public policy factors are key factors for a port's competitiveness for investment income. Investment sources include local private, FDI, local governmental, central governmental,

and international agencies or intergovernmental. As described in Table 3, since all seaports have some accountability to government public policy can affect the competitiveness of all ports, regardless of purpose.

3. Methodology

The Analytic Hierarchy Process (AHP) was used to analyze the data due to its use in decision-making. AHP has the ability to analyze quantitative and qualitative criteria in the same analysis. Saaty (1980) developed the concept of AHP, defining it as “...combining both subjective and objective assessments or perceptions into an integrative framework...” (Wedley et al, 2001, pg. 2) based on ratio scales from pair-wise comparisons. Wedley et al (2001) described the techniques associated with AHP in the following three steps: a) structure a network hierarchy, b) make pair-wise comparisons to yield priorities, and c) synthesize priorities into composite measures of the decision alternatives.

According to Song and Yeo (2004, pg. 11) “...due to its applicability in business decision-making, resource allocation, priority rating, and performance evaluation, AHP has been used in a variety of studies and is applicable to measuring intangible and tangible criteria through ratio scales (Badri, 1999). In addition, by relating variables in a hierarchical, logical manner beginning with a single high-level decision the decision process is clarified. Strategic high-level decisions can be traced in a descending, step-wise manner to lower-level criteria on which the decision will be made. A decision-maker is able to relate the higher-level to the lower-level criteria through pair-wise comparisons (Vargas, 1990).

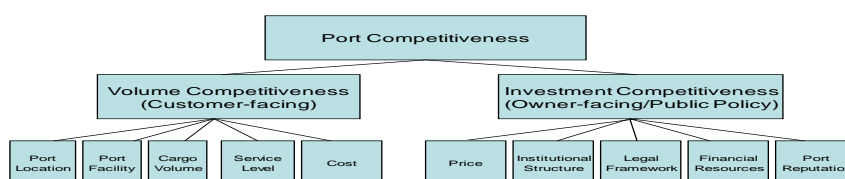
Several studies have applied AHP to maritime decision-making (Song and Yeo, 2004). For example, Frankel (1992) applied it to shipping policies, and Kumar (2002) to shipping liner competition. These studies, however, are limited in that they only utilize the methods analytical and conceptual elements. Haralambides and Yang (2003) applied an improved version of AHP, called fuzzy-set logic, to model shipper choice. This study applies AHP to an empirical investigation of port competitiveness. The data were collected from expert academics, port directors and managers, shippers, carriers, and public officials.

3.1. Step 1: The Decision Hierarchy

The first step required for AHP analysis is to establish a network structure. This can be done by: a) Identifying the ultimate goal or decision on the top of the hierarchy, b) establishing one or more mid/lower-level objectives that are the criteria to evaluate the goal, c) link the criteria to specific variables on which the criteria are measured, d) listing identified alternatives on the bottom, which are linked with the higher level variables, criteria and the ultimate goal of the decision.

The ultimate goal of this study is Port Competitiveness, which is positioned at the top of the hierarchy. Next, mid-level goals are Volume Competitiveness and Investment Competitiveness. The third level involves the variables and attributes of port competitiveness, which will be identified using empirical techniques and the literature. These are listed in the middle of the network structure. Finally, specific container ports in countries such as Asia, Europe, India and the U.S. – the port alternatives – are listed at the bottom of the network. Figure 1 illustrates the conceptual framework for port competitiveness derived from the AHP method as described above.

Figure 1: AHP Structure for Port Competitiveness



3.2. Step 2: Determining weights on criteria and alternatives

In this stage, pair-wise comparisons are used to determine the relative weights that represent the importance of one criterion over another. The greater the relative weight, the higher the importance of the factor to the decision. The computational procedures are based on Saaty (1980).

3.3. Step 3: Ranking Alternatives

The final step involves summing the product of the weighted values of each criterion to develop scores. Higher scores represent greater port competitiveness.

4. Survey Instrument

The survey instrument used was adapted, by permission, from the Song & Yeo (2004) items and scales, except for Port Costs. In this study new items had to be developed to measure Investment Competitiveness. This made it more robust macro-level criteria and three levels of hierarchy to assess competitiveness along two dimensions rather than the single dimension of Song & Yeo (2004). As reliable objective cost data were still unavailable for all ports, the items in this study were subjective. While the variables comprising Investment Competitiveness were developed by the World Bank (2007), the items measuring the variables had to be developed from scratch; however to maintain consistency, the structure of these items and responses are consistent with those of 'Volume Competitiveness'.

After initial development of the items measuring Port Cost in Volume Competitiveness and five variables of Investment Competitiveness, they were administered to five academics who are experts in port and maritime affairs. The academics were asked to evaluate the items for readability and content validity. After several iterations and minor revisions, the items were administered to 11 port managers and academics at the ports of Mayaguez, Incheon, Los Angeles/Long Beach, LeHarve, Melbourne, and Busan to evaluate the readability, clarity, and appropriateness for measuring the variables of interest. This method is consistent with one suggested by Dillman (2001), which involves pretesting and pilot testing survey instruments to ensure reliability prior to administration to a full sample. To pretest the instrument, it was administered to a convenience sample of experts and port administrators.

Invitations were sent to 28 experts and managers, representing eight ports. Those who agreed to participate in the pilot study are Busan Port (Korea), the port of Los Angeles/Long Beach (US), port of LeHavre (France), Port of Incheon (Korea), Port of Chennai (India), Port of Mayaguez (Puerto Rico), Port of Melbourne (Australia), Port of New York/New Jersey (US).

5. Pilot Study Results

The following tables report the results of the pilot study. Due to sample size adjustments were made to conduct the AHP analysis. The results are reported in Tables 3-7. The Continuity Index (CI) for logical consistency was .80, which is less than the critical value of 1.0 (Song and Yeo, 2004).

Table 5 reports the general titles and number of respondents in the pilot study. All categories of respondents in the study are represented, while those of academics represent the greatest number.

Table 3: Port Affiliation & Position

	Port (Asst.) Director	Elected Official	Port Senior Manager	Researcher	Shipper	Carrier
Busan	2	2	1	3		1
LA/LB	1	1	1		2	1
NY/NJ	1				1	
Melbourne				1		
Chennai					1	
Incheon	1		1			

Mayaguez	1			2		
LeHavre				2		
No Specific Port Affiliation				2		

Table 4 reports the scores of the results of the pair-wise comparisons. As a result, Port Location is the most important priority to estimating the Volume Competitiveness of global seaports. In general, the southern-most seaports in the northern hemisphere enjoy competitive advantages over those in the northern-most areas primarily because of the lessening effects of winter on container port operations. The second priority is Service Level. Port customers want to know that their cargo will be off-loaded and on-loaded within the expected time period. The third competitive factor is Port Cost. This is not surprising since globalization is founded on the premise that the savings in production of goods and services. The fourth most important factor is Port Facility, which involves the activities and infrastructure that support the shipping liners. The fifth priority is Cargo Volume, which measures the actual amount of cargo a port handles.

Table 4: Volume Competitiveness - Pair-wise Comparison Matrix, Weights, & Priority

	Cargo Volume	Port Facility	Port Location	Service Level	Port Cost	Weight	Priority
Cargo Volume	1	3.33	.445	.95	.885	.087	5
Port Facility		1	.848	2.544	2.14	.171	4
Port Location			1	3.269	2.889	.282	1
Service Level				1	3.056	.276	2
Port Cost					1	.184	3

Table 5 reports the results of Investment Competitiveness. The highest priority to attract new investors is Institutional Structure. This is intuitive since investors want port administrators to act in the best interest of the port business, free from excessive regulatory influence. The second priority is Financial Resources. This means that investors want the port to have sufficient capital or access to credit to respond to changes. The third priority is Port Reputation, which involves the port's reputation for treating liners and port users fairly. The fourth priority is Price, which involves a port's ability to charge fair-market prices for its services. This differs from Port Cost – measured in Volume Competitiveness – because Price has more to do with matching what competitors charge for similar services rather than any build-on of profit over port cost. The fifth priority is Legal Structure, which involves the avenue of dispute resolution for port users. While important, it may have ranked last because less than 5%, of all business transactions result in a dispute or claim by a port user.

Table 5: Investment Competitiveness - Pair-wise Comparison Matrix, Weights, & Priority

	Price	Institutional Structure	Legal Structure	Financial Resources	Port Reputation	Weight	Priority
Price	1	1.245	1.49	1.43	1.434	.163	4
Institutional Structure		1	2.158	2.178	2.184	.246	1
Legal Structure			1	1.768	1.595	.153	5
Financial Resources				1	2.10	.243	2
Port Reputation					1	.195	3

Table 6 reports the overall values of Volume Competitiveness for each port. As a result, each port is ranked for competitiveness. As expected, Busan ranked highest among the ports in the pilot study because it is a transshipment, mega-hub port, handling the fifth-largest volume of all seaports. Los Angeles/Long Beach ports ranked second, which also corresponds to the 2005 volume estimates. This provides external validity for the instrument because results agree with actual port volume.

Table 6: Overall Values of Volume Competitiveness

	Cargo Volume (.087)	Port Facility (.171)	Port Location (.282)	Service Level (.276)	Port Cost (.184)	Overall Values	Rank
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Busan	0.5011	0.3750	0.3099	0.2062	0.1773	0.1570	1
LA/Long Beach	0.1415	0.1610	0.2856	0.2014	0.1930	0.0983	2
LeHarve	0.1313	0.1240	0.1112	0.1488	0.0743	0.0610	5
Incheon	0.0900	0.1508	0.0937	0.1921	0.2075	0.0834	3
NY/NJ	0.0332	0.1467	0.0520	0.1781	0.2130	0.0735	4
Chennai	0.0272	0.0202	0.0307	0.0500	0.1123	0.0281	6
Melbourne	0.0321	0.0104	0.0455	0.0103	0.0125	0.0133	8
Mayaguez	0.0435	0.0120	0.0714	0.0138	0.0104	0.0160	7

Table 7 reports the values for Investment Competitiveness by individual port. In this case the results were somewhat surprising. Incheon ranked as having the highest competitiveness for new investment, followed closely by Los Angeles/Long Beach and Busan. This probably occurred because Incheon is in the midst of a planning program to create 30 new container berths on the west coast. It is near the Seoul/Incheon Airport, with the potential of making the Incheon area an important intermodal hub. This may explain why Incheon was ranked highest for investment because it has the highest potential for new volume growth – over that of the older ports of Los Angeles/Long Beach or Busan.

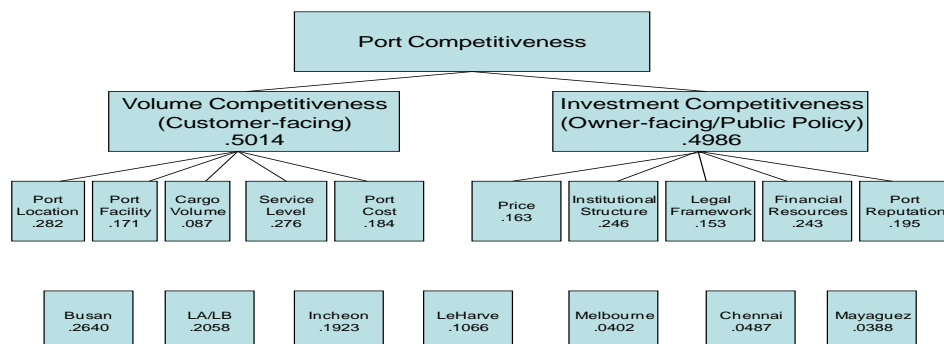
Table 7: Overall Values of Investment Competitiveness

	Price (.163)	Institutional Structure (.246)	Legal Framework (.153)	Financial Resources (.243)	Port Reputation (.195)	Overall Values	Rank
Busan	0.2002	0.2229	0.1776	0.2430	0.2271	0.1070	3
LA/Long Bc	0.1670	0.1994	0.1742	0.2740	0.2602	0.1075	2
LeHarve	0.1114	0.0542	0.0976	0.0912	0.1017	0.0456	5
Incheon	0.1779	0.2311	0.2710	0.2610	0.1451	0.1089	1
NY/NJ	0.1776	0.1517	0.1235	0.0703	0.0909	0.0614	4
Chennai	0.0622	0.0135	0.0321	0.0122	0.0843	0.0206	8
Melbourne	0.0557	0.0271	0.0638	0.0383	0.0800	0.0269	6
Mayaguez	0.0479	0.1006	0.0604	0.0100	0.0100	0.0228	7

6. Conclusions

Because this study is a pilot for instrument testing and analytical evaluation, its conclusions must be considered suspect at this point. However, Figure 2 shows the weighted analytical hierarchy. The weights support the priority of each factor in improving port competition, with the score for each port supporting its competitiveness relative to others in the study. The weights for the higher-order factors Volume and Investment competitiveness support the proposition that they are equally important. This means that a port that emphasizes attracting one factor over the other harms their long-term competitiveness.

Figure 2: The Weighted Analytical Hierarchy



While the results of this pilot study are based on sufficiently scaling the empirical data to a level to allow an AHP analysis. The results of the seven ports suggest that the instrument is sufficiently measuring the factors of interest because they generally conform to expected results and previous literature. The higher-order factors appear to be equally important. This means that it may be unnecessary to develop a single highest-order Competitiveness factor for each port because no new information is gained. If this result holds up in the full study sample, the highest-order Competitiveness factor should be dropped.

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Port Technology of the Future

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Abstract

New port technology is essential to maintain economic growth and competitiveness. Developing new methods and technologies for ports has become an entirely separate economic activity. Until recently there was very little competition between ports and port related costs were relatively insignificant in comparison to the high cost of ocean and inland transport. There was little incentive to improve port efficiency and effectiveness.

Most ports are competing with one another on a global scale and this has led the drive to improve port efficiency, lower cargo handling costs and integrate port services with other sectors of the global distribution network with regard to lowering emissions, safety and security. The maritime sector has considerable influence on the volumes and conditions of trade and the capacity for economic development. Developing new practices and technologies for ports has become vital for maintaining growth and generating trade. New port technology and capital investment in infrastructure is essential to maintaining economic growth and competitiveness. Global competition, intelligent transport systems (ITS) and communication technologies are continuously modifying the environment.

The future is bringing increasing demands for greater efficiency and for more sustainable designs in cargo handling technologies. Moreover, the scarcity of land is forcing port companies to realize higher area utilizations. Terminal operators have the same objectives but they are also looking for cost reduction through decreased life cycle costs, energy consumption, maintenance etc. This is forcing terminal operators to invest in more sustainable, environmentally friendly and cost effective cargo handling equipment. The challenge is how to balance service requirements, costs and demand for sustainability.

Ports play a vital role in economic growth by attracting and generating trade. A port that is not able to cope with rapidly advancing technologies will not be in a position to foster the development of the trade sector. Therefore the development of new cargo handling technology is of paramount importance if a port is to succeed in implementing its economic role.

The main problem in handling increasing levels of cargo is managing the internal traffic and optimizing space inside smaller and medium sized ports. A new generation of cargo handling technology has been designed in the form of an Intelligent Autonomous Vehicle (IAV). The IAV is a clean, safe, intelligent vehicle which will contribute to improving the traffic management and space optimization inside confined space by developing a clean, safe and intelligent intermodal transport system.

Keywords: Intelligent Autonomous Vehicle (IAV), Intelligent Transport Systems (ITS), Space Optimisation, Traffic Management, Globalisation.

1. Introduction

In an ever changing global scene, the maritime sector has had to take on many challenges. Due to the revolution of container shipping the world economy has become more accessible with container throughput experiencing steady growth over the last fifth years. The international seaport business has changed radically

within the space of several years. Globalisation has brought about changes in the structure of the world economy and the shipping and port industries have had to respond to the challenges.

New port technology is essential to maintain economic growth and competitiveness. Developing new methods and technologies for ports has become an entirely separate economic activity. Until recently there was very little competition between ports and port related costs were relatively insignificant in comparison to the high cost of ocean and inland transport. There was little incentive to improve port efficiency and effectiveness. Increasing global competition and continued development of emerging countries has forced changes in the way ports conduct their business. Most ports are competing with one another on a global scale and this has led the drive to improve port efficiency, lower cargo handling costs and integrate port services with other sectors of the global distribution network with regard to lowering emissions, safety and security.

The maritime sector has considerable influence on the volumes and conditions of trade and the capacity for economic development. Developing new practices and technologies for ports has become vital for maintaining growth and generating trade. New port technology and capital investment in infrastructure is essential to maintaining economic growth and competitiveness. Global competition, intelligent transport systems (ITS) and communication technologies are continuously modifying the environment.

The future is bringing increasing demands for greater efficiency and for more sustainable designs in cargo handling technologies. Moreover, the scarcity of land is forcing port companies to realize higher area utilizations. Terminal operators have the same objectives but they are also looking for cost reduction through decreased life cycle costs, energy consumption, maintenance etc. This is forcing terminal operators to invest in more sustainable, environmentally friendly and cost effective cargo handling equipment. The challenge is how to balance service requirements, costs and demand for sustainability.

Ports no longer operate in an insulated or isolated environment. They face the same competitive forces that companies in other industries experience. There is rivalry among existing competitors, continuing threat of new entrants, potential for global substitutes, presence of powerful customers and powerful supplies. There are also regulative and legislative boundaries that must be adhered to.

Over the last century seaports tended to be instruments of state powers and port access was regarded as a means to control markets. Competition between ports was minimal and port related costs were relatively insignificant in comparison to the high cost of ocean and inland transport. As a result, there was little incentive to improve port efficiency.

2. Intelligent Transport Systems (ITS)

Intelligent Transport Systems (ITS) is a wider term for the range of intelligent technologies that applies to transport vehicles and infrastructure. It delivers a host of advanced information and communication technologies to reduce emissions, improve safety, relieve congestion and enhance productivity. In the maritime sector it manages to coordinate and optimise space and manage traffic in a confined space, diminish vehicle emissions and improve air quality. The aim is to reduce the carbon footprint in transport by 60% by 2050. ITS provide an integrated, safer, more efficient, environmental and sustainable transport systems.

Under the Kyoto protocol Ireland, as part of the European Union, has agreed to limit its greenhouse gas (GHG) emissions to being no more than 13% greater than 1990 levels by 2012. Greenhouse gases are widely believed to be the cause of an increase in the average yearly temperature of the earth surface, contributing to melting of polar ice caps and adverse weather conditions worldwide. Despite major improvements in all sectors of its economy, Ireland has only managed to maintain levels at 23% greater than 1990 levels. Transport is a major determinant of the amount of CO₂ emitted in Ireland, and transport companies continually strive to reduce their 'carbon footprint'.

Some EU members have deployed ITS services but it is not providing geographical continuity throughout the region so Directive 2010/40/EU adopted on 7th July 2010 was set up with a view to creating specifications on how ITS should be organized and deployed.

The common aim was to set up a framework to help EU ports to sustain development and raise the finance they need to invest in modern technology. Modernisation will help with attracting new business for ports and play a crucial part in solving real intermodal solutions for EU transport. In order to justify capital expenditure on facilities and equipment, ports need to achieve best international standards in areas such as cargo-handling and the overall cost of operations.

3. North West Europe Region

The coastal region of North West Europe (NWE) stretching from Ireland to Rotterdam is of huge importance but despite this fact few of its smaller and medium sized ports are able to keep pace with growth due to the immense pressure they are under. This pressure is due to increasing container traffic, the economic scarcity of land resources and escalating environmental concerns. These concerns are more referent to urban centre ports such as Dublin Port and other small ports for example Oostende in Belgium and Radicate in France. The main problem in handling increasing levels of cargo is managing the internal traffic and optimizing space inside smaller and medium sized ports.

There is a constant increase in the freight passing through European ports. For example, the volume of containerised freight entering and leaving seaports has doubled within the space of several years. Around 90% of the EU's trade with third countries passes through the ports of Europe, with some 3.2 billion tonnes of freight being loaded and unloaded annually.

The EU's seaports play a vital part in ensuring the competitiveness of both its internal and external trade, and they provide essential links to its islands and remote regions. Moreover, the ports generate more than half a million jobs either directly or indirectly, and they drive the dynamism and development of entire regions, including most of the EU's remote regions.

Europe needs a network of accessible and efficient ports. It needs greater port capacity, and existing capacity has to be streamlined. EU ports must identify all the issues they must resolve if they are to meet the ever-growing demand for transport, cope with technology change (such as containerised freight, intelligent transport systems (ITS) and new information and communication technologies (ICT) and address the need to reduce emissions. Europe's main transport arteries need to become 'green', taking account of environmental concerns as well as the general need for safety and security. All ports must meet these challenges, develop their operations and become more competitive.

4. Intelligent Autonomous Vehicle (IAV)

A new generation of cargo handling technology has been designed in the framework of Intelligent Transport for Dynamic Environment (InTraDE) an EU funded project to which Dublin Institute of Technology (DIT) is a partner with Dublin Port Company as a sub partner. Participation in the project will contribute to improving the traffic management and space optimization inside confined space by developing a clean, safe and intelligent transport system such as an Intelligent Autonomous Vehicle (IAV).

The IAV is similar to the Automated Guided vehicle (AGV) but is technologically superior as it is battery operated making it more economically and environmentally efficient. In contrast to the AGV, the IAV does not have to follow designated routes embedded in the infrastructure to reach its destination.

The IAV is an individual unit which can also work in groups allowing it to form a platoon similar to a train with locomotives. The unit capacity of an IAV is one TEU (twenty foot equivalent unit). Two IAV's will be required to transport two TEU or one FEU (forty foot equivalent unit).

All four wheels have actuators and a failure in any of the wheels individually does not stop the vehicle from operating. The unit is battery operated and the wheels offer 360 degrees movement allowing the vehicle to move in any direction within a confined space.

The IAV is a multi-input, multi-data (MIMD) system equipped with several sensors which will enable it to benefit from Geographical Positioning System (GPS), allowing it to move unmanned around port terminals, delivering containers to and from marshaling areas. Although the IAV is not exactly new, what makes it different is that it does not require a guidance system such as rails or transponders set into the ground. Traffic management and space optimization is a problem with the future development of port terminals in NWE. The problem can be solved by having a remote ‘traffic control centre’ directing vehicles to marshalling areas where the containers are handled by IAV’s.

Table 1: Battery Specification of IAV

Working Temperature	-10C, +40C
Storage Temperature	-20C, +50C

Table 2: Payload Volume of 20ft. Container

Length	6M
Width	2.4M
Height	2.6M
Volume	1360 CU FT

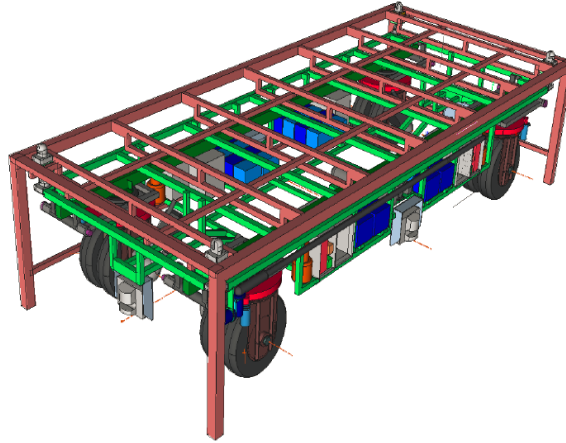
Table 3: Summary of Technical Specifications of IAV

Weight (without load)	3000KG
Payload	7000KG
Wheels Diameter	760MM
Dimensions	L: 7M W: 2.5M
Height of Landing Try	1.2M

Table 4: Characteristics of IAV

4 Wheels	Double Drive & Steering
Mass of Vehicle	2225 Tons
Height	1300 MM
Width	2500 MM
Length	7000 MM
Wheel Diameter	760 MM
Height under the Try	1197 MM
Position of Center of Gravity	0MM, 809MM, 0MM

Figure 1: IAV Design



5. Dublin Port

Dublin is Ireland's biggest and busiest port and although volumes dropped in 2009 and in spite of the economic downturn, exports in 2010 increased by 6.1% and again by 2.8% in 2011. This increase is expected to double over the next thirty years. The port is crucial to the Irish economy as its function is to facilitate the movement of goods and people, in an efficient and cost effective manner.

The port handles over €35 billion worth of trade every year and supports some 4,000 jobs locally. 90% of Ireland's GDP is exported with 42 % being handled through Dublin Port. The port offers multi-modal services with connections to Rotterdam, Antwerp, Le Havre, Felixstowe, Hamburg, Southampton and Liverpool which are important strategic trading hubs.

In line with the Port Company's ambitions and growth forecasts, there is a need to optimise the use of Intelligent Transport System (ITS) in Dublin port. Container ships are now carrying more units per voyage, therefore safety, security and the need to put more environmentally- sustainable practices in place are putting more demand on the port.

There is a need to optimise the use of Intelligent Transport Systems (ITS) within international ports such as Dublin. Currently in Dublin Port, the movement of cargo is operated by shunter vehicles differing from AGV's as in other international ports.

Current Technology

Figure 2: Shunter Vehicle



Figure 3L: Automated Guided Vehicle AGV)



5.1 Suitability and Application of IAV in Dublin Port

If Dublin port is to grow and expand, there will be a need for some reconfiguration of the existing port with redevelopment as required. There is a limit to the volume of freight that can be handled in the ports existing estate and infrastructure. Therefore, the introduction of the IAV and the application of the virtual port simulator will be very valuable in forecasting the impact of changing traffic flows and the foreseen increase in efficiency and cost effectiveness of cargo handling in the port by designing a case study of Dublin Ferryport Terminal (DFT) layout using a virtual simulator.

Figure 4: Dublin Ferryport Terminal (DFT)



IAVs will improve the traffic in Dublin port in terms of congestion, when the volume of vehicles is dense according to space motion. These vehicles will alter their speeds and trajectories according to the traffic status and the environmental changes such as pollution and noise. The auto-control will help significantly in decreasing the emission rate of pollution gases during the vehicles mission. In order to be efficient, cargo handling has to be situated close to the quay wall where vessels are operating, otherwise, valuable time will be lost moving the cargo from ship to storage area and vice versa. In turn, this will impact on the turn-around time of vessels, a crucial factor in vessel and port efficiency. The IAV will reduce the time lost in moving cargo from ship to storage area and vice versa by 10%. In addition, the environmental benefits will include a 20% reduction in air pollution.

The novel conception approach of the IAV will identify automatic navigation routes in order to overcome any infrastructural barrier in Dublin Port. It does not require fixed tracks (and inherent costly investment) commonly required for completely automated vehicles. A major consideration in the development of the IAV is its suitability for Dublin Port in terms of its payload capabilities and its capabilities to adapt to a varied

range of environmental parameters which present themselves in the expansion of the Port.

6. Simulation of Dublin Port using IAV SCANeR Studio Software

The simulation software used is called SCANeR Studio simulation engine. It has adapted techniques to develop a real-time simulation for the study of traffic flows within Dublin port and other international ports. Data and information regarding Dublin Port was imputed in the simulator in order to finalise a generic 3D dynamic simulator of the port. The tool employs an interactive approach between vehicles, traffic lights and roads that enables users to visualize a real port network and the vehicles that drive in it. The technique developed can be changed to different port layouts due to the flexible extensible method with which it has been implemented. The main study of the simulator is to set parameter values of the actual port system. Simulation is the perfect tool for evaluating system parameter values as it reduces the cost and time of a project by allowing the user to quickly evaluate the performance of different layouts, a process that is time consuming and extraordinarily expensive. The robustness of the system can be tested using different scenarios, allowing you to explore these scenarios without changing the values therefore any changes can be easily made.

The simulator will help significantly in the pre-analysis before experimental tests of the vehicle are carried out. With the different developed vehicles, infrastructure and environment, validation of the developed algorithms on control, monitoring, space optimisation and traffic management can be carried out before real integration begins.

The software will identify potential obstacles and related problems and will reduce the number of obstacles in the port area by 3%. It will achieve a more effective method of moving cargo from ship to storage area and vice versa with a minimum efficiency improvement of 10%. Obtain a safe environment within the port area due to the simulators capabilities to locate the position of the goods at all times, a reduction in the loss or damage of cargo by 4% will be a target. Reduction in the level of accidents by 5% and it will also aim to increase the use of information and communication technology (ICT) within Dublin Port operations by 5%.

7. Conclusion

The objective of this study is to minimize the work load of the terminal operator which in turn will reduce the turn- around time of vessels, a crucial factor in vessel efficiency particularly in Dublin Port. Safety must have top priority, but this interferes with land availability and also productivity. The introduction of new and bigger vessels being phased into the NWE region has a significant impact on terminal operators. Container terminals are important hubs in the modern logistic network that ensures efficient and cost effective intermodal container turn- around times. The face the challenge of turning around not only more but also larger vessels in the shortest possible time and this has to be coordinated and planned. Expanding port capacity by improving ITS appears to be the only viable solution.

The main cornerstone for future EU transport policy is the 2011 EU White Paper entitled ‘Roadmap to a Single European Transport Area – Towards a Competitive and Resource Efficient Transport System.’ The goal is to set up a new generation of terminals that will improve the productivity, efficiency and throughput of cargo handling with more advance ways of managing traffic and space optimization. In order to meet these challenges we need to use less energy, use cleaner energy and exploit efficiently a multimodal integrated and ‘intelligent’ network.

The inability of current terminal technology to adequately serve cargo handling needs is a major deterrent to inter-modalism, but one which ITS can effectively address. ITS technology transit times will address major problems, such as congestion, longer transit times from ship to stack and vice versa as well as safety concerns. This novel technology will adapt to the specific environment in Dublin port, which could then be transferred to different sizes of ports and terminals in the NWE region and beyond.

Acknowledgements

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Formulating the Competency Framework for Maritime Logistics Professionals

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Abstract

Much have been researched about the critical importance of logistics to the national and regional economy, especially in the context that customers are more and more demanding of the supply chain nowadays desiring for quick response to orders and greater varieties of logistics options. Undoubtedly, the success of logistics and supply chain management depends very much on the skilled workforce employed in the sector. Leading companies have recognised the vital role that people play in driving innovation in their supply chain and improving their ability to produce results, rather than investing only on technology and processes. This applies both to the logistics and supply chain as well as the maritime industry. In this respect, managing maritime logistics and supply chain would also require people with good competencies, especially in the time of new challenges. Despite the importance of this issue, no research has been found in the contemporary literature of which necessary skills and knowledge a maritime logistics executives should possess to be successful in their job in the future. In this paper, this research issue is explored by formulating a competency framework for maritime logistics executives and validating this proposed framework empirically through in-depth interviews with senior maritime logistics executives both in Singapore and Korea. The proposed framework contains three groups of business-, logistics- and management-related competencies, with each group further classified into generalist and maritime specific skills and knowledge. As a result, important academic and managerial insights are drawn to the design and implementation of human resource development policy for executives involved in maritime logistics operations.

Keywords: maritime logistics, competency profile, human resource development, human capital

1. Introduction

Logistics and supply chain management plays a critical role in the economy of every country. Like any other economic sector, a skilled workforce in logistics and supply chain contributes greatly to the success of the sector. As business environments continue to change rapidly, logistics and supply chain sectors face many challenges, of which the need for well trained and skilled logistics professionals is absolutely essential. To reflect this, Closs (2000) suggested that ‘one of the major challenges to management in the next decade is the scarcity of trained supply chain managers’, and that ‘substantial change in logistics and supply chain education is necessary’ to meet these challenges. This perception has recently been reinforced by Carter and Carter (2007) who argued that supply management organisations would take on a higher value role in the coming decade, and thus success would hinge on whether they can attract, develop, and retain individuals with the right skills and capabilities to excel in the future. This view is further elaborated by Green (2010) of the Accenture Supply Chain Academy in that leading companies in recent years have recognised the vital role that people play in driving innovation in their supply chain and improving their ability to produce results, rather than investing only on technology and processes.

Managing the supply chain has become increasingly more complex as logisticians attempt to adapt to

turbulent and competitive market environments. Adding to the complexity is managing the paradox of achieving cost efficiencies whilst improving customer service and improving customer and supplier relationships within the supply chain (Christopher, 1998). It is argued that maritime logistics and supply chains share a lot of characteristics with normal business logistics and supply chains, and thus managing maritime logistics and supply chains should shares some common competencies required for normal business logistics and supply chains. In this respect, maritime logistics is defined as the part of the supply chain process that plans, implements, and controls the efficient, effective flow and storage of goods, services, and related information from the point of origin to the point of consumption in order to meet customers' requirements in the *maritime* and business environments. In this context, one issue that arises is what knowledge and skills are necessary for maritime logistics professionals to be able to meet the broader challenges of their role in a globalised market. Similar to general logisticians, it is envisaged that maritime logistics professionals must be multi-talented across a range of management skills as well as having the depth of logistics knowledge and abilities, which means they must have both generalist and specialist (maritime) knowledge and skills (Gammelgaard and Larson, 2001; Razzaque and Sirat, 2001; Murphy and Poist, 2006).

This paper aims to address the above mentioned issue and is organised in four sections. First, a research background is depicted to examine how the research issue has been addressed in the contemporary literature and identify room for further investigation in this study. This is followed by the explanation on the development of the conceptual framework. Next, the research methodology in this study with the data collection and sampling methods will be explained. Findings and conclusions will be presented next, followed by a discussion on both academic and managerial implications. Finally, a conclusion is presented together with some notes on limitations and directions for future research.

2. Research Background

Leading companies have recognised the vital role that people play in driving innovation in their supply chain and improving their ability to produce results, rather than investing only on technology and processes (Green 2010). This applies to both logistics and supply chain as well as maritime industry. Maritime companies, specifically shipping and port, are integrating intensively to logistics and supply chains. Therefore, appropriate attention now must also turn to performance improvement through people rather than relying solely on equipment and technology. For example, the port industry has changes markedly in recent years (Meersman et al., 2005). In the last decade, there are several trends greatly affecting ports and contributing to alter their patterns of development as well as their people's profile. Among these, deregulation and the increased competition, both intra-ports, inter-ports and between ports and other transport modes, have greatly had important effects on the port industry (Notteboom and Winkelmans, 2001; Huybrechts et al., 2002). Besides, huge capital investment in terminals and equipment especially to serve container trades has added up to the pressure for changes that ports have been facing. Many ports have invested intensively on specialized container handling equipment and transformed themselves from multi-purpose or general cargo ports to dedicated container terminals. This has had tremendous implications on port workers, supervisors and managers in terms of changing job profile, skills, and knowledge to response effectively to the change in cargo demography. These recent trends and challenges have brought about transformations such as the methods of transport have changed significantly and container transport has now become even more popular. More container terminals have been replacing conventional cargo ones, and thus the job profile of the former dockworker has gradually been replaced by a set of competencies required by port workers employed by terminals using innovative technologies (IPTC, 2003). Substituting capital for labor, containerization and related developments have also resulted in substantial reduction in port employment, accompanied by increasing requirements on enhanced labour productivity. In addition, job profiles have also changed radically as a result of structural adjustments calling for new management techniques and working skills, in that multitask workers and multi-skilled operators are becoming more common in ports.

It is widely perceived that many shipping companies are now providing more than port-to-port services while many ports are also providing more than traditional cargo handling and storage services, moving toward an integrated logistics maritime supply chain. At the same time, there is generally a trend that these companies are shifting from hardware-based interfaces towards knowledge-intensive platforms, providing their customers more value-added and integrated logistics services. Thus, it is critical to identify necessary knowledge and

skills for maritime logistics professionals to be able to meet the broader challenges of their role in a globalised market.

3. Conceptual Framework Development

The importance of human competence in improving organizational performance has been widely acknowledged in the literature (McClelland, 1973; Boyatzis, 1982; Spencer and Spencer, 1993; McLagan, 1997). Competencies are defined as skills, knowledge, abilities, and other attributes such as values and attitudes necessary for the effective performance of activities (Pinto and Walker, 1978; Hayes, 1980). Recent authors such as McGee et al. (2005), Johnson et al. (2009), Ireland et al. (2009) and Jones and Hill (2010) concur that a competence is the product of organizational learning and experience and represents real proficiency in performing an internal activity in the organization. A competency is a mixture between the skill, knowledge, ability and other sets of characteristics that an employee possesses which enable them to perform their activities more efficiently and effectively. It has also long been argued that there is a strong linkage between employees' competency level and the firm's performance (Campbell, 1990; Swanson, 1990). In addition, it is also ascertained that a distinctive competence is a competitive resource because it gives a company a competitively valuable capability unmatched by rivals, can underpin and add real punch to a company, and is a basis for sustainable competitive advantage, especially in the knowledge-based economy and industry (Hafeez et al., 2002; Johnson et al., 2009).

As maritime logistics and supply chain operations share a lot of characteristics with the generic supply chains, maritime logistics professionals should first possess generic competencies of logistics professionals. In this respect, it is suggested in many studies that logistics professionals require many skills to be effective (La Londe 1990; Murphy and Poist 1991a, 1991b, 1993, 1998; Gibson et al. 1998, etc.), and that skills for logistics professionals spread over from technological, to organisational and interpersonal ones (Pilnick and Gabel 1998; Young 1998; Le May et al. 1999). What becomes apparent is that to become a successful logistics manager, one may need to take on super-human characteristics to take on the plethora of activities. Literature on competency requirements for transport and logistics professionals was also reviewed to identify and determine what skills, knowledge and abilities would most be appropriate to maritime logistics professionals in performing their job successfully. In this connection, a number of authors have published their research in the quest to identify and validate essential competency requirements for transport and logistics professionals, for example Gibson, Gibson and Rutner (1998), Murphy and Poist (1991a, 1991b, 1993, 1998, 2006), Pilnick and Gabel (1998), Young (1998), Le May et al. (1999). The most recent literature published in this area is by Thai et al. (2011) in which a conceptual model of competencies for logistics professionals including 25 business, 23 logistics and 20 management skills was built based on the BLM framework with modification and adjustment. This study is perceived to include all important findings from the earlier studies while also presented some new insights and findings in this research area. The framework presented and validated in this study was thus selected as a base to conduct a critical review and analysis to determine which skills, knowledge and abilities in this framework would be most appropriate for maritime logistics professionals. The results are summarized in Table 1.

Table 1: Competencies in Transport and Logistics Most Suitable to Maritime Professionals

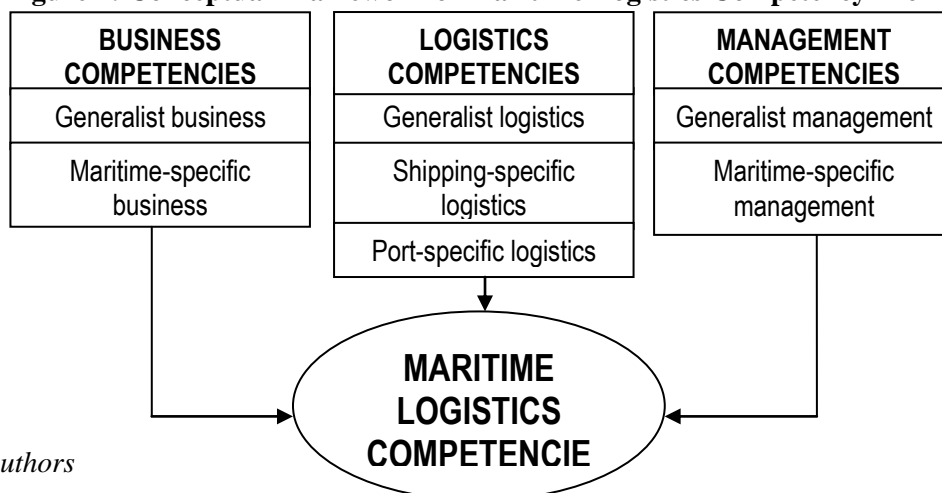
Competency Group	Skills, Knowledge And Abilities
Business-related	<ul style="list-style-type: none"> • Accounting & financial management • Analysis statistical data • Managing client relationships • General business administration • Human resource management • Quality management • International business • Risk management • Impact of globalization & climate change • Strategic planning & management • Economic principles

	<ul style="list-style-type: none"> • Information system management • Industrial relations • Occupational health & safety • Corporate social responsibility
Logistics-related	<ul style="list-style-type: none"> • Customer service • Contract management • Purchasing • Materials handling • Transportation management • Packaging • Inventory management • Warehousing • Salvage and scrap disposal • Reverse logistics
Management-related	<ul style="list-style-type: none"> • Ability to plan, organize, lead & control • Effective oral & written communication • Effective supervision of staff • Ability to delegate, train & motivate staff • Ability to negotiate • Problem-solving ability • Effective time management • Ability to adapt to organizational change • Personal enthusiasm & integrity • Knowing two or more languages

Source: The Authors, compiled from Thai et al. (2011)

In addition, it is important that maritime logistics professionals possess competencies specific to maritime logistics as the area of their specialisation. Since maritime logistics professionals need to possess generic competencies in the business-, logistics- and management-related areas, it is also essential that they possess necessary skills and knowledge in the specialised fields of shipping and port business, logistics and management. Therefore, maritime logistics professionals should possess three main competency groups of business, logistics and management, with two subgroups of generalist (those competencies which are essential to generic logistics and transport professionals, as identified in Table 1) and maritime-related competencies. The logistics-related group is further classified into generalist, shipping- and port-related subgroups of competencies which are deemed important for maritime logistics professionals to possess in performing various shipping and port logistics activities successfully. The competency profile of maritime logistics professionals is depicted in Figure 1.

Figure 1: Conceptual Framework of Maritime Logistics Competency Profile



Source: The Authors

In order to determine which maritime-specific competencies in the areas of business, logistics and management are most essential for maritime logistics professionals, a dual research approach is adopted. Specifically, we conducted a thorough review of related literature on the competency profile of shipping and port professionals as well as the training programs of maritime business institutions around the world to synthesise the most common and important shipping- and port-related skills and knowledge that are important for professionals working in the field of maritime logistics. This review exercise reveals that, surprisingly, not much research has been conducted in this area of interest, and the only relevant research conducted recently is by Thai (2012) which examined the competency profile of port personnel. Together with this study, the training programs of those universities and academies which offer maritime business qualifications are critically examined to derive the common and most important skills and knowledge for maritime logistics professionals. Overall, the comprehensive competency profile of maritime logistics professionals is proposed in Table 2.

Table 2: Proposed Competency Framework for Maritime Logistics Professionals

Competency group	Competency sub-groups	Skills, knowledge and abilities
Business-related	Generalist	<ol style="list-style-type: none"> 1. Accounting & financial management 2. Analysing statistical data 3. General business administration 4. Human resource management 5. Marketing 6. Quality and customer service management 7. International business 8. Risk management, including BCM 9. Impact of globalization & climate change 10. Strategic planning & management 11. Economic principles 12. Information system management 13. Industrial relations 14. Occupational health & safety 15. Corporate social responsibility
	Maritime-specific	<ol style="list-style-type: none"> 16. World trade and shipping 17. Exporting & importing 18. Maritime economics 19. International framework of shipping 20. Maritime law and marine insurance 21. Shipping & port marketing 22. Roles and functions of ports 23. Customs procedures 24. Dangerous cargo regulations 25. Port safety & security, including ISPS Code, 24-hour rule, CSI
Logistics-related	Generalist	<ol style="list-style-type: none"> 26. Supply chain management 27. Contract management 28. Purchasing 29. Materials handling 30. Transportation management 31. Packaging 32. Inventory management 33. Warehousing 34. Salvage and scrap disposal 35. Reverse logistics
	Port-specific	<ol style="list-style-type: none"> 36. Navigation and traffic control 37. Planning and operations for conventional cargo terminals (including dry bulk, liquid bulk & general cargo handling)

		38. Transit shed and warehouse operations 39. Freight station operations 40. Container ship and yard operations 41. Berth planning & scheduling 42. Ship stowage planning 43. Quay transfer operations 44. Dangerous cargo operations 45. Reefer cargo operations 46. Project cargo operations 47. Planning & operations of logistics zones
	Shipping-specific	48. International transport systems 49. Freight forwarding & shipping agency 50. Network & transportation system design and optimization 51. Fleet size & mix decisions 52. Ship routing & scheduling 53. Cargo handling operations 54. Ship brokering & chartering
Management-related	Generalist	55. Ability to plan, organize, lead & control 56. Effective oral & written communication 57. Effective supervision of staff 58. Ability to delegate, train & motivate staff 59. Ability to negotiate 60. Problem-solving ability 61. Effective time management 62. Ability to adapt to organizational change 63. Personal enthusiasm & integrity 64. Team building and communication 65. Knowing two or more languages
	Maritime-specific	66. Maritime strategy 67. Shipping management 68. Quality management in shipping 69. Port strategic planning, master planning and operations planning 70. Management Information System, including terminal planning systems 71. Time in port and port productivity management, including KPI measurement

Source: The Authors

4. Research Methodology

In order to empirically validate the proposed competency profile of maritime logistics professionals, in-depth interview was selected as the method of data collection due to the exploratory nature of the research issue. Because of the international nature of maritime logistics operations, we adopted the cross-country study approach in collecting the necessary empirical data to validate the proposed conceptual framework. Overall, six in-depth interviews were conducted in Singapore and Korea, with three in each country. The interviewees were selected based on the authors' personal contact database. The interviewees who are all senior managers in their respective organisations were selected based on their vast experience in the shipping and port operations and management as well as their intensive involvement in the area of maritime logistics in their daily work.

The interviewees from Singapore include a regional trade president of the most well-known shipping company in the country, a general manager of a local liner shipping company, and a retired senior executive who had spent most of his life working in various shipping companies and ports in Singapore. Meanwhile, the

in-depth interviews were also conducted with two senior managers in two shipping companies and a senior manager from a freight forwarding company in Korea. All the interviewees possess about 15 – 25 years work experience in the area of shipping and port businesses. The interviews were conducted at the interviewees' premises, lasted from 40 – 60 minutes, recorded with their permission, and were later transcribed to extract the important information and data. During the interviews, the interviewees were briefed about the objectives of the research and provided with the proposed competency profile of maritime logistics professionals for comments. Specifically, they were asked to express their opinion and feedback on (1) whether each competency in the proposed framework is relevant and important for maritime logistics professionals to possess, (2) which competency requirements are urgently needed for maritime logistics professionals at the moment, and (3) which competency requirements are important for maritime logistics professionals to learn and acquire so that they can be successful in the future.

5. Findings and Discussion

5.1 General perception of the proposed competency framework

Generally the interviewees both in Singapore and Korea perceived that the suggested framework includes important competencies that are essential for professionals dealing with maritime logistics and they are very comprehensive. The general consensus which was found across the interviews is that maritime logistics professionals would need a broad range of skills and knowledge to be able to perform their job effectively. In this respect, there was a high level of consensus among interviewees that maritime logistics professionals should possess not only the core competencies in logistics but also those in the business and especially management-related competencies if they want to move up in their career ladder. The interviewees also agreed that maritime logistics professionals need to acquire essential business-, logistics- and management-related competencies both of generic nature as well as those are specific to maritime logistics operations. This finding is in line with various previous literature, such as those by Gammelgaard and Larson (2001), Razzaque and Sirat (2001), and Murphy and Poist (2006) and supports the argument that logistics professionals of the future would need a wide range of competencies, normally of cross-disciplinary nature. The following quote best illustrates the above finding:

... those who are involved in maritime logistics would be required to possess a broad range of skills to be ready for the workforce... The world is changing rapidly everyday with renders constantly new difficulties and challenges and the logistics professionals must be ready for it by equipping themselves with skills and knowledge of various fields and areas, from business to operations and management...

Besides the general perception of the overall relevance and importance of the proposed competency framework, interviewees also highlighted several aspects where amendments are needed. First of all, some recommendations were made for the sub-group of generalist competencies in the business-related group. Some interviewees perceived that this sub-group should also include competencies such as *project management* and *principles of commercial and transport law* to better reflect the full spectrum of areas that maritime logistics professionals are to deal with. Indeed, logistics professionals need to possess knowledge and skills in project management, including project financing, as well as a good understanding of commercial and transport law since every maritime logistics project involves various stakeholders in the maritime supply chain. Besides, it was also perceived that *general business administration*, which is a general business competency, should be revised to include *organisational behaviour, corporate governance and leadership*. Meanwhile, *impact of globalisation and climate change* should also be reworded as *international regulatory changes* since maritime logistics professionals are expected to be mindful and knowledgeable about not only the organisation but also changes in the environment in which they are working. This will allow the cultivation of the learning culture and behaviour for all maritime logistics professionals involved which helps to raise the organisation above their competitors. Meanwhile, in the maritime specific sub-group of the business-related competency group, the knowledge on *exporting and importing* should be reworded as *exporting and importing procedures and INCOTERMS*. Indeed, this suggestion reflects a clearer knowledge scope since maritime logistics professionals need to be proficient in conducting importing and exporting transactions as well as the interpretation and application of international commercial terms in their daily work.

Some changes in the logistics-related competencies group were also deemed important by interviewees. First, in the port specific sub-group, *planning and operations for conventional terminals* and some other related competencies in *transit shed and warehouse operations*, *berth planning and scheduling*, etc. should be reworded as *planning and operations for ships and terminals (including berth planning and scheduling, ship, yard and warehouse operations, specialized cargo operations)*. In fact, the latter is inclusive of all of the former as it represents the skills and knowledge necessary in performing port logistics activities regardless of the types of cargo involved. In addition, it was also perceived by some Korean interviewees that a new competency of *port network analysis and optimisation* should be included in this sub-group. This is valid given that one of the important tasks that maritime logistics professionals might be required to perform is to optimise the whole supply chain network so as to achieve the global optimisation objective in supply chain management. In addition, it was also recommended by some interviewees in Singapore that *international transport systems* in the shipping specific sub-group should be reworded as *multimodal transport*, which is accepted due to the universal use in training programs of the latter term.

Interviewees also suggested some changes in the management-related group of competencies. Specifically, the generalist sub-group should also include *cross-cultural management* and *change management*. These are considered important knowledge and skills for maritime logistics professionals given the international nature of maritime logistics business and the dynamics of the business environment today. Meanwhile, the adjective ‘effective’ was perceived redundant in some competencies in this sub-group as their meaning is self-explanatory without further explanation. In the maritime specific sub-group, the phrase ‘including terminal planning systems’ preceding the *Management Information System* was suggested to be removed. This is accepted since maritime logistics professionals need to be knowledgeable in the use of the management information system not only in the port and terminal context but also in others such as a shipping or logistics organisation. Subsequently, this competency, together with *quality management in shipping*, are relocated to the generalist sub-group of the business-related competency group as the knowledge of general management information system and quality management would be able to apply in the context of maritime logistics.

5.2. Competency requirements now and in the future

Interviewees, especially those in Korea, perceived that maritime logistics professionals would urgently need the business-related competencies as they should have the bird-eye view on the business issues which would affect their logistics operations. This is in line with other literature on the necessary skills and knowledge for general logistics professionals in that business-related skills and knowledge are deemed essential. In addition, it was perceived that there is the need in the future for maritime logistics professionals to upgrade their competency profile with more skills and knowledge on the shipping and port specific logistics competencies. General management competencies were also seen as critical in the future as they are important for the progression of maritime logistics professionals from the executive to the management level in their career path.

Overall, with the empirical validation through a series of in-depth interviews in Singapore and Korea, the proposed competency framework for maritime logistics professionals was revised accordingly. This is summarised in Table 3.

Table 3: Revised Competency Framework for Maritime Logistics Professionals

Competency group	Competency sub-groups	Skills, knowledge and abilities
Business-related	Generalist	<ol style="list-style-type: none"> 1. Accounting & financial management 2. Analysing statistical data 3. General business administration, including organizational behavior, corporate governance & leadership 4. Human resource management 5. Marketing 6. Quality and customer service management 7. International business 8. Risk management, including Business Continuity Management (BCM)

		9. Project management 10. Principles of commercial and transport law 11. International regulatory changes 12. Strategic planning & management 13. Economic principles 14. Management Information System 15. Industrial relations 16. Occupational health & safety 17. Corporate social responsibility
	Maritime-specific	18. World trade and shipping 19. Exporting & importing procedures and INCOTERMS 20. Maritime economics 21. International framework of shipping 22. Maritime law and marine insurance 23. Shipping & port marketing 24. Roles and functions of ports 25. Customs procedures 26. Dangerous cargo regulations 27. Port safety & security
Logistics-related	Generalist	28. Supply chain management 29. Contract management 30. Purchasing 31. Materials handling 32. Transportation management 33. Packaging 34. Inventory management 35. Warehousing 36. Salvage and scrap disposal 37. Reverse logistics
	Port-specific	38. Navigation and traffic control 39. Port network analysis and optimisation 40. Planning and operations for ships and terminals (including berth planning and scheduling, ship, yard and warehouse operations, specialized cargo operations)
	Shipping-specific	41. Multimodal transport 42. Freight forwarding & shipping agency 43. Network & transportation system design and optimization 44. Fleet size & mix decisions 45. Ship routing & scheduling 46. Cargo handling operations 47. Ship brokering & chartering
Management-related	Generalist	48. Ability to plan, organize, lead & control 49. Oral & written communication 50. Supervision of staff 51. Ability to delegate, train & motivate staff 52. Ability to negotiate 53. Problem-solving ability 54. Time management 55. Ability to adapt to organizational change 56. Personal enthusiasm & integrity 57. Team building and communication 58. Cross-cultural and change management 59. Knowing two or more languages
	Maritime-	60. Maritime strategy

	specific	61. Shipping management 62. Port strategic planning, master planning and operations planning 63. Time in port and port productivity management, including KPI measurement
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Source: The Authors

6. Conclusion, Implications and Recommendations

The maritime industry has changed drastically, thus maritime logistics professionals have to acquire and possess new competencies from cross-functional areas in order to be effective and successful in their job now and in the future. In this paper, a competency framework for maritime logistics professionals was proposed, and through the empirical validation it was evidenced that the framework is relevant and the proposed competencies are deemed necessary and important for those who are involved in maritime logistics operations. Specifically, it is essential that maritime logistics professionals possess competencies in three main areas of business, logistics, and management, with each group consists of both generalist and maritime specific skills and knowledge. It is also evidenced from this research that essential competency requirements for maritime logistics professionals should go beyond those conventional in shipping and port operations and encompass also those in logistics and supply chain management.

This research is of both academic and managerial implications. First, it contributes to fill the gap in the contemporary literature on what skills and knowledge are important for maritime logistics professionals to possess so as to be successful in their job and career. This will lay the background for future research on the education and training programs which are needed to supply maritime logistics professionals with essential competencies. For organisations which are involved in maritime logistics operations, the findings of this research can help senior management identify the areas of competencies which are critical for their maritime logistics personnel to acquire, and design subsequent training and education programs accordingly. Due to the qualitative nature of the method of data collection, conducting this research using other quantitative methods such as surveys and in other countries would help to enhance its reliability, validity and generalisability.

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Maritime Security Requirements for Shipping Companies and Ports: Implementation, Importance and Effectiveness

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Abstract

In the aftermath of the 9/11 event in 2001, maritime security has become one of the main issues on the international maritime agenda, with a strong orientation on anti-terrorism actions. Since that time, a significant number of various regulations in the field of maritime security has come into force and imposed a long list of compulsory and voluntary maritime security requirements on shipping companies and ports. Existing data show that not all of these requirements are generally implemented. One of the reasons is the lack of resources needed for the implementation of those requirements, another is the misunderstanding of their importance. Besides, some of the implemented requirements may be found ineffective in achieving their intended goals. Therefore, the main objectives of this study are to identify the security requirements imposed on shipping companies and ports, to investigate which of them are generally implemented, and to explore the perceived importance and observed effectiveness of these requirements. To achieve the expected objectives, a comprehensive literature review of maritime security regulations and relevant literature was done to compose a detailed list of requirements for shipping companies and ports, and in-depth structured interviews with industry professionals have been conducted to obtain the information about the existing situation in their organizations. The findings of the study showed that majority of listed requirements were implemented in interviewed organizations. Several of the compulsory requirements were found not important or not effective for security improvement, however they were implemented because of their mandatory nature. Meanwhile, some of the voluntary requirements were not implemented, if they were found unimportant or ineffective by the organizations. Moreover, the different interviewees' opinions about the importance and effectiveness of some security requirements can lead to a conclusion about different approaches chosen for security management in the organizations. Additionally, as collateral results, this paper provides some proved impacts of implementation of security requirements on the organizational performance of shipping companies. These findings have both academic and managerial implications. They can be useful for researchers working on the related topics, for security managers in shipping companies and ports, as well as for regulatory bodies when considering changes in maritime security related documents.

Keywords: Maritime Security, Security Regulations, Security Requirements

1. Introduction

1.1. Background Information

The problem of maritime security has existed for hundreds of years. Piracy, cargo pilferage, smuggling, stowaway were considered as prime issues. For a long time, there were no legal ways to deal with these problems. Different international and national organizations have tried to improve the situation by introducing various rules and conventions, such as the International Convention for the Safety of Life at Sea (SOLAS) and

Convention for the Suppression of Unlawful Acts against the Safety of Maritime Navigation (SUA Convention) (IMO, 1974, 1988). The 9/11 event in 2001 and the bombing of the French oil tanker Limburg in October 2002 made maritime security a hot issue in the international maritime agenda with a strong orientation on anti-terrorism actions. During a short period of time after these events a lot of new maritime security regulations and best-practice documents came into force. Nowadays there are significant number of conventions, codes, standards, programs, and other documents regulating maritime security, which impose a long list of compulsory and voluntary security requirements on shipping companies and ports.

1.2. Problem Identification

The diversity of maritime security initiatives poses a very important problem for shipping companies and port operators - how to meet and maintain all existing requirements in maritime security area, while not jeopardizing organizational performance. The implementation of these regulations is a very costly and time-consuming process and requires a lot of other resources. However, benefits from the implementation of a new security regime are still not clearly identified, whereas some shipping companies and ports even have reported negative impact on their organizational performance (APEC, 2002; Banomyong, 2005; Eyefortransport, 2002; Thibault et al., 2006; Timlen, 2007; Voort et al., 2002). Therefore, some doubts may appear in the maritime industry regarding the necessity to implement all proposed security requirements. Just a few papers have been conducted on studying the implementation of maritime security measures (Gutiérrez et al., 2007; Thai, 2007; Voss et al., 2009). Moreover, there is not much information regarding their importance and effectiveness. The question whether the perceived importance of security requirements may affect their implementation or not has not been studied a lot. Thus, to fill the existing gap and in this way to increase the understanding of the current security regime in the shipping industry, it is necessary to study the implementation of maritime security requirements, their importance and effectiveness.

2. Literature Review

2.1. Maritime security regulations and requirements for shipping companies and ports

2.1.1. Regulations

As a part of maritime law, maritime security regulations have a very diverse nature. The maritime security requirements for shipping companies and ports may be found in various sources. In some literature these sources are divided into three sets (Bichou et al., 2007; Gutierrez & Hintsä, 2006; Talley, 2008).

The first set includes regulations proposed by different international organizations. A prevailing legal document regulating maritime security is the International Ship and Port Facility Security Code (ISPS Code) (IMO, 2002). It came into force on 1 July 2004 together with other amendments of SOLAS Convention, and imposed a list of compulsory requirements on shipping companies and ships, engaging in international voyage, as well as on port facilities serving such ships. The Code of Practice on Security in Ports provides detailed guidance for implementation of port security related requirements contained in the ISPS Code (IMO & ILO, 2003). The Seafarers' Identity Documents Convention is another document from these set, requiring every seafarer to have a seafarers' identity document (ILO, 2003). The Framework of Standards to Secure and Facilitate Global Trade (SAFE Framework), a program developed by World Customs Organization (WCO) based on the contractual relationship between Customs and supply chain participants, aims to enhance the facilitation and security of international trade (WCO, 2007).

The second set of maritime security initiatives has been introduced at the national and regional levels. It includes states' national regulation, as well as programs, rules or agreements developed by unions of countries. The set represents a mix of mandatory regulations and voluntary programs, each of those should be consistent with international legislation. The most significant documents of the second set have been introduced in the United States (US), the European Union (EU) and Asia-Pacific Economic Cooperation (APEC) Region. After the terrorist attack in September 2001, US government started a very aggressive policy for protection of the national security. Since that time a lot of new security regulations have been developed and implemented in different areas of security, and, *inter alia*, in maritime security. One of the substantial US

introductions is the Container Security Initiative (CSI) (CPB, 2002). CSI is a series of bilateral agreement between the US and foreign-trade country partners, aiming to identify high-risk US-bound containers in foreign ports before loading, using X-ray and gamma-ray technology. The Secure Freight Initiative (SFI) is a part of US layered approach to cargo security, and based on partnership with foreign governments, container terminal operators, and shipping companies about technologies of container scanning (DHS & DoE, 2006). The Presentation of Vessel Cargo Declaration to Customs before Cargo is Laden Abroad Vessel at Foreign Port for Transport to the United States (AMR) is a complementation to CSI, compulsory applicable to all US-bound cargo (DoT, 2002). Import Security Filing and Additional Carrier Requirements (10+2 Rule) is another cargo security initiative of the US that requires all carriers to submit additional information about the cargo to the US Customs before entering the US port (CBP, 2009). Additionally, Advance Notice of Arrival (ANOA) is a mandatory US requirement, aiming to select high risk ships before their arrival to US port (DHS, 2003). In addition, the Custom-Trade Partnership against Terrorism (C-TPAT) is a voluntary agreement between US Customs and businesses involved into shipping of goods to US and was launched in 2001 (CBP, 2001). Similar to WCO Framework of Standards, C-TPAT contains the requirements for businesses willing to enter into contracting relationship with US Customs and enjoy offered benefits. Although the participation in C-TPAT is not compulsory for port operators and shipping companies, some authors believe that “the security recommendations will eventually become the actual requirements” (Banomyong, 2005).

Simultaneously with the US attempts to enhance transport security, the EU also increased its activity in developing new regulations and voluntary programs. In 2004, the EU introduced Regulation on enhancing Ship and Port Facility Security (EU, 2004) that transports into EC law a mandatory part A of the ISPS code and Chapter XI-2, and make some paragraphs of Part B compulsory for Member States. It also widens a list of ships and port facilities, to which the regulation applies, by adding domestic shipping operators and port facilities serving them. As a part of WCO SAFE Framework of Standards, the European Commission developed a set of measures to accelerate the implementation of security related requirements, including the Authorised Economic Operators program (EU, 2007). Besides, the EU Advance Cargo Security Rules (EU 24HR) requires carriers to submit the cargo relating information to port authorities of contracting states before loading in foreign ports or before arrival (EU, 2011). Similar rules exist in China, Canada and Mexico regulations. Besides, the second set also includes the Secure Trade in the APEC Region (STAR) Initiative that aims to enhance security and efficiency in the APEC region’s seaport, airports and other access points (APEC, 2002). Moreover, similar to WCO Framework and C-TPAT, some countries have introduced security programs based on voluntary partnership with the private sector. Among them are Singapore Customs Secure Trade Partnership (STP) Program (Singapore Customs, 2011), Partners in Protection (PIP) in Canada (CBSA, 1994), StairSec in Sweden, New Zealand Secure Export Partnership (Customs Service, 2003), and others.

Some voluntary initiatives, developed by industry players, form a third set of maritime security regulations. Among them is the Smart and Secure Tradelanes (SST) Initiative developed in 2002 by Strategic Council on Security Technology (SCST, 2002) in that the world’s three largest port operators – Hutchison Port Holdings (HPH), P&O Ports and Port of Singapore Authority (PSA) Corporation – cooperate to implement automated tracking detection and security technology for containers bounding for US ports. Moreover, the ISO’s “Specification for Security Management System for the Supply Chain” was developed as guidance for organizations to manage security and implement necessary security measures in the effective manner (ISO, 2007). Similarly, the International Business Anti-Smuggling Coalition (BASC) Standards have been developed by World BASC Organization and serve as a guideline for the implementation of security measures (BASC, 2002).

Regulations from the three sets as listed above can also be classified into mandatory and voluntary nature. Mandatory regulations contain compulsory requirements in terms of implementation. These requirements may be compulsory for all members of shipping industry, regardless of area of their operation, or only for those, operating in a specific region or under specific conditions. Meanwhile, requirements of voluntary nature are not compulsory for implementation. However, as several authors believe, some of them may eventually become a minimum criteria for participating in international trade, as non-compliance often has a negative effect on business performance of shipping companies and ports (Altemöller, 2011; Banomyong, 2005; Gutierrez & Hintsa, 2006; Metaparti, 2010; Rice Jr & Spayd, 2005). Table 1 shows two groups of maritime

security regulations: regulations imposing compulsory security requirements and those containing voluntary recommendations.

2.1.2. Requirements

The regulations as reviewed above impose a long list of various security requirements on shipping companies and ports. However, it is observed that some of the requirements often repeat each other. Nowadays, one of the most discussed problems in the related literature is overlapping and inconsistency between the requirements imposed by different regulatory bodies (Bryant, 2009; Hintsa et al., 2009; Sarathy, 2006; Thibault, et al., 2006; Yang, 2010). Gould et al. (2010) believed that “one of the problems is that there is no single overarching framework for security programmes, and the industry faces overlapping protocols and regulations.” As an example, the ISPS Code requires vessels to submit ship security information prior to entering the port (Pallis, 2006). Similar requirements are found in the EU (Regulation No 725/2004), the US (ANOA) and Singapore regulations (DHS, 2003; EU, 2004; MPA). Besides, the requirement to submit cargo related information 24 hours before cargoes are loaded in foreign port is contained in regulations of different countries such as EU 24HR, US AMR, China 24HR, Canada 24HR, Mexico 24HR (CBSA, 2004; China Custom, 2008; DoT, 2002; EU, 2011; MCA, 2008). It can be argued that the discussed repetition and overlapping of security requirements can be a necessity in many cases, since international regulations are required to be made applicable within a country through enabling national legislations as well as some national regulations are only applicable to goods bound to the specific country. However, this overlapping brings additional problems to shippers and carriers, working with different countries of destinations. For example, Yang (2010) found that survey respondents often met the problem related to the extension of the 24HR to Canada and China: “the lack of uniformity among security initiatives and security transmission systems hinders transmission operations”; additionally, the extension of the rule “has created additional document data-input and cargo inspection costs for exporters and transporters”.

Moreover, majority of voluntary requirements are simultaneously found in different sources, such as WCO SAFE Framework of Standards, AEO Program, C-TPAT, STAR Initiatives, BASC, STP, and ISO Standards among others. This similarity between security requirements may benefit for shipping companies and ports, because compliance with one of the programs sometimes may be considered as a half-way to participation in another similar program since some of the requirements have been already implemented. However, Gutierrez & Hintsa (2006) believed that “it is not possible to say that a company that is certified by one program will have the requisites to be certified by another”. Even though some specific requirements from different sources are quite similar to each other, the documents and programs themselves are significantly different in the process and conditions of implementation, “...in their specific purposes, the instruments they use, as well as their means of implementation” (Altemöller, 2011). As argued by Gutierrez & Hintsa (2006), “while some provide a detailed list of security standards that must be implemented in order to become security compliant, others just mention the security conditions that should be achieved, leaving room for different interpretations on how to implement them”.

Table 1: Regulations of Maritime Security Containing Compulsory and Voluntary Requirements for Shipping Companies and Ports

Maritime security regulations		Regulations, containing compulsory requirements and requirements compulsory under specific conditions		Regulations containing voluntary requirements	
		For shipping companies	For ports	For shipping companies	For ports
Regulations imposing the requirements by levels	International	ISPS Code, Seafarers' Identity Documents (SID) Convention	ISPS Code	SAFE Framework of Standards	Code of Practice on Security in Port, SAFE Framework of Standards
	National and regional	AMR (<i>*for all cargo bound to US</i>), 10+2 Rule (<i>*for all cargo bound to US</i>), ANOA (<i>*for all cargo bound to US</i>), EU Regulation No 725/2004 on Enhancing Ship and Port Facility Security (<i>*all EU Member States</i>), EU 24HR (<i>*for all goods that are arrived to EU countries, Norway, Switzerland</i>), Canada 24HR (<i>*for cargo bound to Canada</i>), China 24HR (<i>*for cargo bound to China</i>), Mexico 24HR (<i>*for cargo bound to Mexico</i>)	CSI (<i>*traffic of cargo to US, agreement with US govt</i>), SFI (<i>*traffic of cargo to US, agreement with US govt</i>), EU Regulation No 725/2004 on Enhancing Ship and Port Facility Security (<i>*all EU Member States</i>),	C-TPAT, EU AEO, STAR initiatives, PIP, STP, StarSec, Secure Export Partnership	C-TPAT, EU AEO, STAR initiatives, PIP, STP, StarSec, Secure Export Partnership
	Industry			ISO Standards, BASC	SST, ISO Standards, BASC

*Note: * indicates conditions, if applicable.*

Abbreviations:

AEO, Authorized Economic Operator; AMR, Advance Manifest Rule; ANOA, Advance Notification of Arrival; BASC, Business Anti-Smuggling Coalition; CSI, Container Security Initiatives; C-TPAT, Custom-Trade Partnership against Terrorism; ISO, the International Organization of Standardization; ISPS, International Ship and Port Facility Security Code; PIP, Partners in Protection; SAFE, Secure and Facilitate Global Trade; SFI, Secure Freight Initiative; SST, Smart and Secure Tradelanes; STAR, Secure Trade in the APEC Region; STP, Singapore Customs Secure Trade Partnership; 24HR, 24 Hour Rule.

Thus, the question about the necessity of unification of the existing common standards and maritime regulations, partly by mutual recognition concept, is widely discussed in the literature (Aigner, 2010; Altemöller, 2011; Gould, et al., 2010; Ireland, 2011; Metaparti, 2010; Mikuriya, 2007; Pallis & Vaggelas, 2008; Stasinopoulos, 2003; Voort, et al., 2002). Widdowson and Holloway (2009) believe that “there is a strong demand for standardization, harmonization and mutual (cross-border) recognition.” The problem of overlapping of security regimes was also discussed in the paper of Grainger (2007), in that the author used the concept of “security spaghetti” to describe the existing situation. However, just a few studies have been conducted on the comparison of security requirements imposed by different regulations. For example, Gutierrez & Hintsä (2006) in their research combined security measures found in different voluntary supply chain security programs. Similarly, our paper provides a list of compulsory and voluntary security requirements for shipping companies and ports, most often met in different regulations.

Based on the review of regulatory documents and other related literature, it is concluded that there are ten most often met categories of security requirements, namely, Physical security, Access control, Personnel security, Cargo security, Security training and awareness, Information and documentation security, Cooperation with authorities, Security of business partners, Crisis management and incident recovery, and Security assessment, response and improvement. In this study, to simplify the understanding of the information, ten categories were combined into four: 1. security onboard the ship and/or in port facility, that includes physical security, access control and cargo security; 2. personnel related security combines personnel security and security training and awareness; 3. cooperation with authorities regarding security issues, solely represented by the category of Cooperation with authorities; and 4. security of overall company management, which includes information and documentation security, security of business partners, crisis management and incident recovery, and security assessment, response and improvement. Table 2 provides a list of compulsory and voluntary security requirements for shipping companies and ports organized into four categories.

2.2. *Implementation, effectiveness and perceived importance of maritime security requirement*

Table 2 provides a comprehensive list of compulsory and voluntary maritime security requirements for shipping companies and ports. However, it is possible that not all of them are practically implemented. One of the reasons is the lack of resources needed for the implementation of those requirements, another is the misunderstanding of their importance. Not many studies have been conducted to verify the implementation of maritime security requirements. Gutiérrez et al. (2007) investigated which security measures were commonly implemented by BASC member companies, as well as cost and effectiveness of their implementation. It was found that the most often implemented voluntary security measures refer to human resource management, and the most effective measures are those of facility management and information management. Moreover, the question about implementation and effectiveness of some security measures was also touched in studies of Voss et al. (2009), Gutiérrez et al. (2007) and Thai (2007). While Gutiérrez et al. (2007) studied effectiveness only with respect to security improvement, Voss et al. (2009) and Thai (2007) also looked at it in regard to some other organizational performance. Besides, there are some studies on the effectiveness of different security regulations, such as US CSI and C-TPAT, conducted by government bodies. They include different studies of the US Government Accountability Office (2008a, 2008b). These studies are important for studying the effectiveness of the whole specific regulation or initiative. However, they did not investigate the effectiveness of any single security measure composing the regulation.

Moreover, some authors believed that effectiveness of security requirements may vary in different cases, and approach to security management chosen by shipping companies and ports may result in different consequences (Gutiérrez, et al., 2007; Thai, 2007). This argument leads to another very important question on how to manage security effectively in shipping companies and ports, which is widely discussed in maritime related literature, however not touched in this study, because it is a wide topic that requires further research.

Table 2: Compulsory and Voluntary Maritime Security Requirements for Shipping Companies and Ports

Categories	Compulsory requirements		Voluntary requirements for shipping companies and ports, most often met in various voluntary security programmes
	For shipping companies	For ports	
Security onboard a ship and/or in port facility	<ul style="list-style-type: none"> - develop SSP; - install SSAS and AIS; - display SIN; - ensure routing checking of cargo (ISPS Code); 	<ul style="list-style-type: none"> - develop PFSP; - ensure routing checking of cargo (ISPS Code); - use NII and RD equipment to identify high-risk containers bound to US; - use optical scanning technology to identify high-risk containers (SFI). 	<ul style="list-style-type: none"> - CCTV, - access control; - identification of employees, visitors, vendors; - inspection of persons and packages; - written procedure for sealing of cargo; - strict procedure for inspection of full and empty containers; - constant control all cargo during shipping processes;
Personnel related security	<ul style="list-style-type: none"> - appoint CSO, SSO; - carry out training and drills (ISPS Code); - ensure SID is held by every seafarer (SID Convention); 	<ul style="list-style-type: none"> - appoint PFSO; - carry out training and drills (ISPS Code); 	<ul style="list-style-type: none"> - screening of current and prospected employees; - procedures for hiring, induction, retaining and termination of employees; - organizational roles and responsibilities; - awareness of the security management policy; - periodic training on crisis management;
Cooperation with authorities regarding security issues	<ul style="list-style-type: none"> - keep records of activities and CSR; - obtain ISSC; - assure necessary security level of ship (ISPS Code); - provide ship security information prior entering port (ISPS Code, EU Regulation No 725/2004, US ANOA, Singapore MPA); - submit cargo related information 24 hours before cargo loading (US AMR, EU 24HR, China 24HR, Canada 24HR, Mexico 24HR); - submit VSP and CSM prior arrival to US port (10+2 Rule); 	<ul style="list-style-type: none"> - keep records of activities; - assure necessary security level of port facility (ISPS Code); - share the information with US CBP; - work with deployed foreign officers in the ports (CSI); 	<ul style="list-style-type: none"> - continuing mutual exchange of information with authorities; - procedures for reporting to relevant authorities of any incidents;

Security of overall company management	- undertake SSA (ISPS Code);	- undertake PFSA (ISPS Code);	- security management documentation system; - procedures for controlling all documents, data and information; - mutual supply chain security policy with business partners; - procedures for screening and selection of business partners; - contingency plans; - analysis of causes of crisis; - BCP; - integrity and adequacy of the SMS; - audits and evaluation of compliance with appropriate legal requirements; - self-assessment procedures.
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Abbreviations:

AIS, Automatic Identification System; BCP, Business Continuity Plan; CBP, US Customs & Border Protection; CCTV, Closed-Circuit Television; CSO, Company Security Officer; CSR, Continuous Synopsis Record; CSM, Container Status Message; ISSC, International Ship Security Certificate; NNI, Non-Intrusive inspectional (equipment); PFSA, Port Facility Security Assessment; PFSO, Port Facility Security Officer; PFSP, Port Facility Security Plan; RD, Radiation Detection (equipment); SID, Seafarer' Identity Documents; SIN, Ship Identification Number; SMS, Security Management System; SSA, Ship Security Assessment; SSAS, Ship Security Alert System; SSO, Ship Security Officer; SSP, Ship Security Plan; VSP, Vessel Stow Plan.

Additionally, it is important to study the effectiveness of security requirements because the lack of knowledge on this topic and misunderstanding of their importance may lead to unwillingness of shipping companies and ports to implement these requirements (Altemöller, 2011; Thibault, et al., 2006; Voss, et al., 2009; Yang, 2010). Moreover, not many papers have focused on studying the importance of security measures as perceived by managers of shipping companies and ports. Some authors just occasionally mentioned the attitudes of the managers towards the importance of one or the other security requirement (Bichou & Gray, 2004; Thai, 2007, 2009; Urciuoli et al., 2010) without a thorough scientific evaluation. Additionally, the question of how the understanding of the importance of security requirements may affect their implementation in shipping companies and ports, has not been studied extensively in the contemporary literature. It is therefore important that this question be addressed further as it implies how security could be managed effectively and contributes to overall business performance of a port or a shipping company.

3. Research Methodology

3.1. The research questions

The review of related literature shows that not many studies have been conducted on the question regarding the implementation of maritime security requirements in shipping companies and ports, their perceived importance and effectiveness, as well as the connection between these issues. To fill this existing gaps this research aims to examine three research questions.

RQ1. What compulsory and voluntary security requirements are implemented by shipping companies and ports?

RQ2. Which of the compulsory and voluntary security requirements are considered as important by shipping companies and ports' managers?

RQ3. Which of the compulsory and voluntary security requirements are viewed as effective, in respect to security and other organizational performance, by shipping companies and ports' managers?

3.2. Method of data collection

Due to the exploratory nature of the research issues, the qualitative method is utilized in this study. The structured interview was applied as the method for data collection. This approach was chosen to make the interview process easier and more convenient for respondents. However, deviations during interviews were necessary to collect some clarifying information.

3.3. Sampling design

Due to the time constraint, three in-depth interviews were conducted. The interviewees were chosen among managers of shipping companies who are in charge of risk and security management such as company security officer, managers of safety and security departments, designated persons ashore etc. Their contact details were derived from existing Nanyang Technological University's databases. The interviewed companies can be considered as big and well-established, two of them operate tankers, and the third company operates containerships.

3.4. Design of research instruments

The interview questionnaire consists of two parts. The first part contains a series of close-ended and open-ended questions designed to elicit participants' views regarding the implementation of compulsory and voluntary maritime security requirements, their importance and effectiveness. The list of requirements was given to respondents during the interview. The second part is designed to solicit the classifying information regarding the interviewee's organization and designation.

4. Findings and Discussion

4.1. Implementation of security requirements

It was observed that interviewed organizations have implemented majority of the listed compulsory and voluntary requirements, with exclusions of those not applicable for the specific type of organization. For example, it was indicated by interviewees who are tanker operators that the following requirements are not applicable for their organizations: routing checking of cargo, submission of cargo related information 24 hours before cargo loading, submission of vessel stow plan and container status message, as well as written procedure for sealing of cargo and procedures for inspection of full and empty containers. Some of them appeared to be a participant of various voluntary partnership programs. It was commented that some voluntary requirements, such as access control, procedures for hiring of employees, screening of current and prospected employees, and some others, were implemented even before the organization's participation in the program. Therefore, the changes of security measures for the certification purposes were not very significant and did not require big investments. However, interviewees indicated that they had to manage some problems, connecting to the lack of common procedure when implementing different voluntary security programs. Although several programs have mutual recognitions with each other, majority of them require separate certification. This is illustrated in one of the interviewees' comment as follows:

The main thing with these programs is that too many programs are coming up and they all have sort of the same requirements... They are quite close, only elements change... We would like to see more mutual recognitions between programs – it's much easier.

Other interviewees consented that for their organizations a problem was that the implementation of security measures often depended on trading area, and that could pose the issue of the lack of unification of regulations while overlapping requirements exist. The US region was found the most troublesome in terms of restrictions and requirements. A typical comment by one of the interviewees is as follows:

We have to spend time and money to go to US ports... There are a lot of various procedures required for ship to do before going to US... And if we don't know them we're in big problems.

Therefore, all of the interviewees agreed upon the need for a common regulatory framework for all regions and countries. However, the opinion was expressed that "because of the political issue and opinions it's not possible to make [such] common framework."

According to the interviewees, only few compulsory requirements were not implemented. For example, one of the organizations did not conduct routing checking of cargo, but left this duty to other participants of the supply chain. This was explained by the good faith relationship between the organization and its business partners, as well as by strict procedures for choosing and assessment of business partners. Moreover, it was found that some of the interviewed organizations did not use SID. It was commented by some interviewees that their organizations used their own identification documents instead because of the convenience issue. Additionally, several voluntary requirements were found not implemented. For example, the security management systems (SMS) in interviewed organizations have been limited by development and assessment of SSPs: "we don't usually keep separate management system besides that implemented under SSP." Some of the interviewees included documents of compliance with voluntary programs in the organization's SMS. One of the interviewee also mentioned that they issued some additional documents, such as security circulars and broadcasts. However, none of the interviewed organizations implemented any common system for the management of security

Apart from the requirements from the list, interviewees identified other security measures implemented in their organizations, such as using tracking system, carrying armed guards on board, designing citadels and safe master points onboard a ship with secure control, navigation and communication systems, developing contingency plans for ships, and other anti-piracy measures such as using binocular vision devices, search lines, bubble wires, bullet-proof helmets, jackets and visors, etc. All of the respondents indicated that their organizations followed the recommendations of IMO Best Management Practice (BMP4) and, if necessary, IMO Guidance on the use of privately contracted armed security personnel on board ships. Moreover, one of

the interviewed organizations was conducting the research on development of independent tracking system, operating when the power on board the ship is cuts off.

4.2. Perceived importance of security requirements

Interviewees were asked to indicate their attitude towards the importance of implementation of specific security requirement for the purpose of enhancing security inside the organization and in the supply chain. It was observed that some of the compulsory requirements were not considered as important for security improvement. Among them were requirements to display SIN, use SID, install AIS, and keep records of activities and CSR. It was commented that these requirements were more important for compliance issue, rather than for enhancing of security, and they were implemented only because they are compulsory for implementation. Similarly, exchange of information with authorities was considered as important in terms of commercial and political issue, rather than security. Additionally, one of the interviewees did not consider screening of employees for security purposes as an important requirement. He believed that the probability of seafarers' involvement in terrorism activity was very low and commented as follow: "I haven't seen so far any person being terminated because of security purposes." All other requirements from the list were recognized as important by all interviewees. They pointed out the importance of SSA and security training and drills, as it was believed that these measures significantly increased vigilance and awareness.

4.3. Effectiveness of security requirements

For the issue of effectiveness, interviewees were asked to indicate whether they found a specific security requirement effective in respect to security and other organizational performance. Security and other organizational performance were studied separately, to find out what other observed impacts of the implementation of security requirements were, apart from security improvement. For security matter, it is worth mentioning that some of the interviewed organizations consider security only as anti-piracy and anti-terrorism measures. It could be explained by the type of organizations. For example, security incidents such as pilferage or smuggling are not frequently observed onboard tankers. Besides, the possibility of the piracy or terrorist attacks is so small that some organizations do not have any statistics. Because of these facts, some interviewees could not give clear answer for the question about security improvement. However, they provided their evaluation of security effectiveness based on the crisis and incident exercises, conducted in their organization, as well as on the general company security culture. Among measures which were not considered as effective for security improvement, interviewees identified the following requirements: to install SSAS, IAS, to display SIN, to keep records of activities and CSR, and to obtain ISSC. However, all respondents agreed that the mentioned requirements can be useful for other purposes, such as post incident investigation, customs clearance, and navigation. Other requirements from the list were considered as effective. However, respondents admitted that some of them did not enhance security inside the organization but could help to improve public security, and they were implemented mostly because of their mandatory nature.

For the matter of effectiveness with respect to other organizational performance, interviewees were asked to provide their opinion on positive and negative impacts of the implementation of security requirements. In general, respondents' opinion about this question was neutral. They could not clearly evaluate if the specific requirement were effective or had negative effects. However, some observations have been done. As mentioned earlier, some of the compulsory requirements, such as AIS, SIN, records of activities, were found effective for the purposes of navigation and post-incident investigation. Additionally, requirements such as clear identification of organizational roles and responsibilities, periodic self-assessment and training on crisis management, resulted in positive changes of organizational procedures and technologies. Interviewees perceived that periodic assessment, as well as training, drills and exercises helped their organizations to identify possible incident causes, whereas identification of responsibilities improved feedback and cooperation with employees. Additionally, one of the interviewees indicated that after analyzing causes of security incidents the organization usually introduced to their customers new technologies or procedures, for example, GPS tracking or high security seals. He commented: "Some customers are very serious about security, others are not so. We need to find a balance." Besides, it was found that the implementation of procedures for controlling all documents, data and information, as well as procedures for reporting to relevant

authorities of any incidents helped organizations to keep customer information confidential and consequently to improve customer satisfaction and company image.

Some of the requirements were found negatively effecting organizational performance. Interviewees indicated that the implementation of requirements of the ISPS Code resulted in extra work and fatigue of the crew, extra jobs for the shore-based staff, and problems for crew to go ashore. Besides, access control created a conflict between security and safety, when doors, closed for security purposes, contradicted safety regulations. Moreover, it was mentioned that SSAS initially brought some problems related to false activation, however after some time the number of false alerts decreased significantly. Finally, the implementation of compulsory requirements, as well as some voluntary ones such as the installation and maintenance of tracking equipment, design of citadels, and the implementation of other anti-piracy measures, requires money, time, information, and advance planning. However, interviewees considered these efforts as a necessity and commented that gradually they became an important part of the everyday organizational activities.

It is observed from the above that several of compulsory requirements were not considered as important and effective for security improvement and were implemented mostly because of their mandatory nature. Meanwhile, majority of voluntary requirements were implemented because the organizations found them important for security purposes. Another important observation is that similar organizations had very different opinions about the effectiveness or importance of the same requirements. This implies the various approaches to security management in different organizations. Some of the interviews believed that the results of security implementation would depend on the approach of implementation of requirements. One of them commented about SSP as follows:

This ISPS requirement is good, but depends on how you do it. If you do a lousy job, of course your plan is not so good, not robust in emergency...

Finally, it was observed that even if interviewed organizations initially had some difficulties when implementing security requirements, nowadays they can manage security in a more effective way. Implementation of security requirements have become a part of everyday activity of the organizations, where required security investments have been balanced by increased taxes and rates, employees and crew have become more habitual with their security duties and responsibilities, customers have become more concerned about the time for delivery of cargo before shipment. These examples support the opinion that effective security management may help shipping companies to achieve positive results, specifically, to reduce negative impacts of implementation of security requirements and achieve more benefits.

5. Academic and Managerial Implications

Firstly, it was observed that majority of compulsory requirements are implemented in the organizations, however not all of them are considered as important or effective for security improvement. Meanwhile, voluntary requirements are implemented only if they are found important or effective. This topic has been poorly studied and can be developed further in the future research. Moreover, these findings can be useful for regulatory bodies when considering changes in security related documents. Secondly, the difference in the interviewees' opinions about importance and effectiveness of some security requirements may be caused by the different approaches chosen for security management in the organizations. The above findings therefore re-affirm that further research should be conducted in the area of maritime security implementation and management. Additionally, this paper and other similar publications can help security managers to change their opinion about different requirements and, therefore, change security management approach in their organizations. Thirdly, as collateral results, this paper provides some proved impacts of implementation of security requirements on organizational performance of shipping companies, which can be used for future research on this topic. Finally, it provides a comprehensive list of compulsory and voluntary security requirements for shipping companies and ports, which is useful for both academic and managerial purposes.

6. Conclusion, Limitations and Future Research Directions

This study aims at investigating the implementation, importance and effectiveness of maritime security requirements in shipping organizations. For this purpose, the combination of different research methods was employed, utilizing the comprehensive literature review to derive a list of compulsory and voluntary security requirements for shipping companies and ports and validate them through several structured interviews with industry professionals. The findings show that majority of listed requirements were implemented in interviewed organizations. Several of the compulsory requirements were found not important or not effective for security improvement, however they were implemented because of their mandatory nature. Meanwhile, some of the voluntary requirements were not implemented if they were found unimportant or ineffective by the organizations. Moreover, some positive and negative impacts of the implementation of security requirements on organizational performance were identified. Several positive impacts were named, such as reduced number of security incidents, increased security awareness, changes in processes and technologies, improved feedback and cooperation with employees, improved customer satisfaction and company image. Negative impacts include extra work and fatigue of the crew, extra jobs, problems for crew to go ashore, conflict between safety and security, as well as extra money, time, information and need for advance planning. Finally, it was concluded that the results of the implementation of security requirements could depend on the approach to security management in organizations.

This study is significant in two ways. Firstly, it provides a comprehensive list of compulsory and voluntary maritime security requirement for shipping companies and ports, which has not been composed before. This list can be used for other research in the related area, as well as by industry professionals for security management and assessment purposes. Secondly, no studies have been conducted before on the investigation of implementation, importance and effectiveness of both compulsory and voluntary maritime security requirements. The research questions examined in this study are significant for future research on the effective management of maritime security in shipping and port organizations.

Nevertheless, some significant limitations exist. The reliability of obtained results is reduced mainly due to the small number of interviews conducted. Additionally, the obvious sample bias is that all three companies are big and well-established in the shipping industry. It means that obtained results cannot accurately reflect the view of the whole industry. However, the study's findings are sufficient to make some preliminary conclusions about the research topic and to infer that further research is necessary in the area of implementation, importance and effectiveness of maritime security measures. Therefore, in the future, more interviews and/or survey should be conducted with other shipping companies of small and medium size, port operators, as well as with shipping councils and professional bodies to obtain more accurate data that reflect the view of the industry.

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The Role of Ports in Supply Chain Disruption Management

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Abstract

The recent rise in a number of calamities and terrorist acts has brought much attention to the vulnerabilities of supply chains. Having passed through many hands that span continents and entities, the reliability and timeliness of freight delivery become increasingly difficult to be assessed. Particularly, at seaports which is an indispensable node in global supply chains and where complex sea and land interfaces come into play, the role of ports in maritime supply chain disruptions needs to be explored. The changing functions of ports and the current supply chain trends denote implications that when identified, will allow better development of mitigation strategies for ports. Despite the importance of this issue, most literature focuses on generic disruptions in the supply chain and those that addresses port-related disruptions do not provide a holistic view of risk management in ports. This research thus aims to fill the literature gap by describing guidelines for port management to operationalise by way of a management model constructed through a comprehensive review of previous research and real life cases and in-depth interviews with management from a port and a port user based in Singapore. The aim is to build a more resilient and sustainable port in the light of challenging evolvement of supply chain trends in the dynamic maritime climate. The management model encompasses three fundamental levels of the port, with strategic responses tailored for the institutional, management and operational levels. Implications to the operations and management of ports in the supply chain context are drawn and future research opportunities are discussed accordingly.

Keywords: supply chain disruption, management model, risk management, port management

1. Introduction

In global supply chains, seaports are critical nodes where value adding and logistics-related activities take place. However, as processes and operations in the ports increase in their complexities and range, the integration of ports into supply chain management creates a higher level of uncertainties for downstream planning, product movement as well as information exchange. For that reason, deficiencies in the ports are capable of developing into augmented unsought effects down supply chains. To make matters worse, supply chain trends and practices increase the likelihood of a disruption occurring and exacerbate the effects of disruptions (Handfield et al., 2007, Kleindorfer and Saad, 2005). The potentiality of ports to administer seamless services, operations and transfer of cargo is obviously very much aspired by port users.

The increasing assimilation and amalgamation of ports into supply chains (Pettit and Beresford, 2009) has amplified the potential of ports in supply chain disruptions. In 2011, the Great East Japan earthquake crippled Japanese north-eastern ports and has damaged port facilities, warehouses and factories in the port areas (Takahashi et al., 2011, Jolly, 2011). One of the supply chain entities affected is Sony which, in particular, subsequently reported a 10% decrease of sales on a year-on-year comparison partly due to the detrimental effects of the earthquake (Sony Global, 2011). On the same note, the West Coast port strike disrupted supply

chain activities belonging to almost half of the 1,500 respondents surveyed to assess the impact of the strike (Institute for Supply Management, 2002). While it is undeniable that not all disruptive events in the ports are capable of upsetting the rest of a supply chain as the existing supply chain network may be adequately competent to attenuate the disruptive impact propagated from the ports, the intention of preventing such a situation reduces frustration for parties whose cargo are lodged in the delays or in complete port closures, and also avoids chaos in the anticipation of thwarting of plans.

Since the introduction of containerization, the focus of research within the maritime industry revolved around improving internal operational efficiencies which does not reflect the actuality of port's integration with its peripherals. However, a handful of research studying the relationship and coordination of ports with its community (Notteboom, 2008, Van Der Horst and De Langen, 2008) is starting to appear. At the same time, elaborate research on general supply chain disruption strategies emerged only in recent years, while study on port disruption strategies concentrate on disruption causes discretely. These collectively epitomize the paucity of a port-wide holistic approach towards the management of port-related supply chain disruption (PSCD).

Hence, this paper seeks to address PSCD threats by way of a management model for minimizing port-related supply chain disruption potential of ports (PSCDM). The paper is presented as follows. The following section reviews literature examining port-related disruption management. The third section presents the methodology while the fourth discusses analysis and findings. The paper then concludes by suggesting implications of the PSCDM and indicating future research directions.

2. Managing Port-Related Disruptions in the Literature

2.1. Challenges in Ports

The evolutionary developments in port functions through three generations usually refer to changes in types of cargo received, port activities and members as well as degree of involvement of the port community (UNESCAP, 2002). The post containerization era witnessed marked progress in value-addedness and increasing integration into supply chains (Pettit and Beresford, 2009). With the growing importance of port hinterland, coordination and cooperation with other transport nodes create anticipated means of creating synergies (Notteboom, 2008). However, some dyadic players in a port supply chain have operational relationships but not contractual relationships and the degree of integration of the chain will be reduced due to the lack of contractual relationships between dyadic parties (Robinson, 2007). Besides, the lack of contractual relationship can also cause variabilities and uncertainties in the port supply chain system. As there already exist conflicts in the intermodal channels (Taylor and Jackson, 2000), the above problems reiterate the need for adopting holistic cooperation within the port and with its peripherals.

The more commonly discussed operational port risks are port accidents (Pinto and Talley, 2006, Darbra and Casal, 2004), port-equipment failures (Mennis et al., 2008, Gurning, 2011), mishandling of dangerous goods (Ellis, 2011), port congestion (Paul and Maloni, 2010), inadequacy of labour skills (Fabiano et al., 2010), hinterland inaccessibility (Gurning and Cahoon, 2009a), breach of security (Pinto and Talley, 2006, Word Port Source) and labour strikes (Blackhurst et al., 2005, Berle et al., 2011). On the other hand, human factors such as a lack of work experience and inadaptability to new skills and technologies contribute to port risks too (Fabiano et al., 2010). Similarly, factors constituting differences among individuals increases the challenges of communication (Horck, 2008). As such, conflicts in personnel and communication are risks of the port as well (Berle et al., 2011). It is difficult to study these risks separately as they can be interconnected, hence, the root cause of any port disruptions should be mitigated instead.

2.2. Mechanisms Addressing Port Disruptions

Practitioners and researchers in the port industry share an ardent aspiration of achieving seamless cargo flow to drive profitability and carve a competitive advantage. This trend is displayed through a profuse research in addressing port connectivity (Robinson, 2002, De Langen and Chouly, 2004, Notteboom, 2008), port efficiency (Estache et al., 2002, Tongzon, 2002, Mennis et al., 2008), port costs (Lirn et al., 2004), integration initiatives (Notteboom and Winkelmans, 2001, Bichou and Gray, 2004, Song and Panayides, 2008) and the

provision of value-added services (UNESCAP, 2002, Carbone and De Martino, 2003). Unfortunately, there have been scant research on port agility (Paixao and Marlow, 2003, Lun et al., 2010) and port's adaptability to market uncertainties (Marlow and Paixão, 2003), which would offer valuable insights in creating guidelines for increasing a port's resilience.

Research related to port disruptions are scattered with regards to the type of risks addressed and the implementation of the proposed measures. There are specific tools such as the multi-level alarm system for collisions within port waters suggested by Chin and Debnath (2009), vessel restoration model by rerouting vessels developed by Guerrero et al. (2008) for the event of US port closures and optimization models applied by Paul and Maloni (2010) to compare different scenarios and severities of disruptions that caused a redirection of vessels to other ports in a network. Other instances include markov chain used by Gurning and Cahoon (2009b) to evaluate wheat supply chain risks and disruption analysis network (DA_NET) applied by Wu et al. (2007) to show propagation of attributes while measuring the impact on the supply chain system. However, these predictive instruments do not provide protection from the port risks.

In addition, there are initiatives which ports can adopt to combat port disruptions. Participating in security initiatives such as the Customs-Trade Partnership Against Terrorism (C-PAT) prevents cargo from being subjected to additional scrutiny. In particular, the United States has been active in its initiatives to counter port security incidents. These range from establishing the US Department of Homeland Security (DHS), utilising radiation detectors in ports, implementating the US Maritime Transportation Security Act (MTSA) and the ISPS Code to revised port security plans which include having extra defense layers in preventing threats (Pinto and Talley, 2006). Other instances of initiatives designed to increase maritime security are CSI and the 24-hour rule (Bichou, 2011). There are also concepts conceived to move part of port functions inland to relieve port congestion. These involve using integrated centres for Transshipment, Storage, Collection and Distribution (TSCD) of freight (Konings, 1996), satellite terminals (Slack, 1999), port-centric logistics (Beresford et al., 2011) and inland ports (Rahimi et al., 2008, Notteboom, 2008). Nonetheless, there are yet to be suggestions explicating means of combining or executing these approaches through specific actions.

In general, contemporary research addressing port disruptions do not provide a full spectrum of remedies targeting aggregated port risks. Hence, the privation of holism in the advent of PSCD management demonstrates the need to address the following research questions:

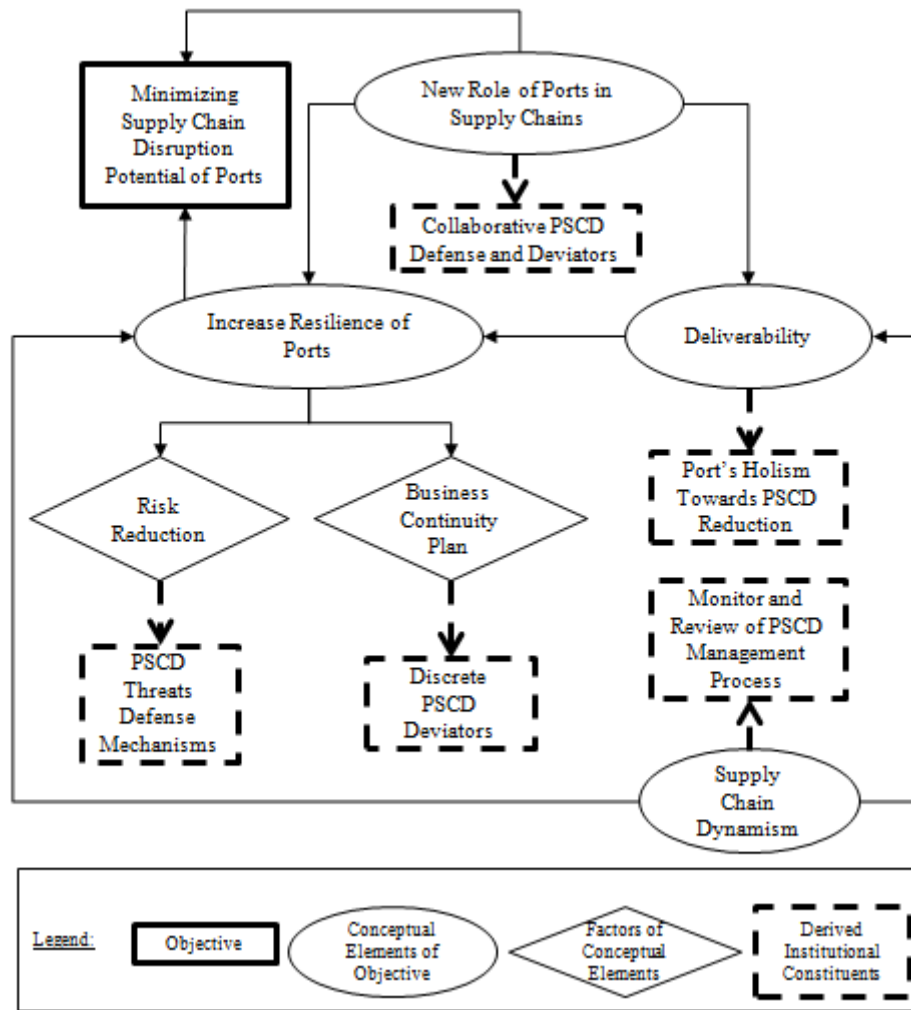
- a. What are the mechanisms which the port should initiate to minimize port-related supply chain disruptions?
- b. How should a holistic approach towards PSCD management be operationalised by the participants involved in port transport chains?

3. Methodology

3.1. Development of the Conceptual Framework

The previous literary work provides theoretical perspectives on tools and initiatives which can be synthesized and further operationalized into management guidelines for reducing the potential of PSCD of a port. Based on previous work, the increased presence of ports felt by supply chains generates larger impact of new deficiencies brought by the interface, drawing attention to the supply chain disruption potential of ports. Increasing the resilience of ports will directly minimize the supply chain disruption potential of ports. As ports are increasingly integrated into supply chains, the exigency for resilient ports is induced. Additionally, the variability in supply chain trends and market uncertainties propel the drive for resilience in the port and at the same time affect the performance of its resilience. The relationship between these factors is displayed in Figure 1.

Figure 1: The Conceptual Framework



Source: Authors

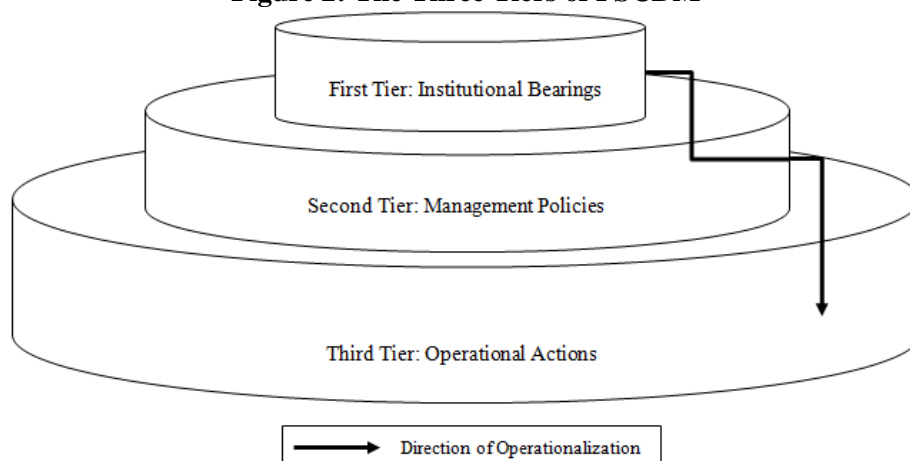
3.2. Derivation of PSCDM from the Conceptual Framework

In the management of disruptions, the objective is to increase resilience which refers to risk reduction and existence of business continuity measures (Christopher and Peck, 2004). In strengthening the resilience of ports, the first step is thus the implementation of protective measures against PSCD threats which are capable of resulting in possible supply chain disruptions. This is represented by ‘PSCD Threats Defense Mechanisms’ dotted box in Figure1. However, should disruptions inevitably occur, either due to ineffectiveness of existing preventive measures or amplifying effects of exogenous variability, a list of interception measures has to be executed in order to expedite the port’s recovery capabilities or deviate the intended consequential paths of the threats. Due to the increasing integration of ports into supply chains, collaborations with multiple parties in the port community to contain or prevent PSCD are as necessary as the action plans executed by ports alone. This explains the two dotted boxes namely, ‘Discrete PSCD Deviators’ and ‘Collaborative PSCD Defense and Deviators’. Nonetheless, the efficaciousness of the above measures requires the proposition from the management level and then acceptance and implementation at the operational level. Therefore, to ensure the deliverability of the action plans, the port’s holism approach is imperative. However, even with a sound disruption-proof layer of protective and mitigative mechanisms coupled with staunch support pledged across the port, the catapultic movement towards resilience can only be swiftly accomplished when the proposed measures remain relevant in the dynamism of the market. This is the reason why regular monitoring and reviewing of the management policies is important. In this manner, the PSCDM is arranged into five institutional constituents, as presented in Figure 1, consisting of *PSCD Threats Defense Mechanisms*, *Discrete PSCD Deviators*, *Collaborative PSCD Defense and Deviators*, *Port’s Holism Towards PSCD Reduction* and

Monitor and Review of PSCD Management Process. Section 4 describes the management model in more details.

To operationalize the above defined directives, the PSCDM is presented in three tiers: Institutional Bearings, Management Policies and Operational Actions, as shown in Figure 2. The highest echelon is the decision-making at the board and top management of the port and these strategic directions dictate management policies at the second tier, which accordingly requires the collaborative effort at port-wide level to attain the intended institutional directives. The epistemological essence of the management model is that awareness is created amongst top and middle-level management in policy making, while the lower-level management will be more acquainted with potential PSCD threats in their supervision of front-line employees in port operations.

Figure 2: The Three Tiers of PSCDM

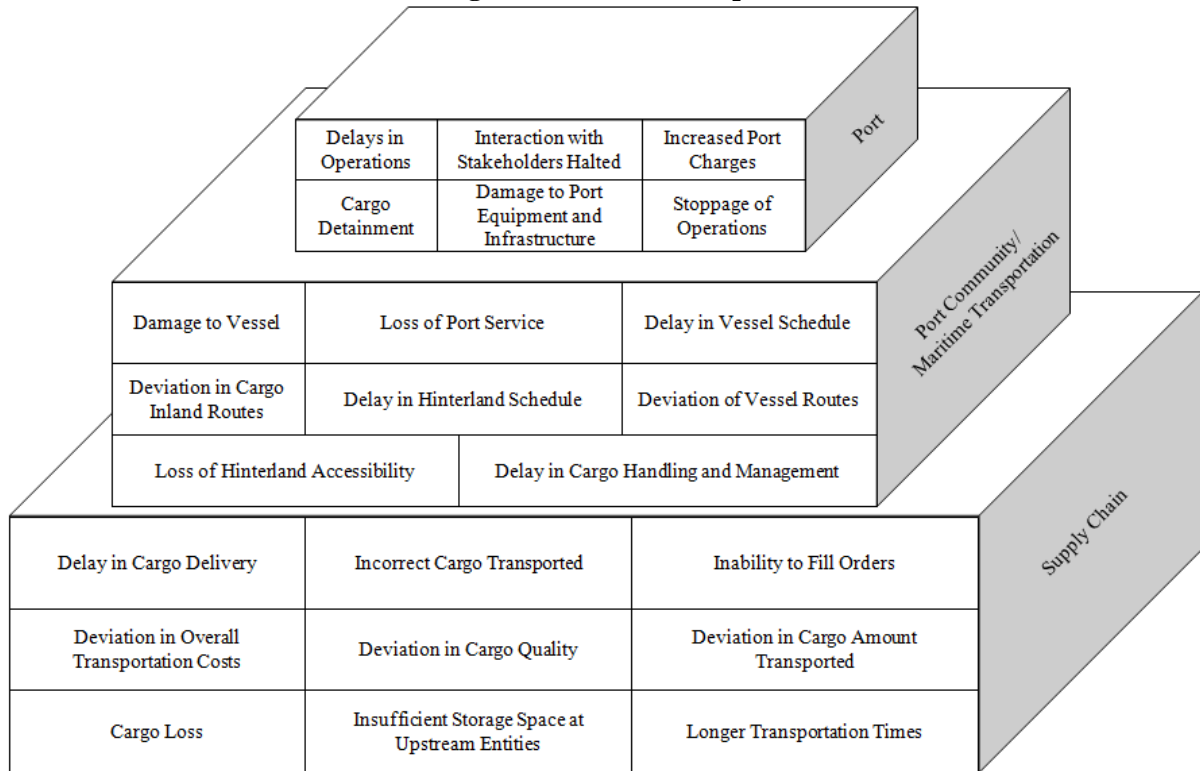


Source: Authors

The development of the operationalised actions involves the application of three theoretical approaches namely, Risk Management (RM), Business Continuity Management (BCM) and Quality Management (QM) at the Institutional Bearings. The three theoretical approaches are the fundamental driving factors that facilitates disruption management at the port. Risks should be reduced or eliminated through RM process. Alternatives and recovery plans have to be in place for emergencies and unavoidable risks and this is achievable through the BCM process. Finally, akin to Kleindorfer and Saad (2005) who applied total quality management (TQM) principles in their implementation of risk mitigating tasks, QM ensures that the port is able to maintain its delivery of services.

The PSCD consequences targeted by the PSCDM are shown in Figure 3. The list of PSCD consequences is developed through deduction from literature and logical inferences. According to literature, there has been no standard way of categorising the reported consequences and the consequences are typically grouped in the manner most relevant to the study. As this study is concerned with the propagating effects of PSCD threats, the PSCD consequences are divided into three levels, the port level, port community/maritime transportation level and the supply chain level. As shown in Figure 3, there are six PSCD consequences at the port level, eight at port community or maritime transportation level and nine at the supply chain level. Each level follows the principles of the four stages of disruptions with increasing severity – delay, deviation, stoppage and loss of service platform summarised by Gurning et al. (2011), wherever possible. In this manner, the classification of PSCD consequences in different levels expresses its range of disruptive effects. For instance, delays in operations at the port level would include delays in cargo loading and discharging and vessel berthing. This is different from the delay in cargo handling and management at the port community level as the latter refers to cargo transfer at inland corridor which takes place outside the port vicinity. Similarly, delay in cargo delivery at the supply chain level would mean that the downstream supply chain entities or end customers receive delayed shipments. In addition, the implied outcome of the PSCD consequences identified in this paper are loss of reputation, loss of profitability and loss of reliability of the port and/or supply chain entities.

Figure 3: PSCD Consequences



Source: Authors

3.3. Data Collection Technique and Administration of the Research Instrument

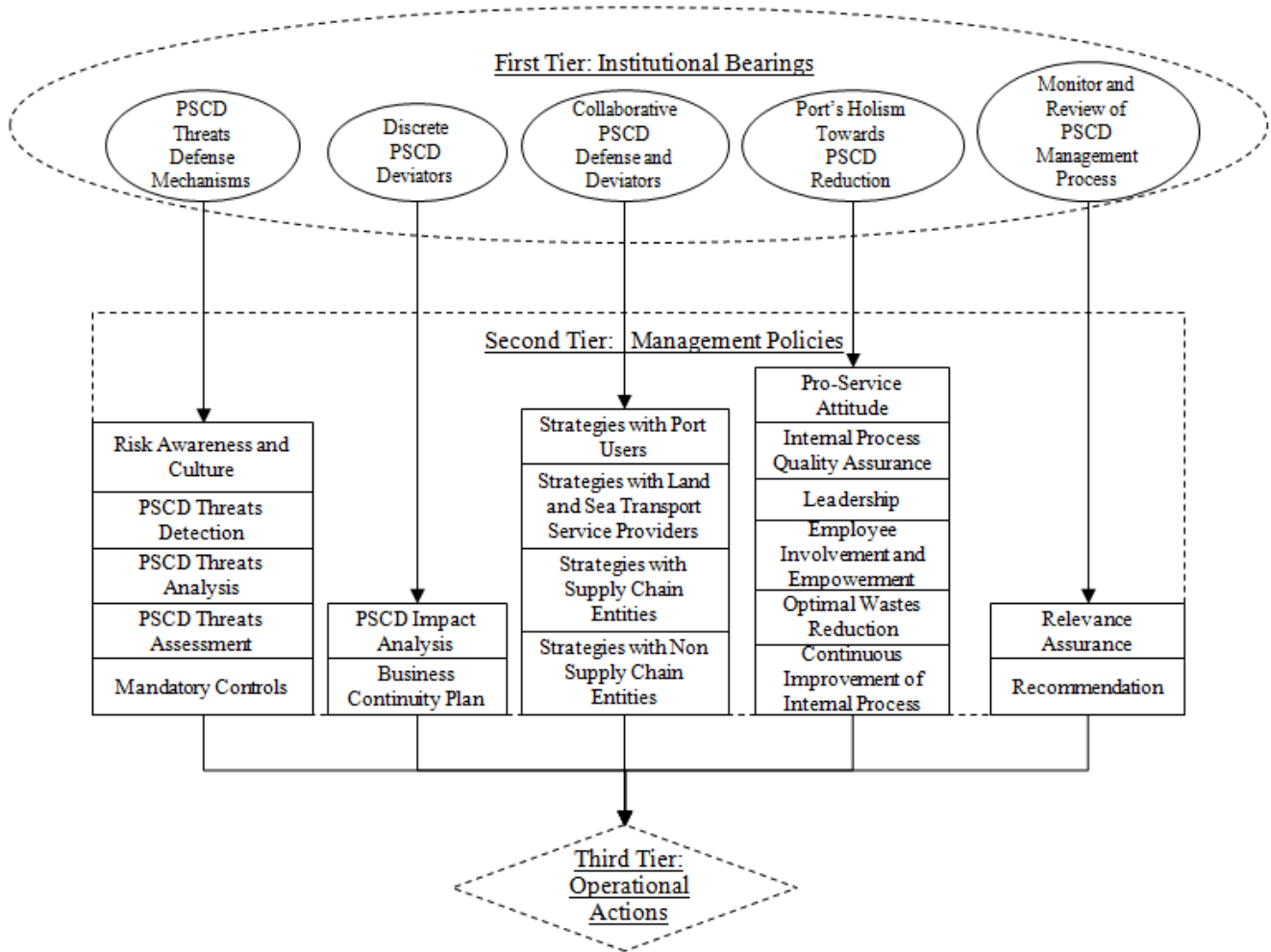
As this is the first stage of a more comprehensive research to be conducted at a later stage, in-depth face-to-face interviews were selected as the main method of data collection. For this research, the sample involved the management from a tanker company and a multi-purpose port based in Singapore. The interviewees were selected based on their designation, experience and the involvement in port operations of the organization they represent. The interviews were conducted at the interviewees' office and audio-recorded when the respondents permit. The main objective of the interviews was to obtain comprehensive insights through highlighting the research questions and the scope of the initial PSCDM in questionnaires designed separately for the port users and port operators. In particular, the initial first two tiers of the PSCDM were shown and explained to the interviewees. Changes were then made to the PSCDM to adapt the first two tiers to the interview responses and current practices at their organizations. After which, the operational actions at the third tier were developed. In summary, the final PSCDM has five institutional bearings at the first tier, 19 groups of management policies at the second and 75 operational actions at the third tier.

4. Analysis and Findings

4.1. Components of PSCDM

Following the results of the interviews, the revised PSCDM is established. Figure 4 provides an overview of all the components of each institutional constituent. Descriptions of the actions of the management policies are presented in the following subsections.

Figure 4: Components of the PSCDM



Source: Authors

4.2. PSCD Threats Defense Mechanisms

The interviewees were consonant in their views that ports contribute to supply chain disruptions and this affirms the applicability of the iterative risk management procedures in designing protective mechanisms for PSCD threats as these steps help identify PSCD threats through risk awareness and culture, provide an understanding of the PSCD threats by analyzing and assessing of the threats, and finally allow the port to administer preventive measures to reduce the likelihood or PSCD threats occurrences and to reduce the impact of undesirable consequences.

4.2.1. Risk Awareness and Culture

The effective management of PSCD threats is generated from intrinsic risk attitude which should be part of the port's culture (Joint Standards Australia/Standards New Zealand Committee OB-007, 2004b). To cultivate risk awareness and culture in the port, discussions about repercussions of changes in relevant regulatory, trade policies and business and political environments should be included during safety and risk assessment meetings and these safety meetings minutes should be circulated among management. During these meetings, tools such as SWOT analysis can be used for scanning of internal port environment and PESTLE analysis can be used for external port environment. The port can also send circulars or monthly publications documenting accidents or near-misses in own and other ports to port management. Checklists should be drawn up for port staff to adhere to, for instances, checklists regarding acceptable Personal Protection Equipment (PPE) requirements and permitted and prohibited activities within yard areas. Staff training on PSCD threats identification and risk management, attendance to risk awareness programs and risk induction sessions for

new employees will also raise awareness on potential PSCD threats that may lead to supply chain disruptions. Cognitive perception of PSCD threats will influence one's behaviour and responsiveness towards a potential PSCD threat and thus risk awareness has to be cultivated to facilitate the management of PSCD threats.

4.2.2. PSCD Threats Detection

Identifying the PSCD threats defines the scope of focus in managing them. This process will depend on the types of cargo handled in the port and the extent of development of the port. In general, PSCD threats can be identified by organizing safety and risk assessment meetings which stakeholders can attend to exchange perceptions and objectives so that external threats can be discovered; developing and re-visiting risk criteria for different functions of the port, stating clearly the acceptance level of each risk; establishing the acceptance level of each risk for different functions of the port; engaging in strict and frequent audits in all aspects of port operations; keeping record of incidents and near misses in own port which resulted in disruptions and use these as case of analysis when conducting risk induction sessions; launching programmed attacks on IT system to reveal loopholes after every upgrade; monitoring risk level at ports using PSCD indicators, which reflect performance and risks level of contracting parties and hinterland transport operators. After which, a list of PSCD threats will be compiled and subject to further analysis and assessment so that they can be classified for treatment.

4.2.3. PSCD Threats Analysis

An analysis of the PSCD threats provides an understanding of the threats in terms of their sources and consequences. The analysis can be carried out by performing 'What If' analysis on the identified threats and expressing the possible consequences, which are the effects of PSCD threats on port infrastructure, port operations and port communication systems, in monetary terms wherever possible. Moreover, the probability of the occurrences of PSCD threats has to be estimated based on past records, research, experiences and interviews with experts. These two steps will enable the mapping of risk matrix which is required for threat assessment process.

4.2.4. PSCD Threats Assessment

The assessment of PSCD threats aims to prioritize solutions for the threats based on the analysis results of the threats (Joint Standards Australia/Standards New Zealand Committee OB-007, 2004b). Therefore, the existing level of risk is to be compared with port's risk criteria and the threat magnitude is prioritized according to the threat's probability (P) and consequences (C) in the following manner: Low P-Low C, Low P-High C, High P-Low C and High P-High C. One interviewee mentioned a practical tool used his organization and it was the Enterprise Risk Management template in which objectives of threats assessment can be achieved. The above actions will reveal which PSCD threats require remedies and the appropriate preventive measures.

4.2.5. Mandatory Controls

Preventive measures will be designed for different categories of PSCD threats to manage them. For PSCD threats falling under High P-High C, the port should adopt risk avoidance measures. These can be restructuring port operations to eliminate High P-High C activities, allowing authorized personnel to enforce stop-work order once any High P-High C activities start to appear in the port, screening the background of potential staff, enforcing and adhering to mandatory security rules and regulations and inspecting port workers for full PPE, alcohol or drug consumption. On the other hand, for PSCD threats belonging to the Low P-High C category, the port should adopt risk transfer or risk sharing measures which include purchasing insurances and negotiating for acceptable dispute and risk management clauses in contracts to preserve the value of each agreement.

For all other PSCD threats, risk minimization measures should be adopted instead. One interviewee emphasized the role that technology plays in port safety and indicated that technology can be reflected from equipment like gantry cranes, stowage system and cargo distribution. As such, the minimization measures may be in the form of encrypting data transmitted through port servers; equipping warehouses with well-

maintained protective mechanisms such as installing fire doors, firewalls and sprinklers; implementing port facility access controls such as implementing biometric identification and verification of staff and truckers, RFID readers, RFID tags for port staff entrance to yard areas; equipping port areas with physical security mechanisms such as installing CCTVs and alarms, have layered security levels, station armed guards who can stop rowdy behaviour or other forms of violation in the port areas; adhering to port infrastructure's Maintenance and Repair Scheme; purchasing data leakage and loss technologies or software; screening integrated information system and internal servers for threats periodically. Additionally, the interviewees mentioned examples which are deemed as practical tools by them and these are investing in critical port infrastructure such as constructing sufficient suitable berths to accommodate vessels, improving port traffic control using Vessel Traffic Separation Scheme and developing better stowage systems. These tools can be explained by the fact that the interviewees were concerned with the availability of the port's main navigational channels and the berth scheduling of vessels, both of which require prudent selection of infrastructure investment.

Finally, for residual risks of all risks treatment and methods, the port should adopt risk retention measures. Possible approaches by doing so are investing in interchangeable parts or equipments or ensure that there are substitutes for key equipments and engaging in self insurance by setting up reserved funds which cover loss and compensation in times of crisis. The abovementioned measures seek to reduce risks in the port. However, business continuity plans should also be designed to expedite recovery process of the port, should unavoidable risks take place.

4.3. Discrete PSCD Deviators

Preventive measures alone are insufficient in reducing the potential of ports in supply chain disruptions. The development of continuity plans is imperative as affirmed by the interviewees. This will ensure a more comprehensive protection from PSCD threats.

4.3.1. PSCD Impact Analysis

An analysis of the PSCD impact will reveal the critical business functions, critical resource requirements and disruption scenarios (Joint Standards Australia/Standards New Zealand Committee OB-007, 2004a) which are preceding steps to business continuity plan. First, the port can map out value stream of port and perform workflow analysis to identify key operations and processes at the port. According to one interviewee, the key processes at container terminals are berthing, quay, yard and gate operations, while that at multi-purpose terminals are likely to further include general cargo operations, bulk cargo operations, warehousing operations and billing. For each key functions and processes, the port has to determine the minimum acceptable level of resources required. Based on historical records, interviews and surveys, the port then determines the length and severity of financial and operational impact resulted from each key functions and processes. The possible outcomes of PSCD disruptions are to be simulated and prioritized in monetary terms.

4.3.2. Business Continuity Plan

Quick decision making is expected during emergencies, hence a documented business continuity actions will be valuable. These actions shall intercept and deviate the paths of PSCD disruptions towards a less disruptive route. Based on results of risk matrix and business impact analysis, the port should establish specific emergency response plans for each department as well as for the port as a whole, documenting procedures to follow, resources to be mobilized, budget to be adhered to and the responsibility of each person involved. For instance, an interviewee indicated that there are resources planned to substitute the duties of key talents in his organization's disaster recovery plans. The response plans have to be executed in the form of drills to ensure concatenation between procedures and coherence between departments. The port can respond to all types of risks in the risk matrix by establishing early warning system or trigger points for the response plans to be activated. For instance, establish trigger points on Master Port Plans so that extra berths or other infrastructure can be developed early enough to accommodate throughput growth and support port's growth strategies. Once trigger points are hit, the port should mobilize previously appointed individual from response team for quick decision making and overlooking the response plans execution.

Throughout the execution of response plans, the port is required to maintain close contact with internal resources for troubleshooting. An interviewee stressed the importance of assigning authority to personnel for decision making and the organization's ability to extend resources to assist the situation. To do so, it is suggested that the port collate contact information of staff for communication of disruptions after business hours and keep a detailed record of procedure manuals. Responding to minimizable and retainable risks in the risk matrix, the port can activate redundant resources. For instance, substitute equipments, interchangeable parts, real time replicated servers and cross-trained staff should be utilized during disruptions. In order to respond to transferrable risks in the risk matrix, the port can enter into short term contracts with external truckers for peak periods or holidays, during which port's internal manpower tend to run low. This action has been suggested in response to a real-life PSCD brought up by an interviewee.

4.4. Collaborative PSCD Defense and Deviators

The increased embeddedness of ports in supply chains has increased the variety of port functions and value-added services. This change in the relationship between ports and their community requires higher communication and collaboration with external parties in order to bring about positive outcomes derived from the changing role of ports.

4.4.1. Strategies with Port Users

Port users are those who will feel immediate impact of PSCD threats. Even with proper contingency actions in place, for these actions to be enacted coherently, the port should organise joint practices or risk management exercises with port users by involving port users' participation in drills in which emergencies such as network system breakdown will require manual document process or submission by agents and shipping lines.

4.4.2. Strategies with Land and Sea Transport Service Providers

Ports, land and sea transport service providers are enmeshed in their operations. Collaborative actions with these parties should work towards increasing schedule and flexible throughput allocation certainty and the extent of assistance in times of crisis. As such, the port can form cartels among several inland ports, hinterland transport operators and port operators to prevent sudden unanticipated changes to demand at any one party and to create synergies in resources allocation. To increase the port's agility, the port can have agreements with multiple hinterland transport operators to use non-contracted throughput with one when the other defaults, develop alternative inland paths together with transport operators, and enter into bilateral contracts with regional ports on leasing of warehousing space, performance of value-added services, berthing space and connections to hinterland to ensure the delivery of contractual duties by the disrupted port as much as possible. The port is thus expected to establish a mechanism to maintain close contact with regional ports, inland ports and land transport operators for these collaborative response plans to be executed in time. The well-being of these service providers will in turn affect the port directly. One way to ensure this is for the port to enter into financial schemes with major hinterland transport operators which may be in the form of lower interest rate loans to major partners to prevent a default of service. Its purpose is to prevent financial woes which can affect the service providers' ability to transport cargo within and out of the port premise. In addition, the integral element of each operation boils down to the employees executing the job; industrial actions will definitely incite a series of operations stoppage and inventory buildup. One possible solution is for the port to enter into collective agreements with its hinterland transport service providers, especially the truckers and stevedores, on issues such as working conditions, working hours and mechanisms to resolve disputes so that industrial actions can be prevented.

4.4.3. Strategies with Supply Chain Entities

As networks of supply chain entities are enmeshed at the port premise, their operations are vulnerable to PSCD. However, damage can be reduced when a high level of responsiveness is displayed by these supply chain entities in terms of quick decision making and effective business continuity management. This will require real time communication with the port especially in the event of a PSCD. Thus, the port needs to establish a mechanism to maintain close contact with cargo owners and emergency response teams from

stevedoring companies and shipping lines in order to ensure the expedited movement of urgent cargo out of the port and also to ascertain the tolerance for delays of the remaining cargo.

4.4.4. Strategies with Non Supply Chain Entities

Influential non supply chain entities which can provide insights to potential PSCD threats are the government or port authorities. Thus, the port can collaborate with relevant government agencies to gain access to intelligence information, such that it has access to information on possible terrorist attacks or contraband. On the other hand, the port can also collaborate with R&D companies to pursue process innovations. Such collaborations should seek to invent smart communication tools and technologies as these will reduce communication costs with port community and also improve port operations and processes with newer and better technologies.

The port then has to ensure that all proposed measures receive support and commitment from organization-wide for the measures to be effectively executed. Hence, a holistic approach towards PSCD management is necessary.

4.5. Port's Holism Towards PSCD Reduction

Be it combating the likelihood of a PSCD threat occurrence or working towards increasing the recovery capability of the port, correspondence between different functions and commitment from across the port are requisites in fulfilling the objectives of the PSCD management. Based on the interview responses, profitability and costs are prominent considerations besides the potential of the role in supply chain disruptions. Thus, while ensuring the protective mechanisms and deviators are effectively implemented, the deliverables from the port must be equally, if not more, attainable as every business is profit-seeking.

4.5.1. Pro-service Attitude

As steering towards resilience and agility is a separate strategic direction from the conventional focus on performance-oriented management, this should not mean a change of course away from profitability, which is a product of customer-retention resulting from good organizational performance. As one interviewee has pointed out, ports are selling service ultimately, hence costs of port service should always be considered. This can be done by establishing the frontier by finding out the threshold of port users for costs and tolerance level for disruptions based on past lessons, complaints and feedback gathered from port users and keep port charges within the threshold. Connectivity is another main deliverability of port service. This can be achieved by establishing the port's own 'single point' electronic system, where port users and the foreland can conveniently share data important to them such as time of ship arrivals, berthing schedules, cargo location, cargo quality, real time updated time of cargo arrival and when cargo is ready for pick up.

4.5.2. Internal Process Quality Assurance

The quality of port service delivered is also intrinsically defined by that of internal processes. Quality assurance of internal process can be achieved through implementing operational-level agreements between departments to ensure timeliness in the execution of internal processes and to reduce conflicts. Another approach is through updating revised data and forecasts on shared system visible to all functions in the port, so that any changes can be communicated across departments and revised plans can be prepared by respective departments as soon as possible. The information to be shared should include changes in stowage plans, changes in yard space availability, changes in warehousing space and activities on berth allocation system. Higher connectivity and an integrated level of communication would mean the advancement towards better technologies. Hence skills, knowledge and technology proficiency upgrading of port staff should also be considered.

4.5.3. Leadership

Support of PSCD management policies needs to be explicitly reflected through leadership style as commitment is bidirectional (Coetzee, 2005). Methods for the port to do so include entering into a harmonious corporativism involving parties from the government, labour and employers which schemes addresses workers' welfare as well as port business concerns, involving elected representatives of staff from each function in disaster recovery planning and crisis management instead of finger-pointing, inviting front-line staff to voice their grievances at periodic redress meetings, appointing trained personnel in handling media queries and communication with next-of-kin when crisis occurs, allowing elected representatives from different functions to attend safety and functional meetings with management and communicating changes in policies or processes through small group meetings. These actions will help break down the management barrier.

4.5.4. Employee Involvement and Empowerment

Organization-wide commitment forms the requisite of effective implementation of an organization's objectives (Coetzee, 2005). Commitment can be developed through making the employees feel valued and respected. This can be done by encouraging constructive feedback by giving out rewards regularly for feedback on useful and practical process improvements, providing a portal for staff comments regarding process improvement on condition of anonymity, enforce compulsory participation in emergency and evacuation drills, holding discussions between tripartite parties and present findings before laying down rules, delegating authority to front-line individuals for quick actions to be undertaken to contain any undesirable impact as far as possible at the operational level and approaching staff from different functions and levels for opinions, through interviews, surveys and feedback sessions, before deciding on new policies or any major revamp.

4.5.5. Optimal Wastes Reduction

The absence of buffers exposes the port to greater vulnerabilities. Thus, wastes should be reduced optimally and this can be achieved through making Activity Based Costing compulsory for each expense group of disruption plans and encouraging the conservation of resources wherever possible by preventing previous expenditures affect subsequent budget approvals.

4.5.6. Continuous Improvement of Internal Process

A constant effort engaged by the port in improving port operations and processes shall increase the port's efficiency and effectiveness. The port can regularly conduct and re-evaluate workflow analysis to improve process efficiency and reduce costs, conduct cross-industry benchmarking about supply chain disruption potential and gather feedback from port users on areas to improve in and where port has excelled in through forums, surveys, or informal events. Alternatively, the port can learn from own or other's experiences by adopting and sharing post-disruption lessons learnt within port and shipping industry through exchanging information on forums and with members of associations.

4.6. Monitor and Review of PSCD Management Process

The maritime industry is dynamic and the market is constantly filled with changing business trends. Existing plans and policies need to be monitored to identify new challenges, and reviewed for new improvements.

4.6.1. Relevance Assurance

To ensure relevance to the dynamic market setting, even when equilibrium has been restored, the port needs to collect feedback periodically from port users to understand their changing needs and to ensure that the actual level of service is in line with the expected outcomes. Moreover, the port needs to review and revise risk management policies and plans or and replace servers as and when risk landscape changes.

4.6.2. Recommendation

The PSCD management and recovery process should be evaluated to identify lessons learnt such that future PSCD can be managed more effectively. An interviewee suggested that to do so, the port can carry out post-drills evaluation to ensure alignment of drill results with port's objectives and conduct post mortem analysis on PSCD disruption management after disruptive events to identify areas for improvement accordingly.

5. Implications of the PSCDM

The results of this research provide a comprehensive academic groundwork for defining the facilitative actions and activities which individuals at the three tiers of the port can partake of. This allows a more extensive analysis in the supply chain disruption management discipline as ports are capable of playing an effective role in containing or contributing to supply chain risks due to the increasing importance of ports in supply chain environments. Hence, this aspect of research warrants attention to avoid underestimation or overestimation of supply chain risks in other supply chain disruption management studies.

As resilience of a port constitutes its competitive advantage, this management model also assists port management in retaining its clients by ensuring the functionality of port operations and increasing the port's adaptability to disruptions such that cargo can be passed on successfully to subsequent supply chain entities within the stipulated time. Furthermore, with a holistic approach adopted by the port in managing PSCD, a proximate relationship is fostered with its community and this manifestation would likely generate greater synergies in cooperation of other aspects.

6. Conclusion and Future Research Possibilities

Due to the absence of formalised procedures for minimizing the port-related supply chain disruption risks, this paper has proposed and preliminarily validated a holistic management model addressing actions at the institutional, management and operational levels to fill the gap. Characteristics of resilience, supply chain market and current role of ports are studied in the synthesis of the PSCDM. The execution of the management model is a participative practice which incorporates inter-disciplinary knowledge and experiences. Besides the application of risk management and business continuity management, the PSCDM achieves its objectives through integrative administration of interorganizational relationship development and operational excellence principles. However, the liner market differs greatly from that of bulk and addressing them separately could provide more specific actions catered to a particular market. On the same note, the development degree of ports varies and thus the PSCDM will likely cause discrepancies of resulted outcomes when applied to different ports. A future research opportunity could be to quantitatively validate the actions through surveys. Moreover, the right actions alone are insufficient in containing disruptions. The right action at the right time would be necessary, hence trigger points or indicators in relation to PSCD threats have to be created in order to notify ports the point of time to execute these actions. Additionally, the actions to increase recovery capabilities of the port following a PSCD should also be defined to create an even more comprehensive coverage from the disruption.

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Environmental Efficiency of Ports: A DEA Approach

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Abstract

Numerous studies were conducted to analyze ports' productivity, efficiency and competitiveness based on commercial goods and services that ports produce. However, no empirical study has been yet undertaken regarding the environmental efficiency of ports since all previous studies have not considered undesirable outputs that ports generate, for instance, CO₂ emissions. To fill the gap in the literature, the objective of this study is to estimate environmental efficiency of ports. More specifically, this paper intends to analyze environmental efficiency of ports in Korea and to estimate the potential CO₂ emission reduction by port in the country. The main methodology is a Slacks-Based Measure Data Envelopment Analysis (SBM-DEA) model. Data were collected and estimated on labor, capital and energy used as major inputs of port sector and on cargo tonnage and vessel tonnage handled as desirable output and on CO₂ emissions as undesirable output. The SBM-DEA model could provide us with more comprehensive efficiency of combining economic performance and environmental performance and also capture slack values of input excess and undesirable output excess (CO₂) as well as desirable output shortage. Using the model and the data, it was found that Korean ports are deemed to be economically inefficient, but environmentally efficient when considering economic and environmental performances simultaneously.

Keywords: Environmental efficiency, ports, DEA

1. Introduction

Ports have been attempting to increase their competitiveness by enhancing their productivity, providing better quality services and reducing their costs. In addition, contemporary ports are required to operate their ports more environmentally friendly due to increasing awareness and concerns of their stakeholders arising from global warming and climate change issues. Therefore, more ports are investing in environmental facilities to respond to the needs and concerns of their stakeholders.

Numerous studies were conducted to analyse ports' productivity, efficiency and competitiveness based on commercial goods and services that ports produce. However, no empirical study has been yet undertaken regarding the environmental efficiency of ports since all previous studies have not considered undesirable outputs that ports generate, for instance, CO₂ emissions. Therefore, it is important to revisit ports efficiency from an environmental perspective. To fill the gap in the literature, the objective of this study is to estimate environmental efficiency of ports. More specifically, this paper intends to analyse environmental efficiency of ports in Korea and to estimate the potential CO₂ emissions reduction by port in the country. The main methodology is a Slacks-Based Measure Data Envelopment Analysis (SBM-DEA) model. A non-radial SBM-DEA developed by Tone (2001) and upgraded by Zhou et al. (2006) and Lozano and Gutiérrez (2011), incorporating undesirable outputs is employed. Data are collected and estimated on labour, capital and energy used as major inputs of port sector and on cargo tonnage and vessel tonnage handled as desirable output and on CO₂ emissions as undesirable output.

The paper is organized as follows. Section II deals with literature review. Section III explains the methodology of SBM-DEA model. Section IV describes the data used in the model, and the test results as well as their policy implications. Finally the paper is concluded suggesting avenue of future research.

2. Relevant Literature Review

Various approaches for measuring environmental efficiency have been attempted in the literature. The direct approach for measuring the environmental performance was pioneered by Pittman (1983), who extended Caves et al. (1982)'s study by incorporating undesirable outputs such as pollutants into a multilateral productivity index. The problem with Pittman's approach is measuring the price of pollutants, though he suggests using the shadow price of complying with environmental regulations. It is still difficult to measure the shadow price of undesirable outputs (Zhou et al., 2007). Another line of approach, which has become dominant in this area, is using Data Envelopment Analysis (DEA).

Charnes et al. (1978) first proposed the original Constant Return to Scale Data Envelopment Analysis (CCR-DEA). Later, Banker et al. (1984) extended it to the Variable Return to Scale DEA (BCC-DEA) model. The DEA is used to identify the best practice within the set of comparable decision-making units (DMUs) and form an efficient frontier. The CCR model is appropriately referred to as providing a radial projection. Specifically, each input is reduced by the same proportionality (Cook and Seiford, 2009). The DEA model has been gaining great popularity in various industry sectors such as in the energy field (Hu and Wang, 2006; Hu and Kao, 2007); banks or financial institutions (Lin et al., 2009; Staub et al., 2010) and logistics (Curi et al., 2011; Joo et al., 2010; Lin and Hong, 2006; Merkert and Hensher, 2011; Tongzon, 2001). The progress in DEA in the past thirty years is well reviewed by Cook and Seiford (2009). It is noteworthy that DEA with its environmental consideration is gaining popularity in other sectors than logistics and port sectors due to the rapidly-increasing awareness of environmental concerns. The main reason for the DEA's popularity in environmental efficiency is that it can provide a synthetic energy performance index with multiple inputs and outputs. More recent approaches in handling undesirable outputs for the DEA framework are the slacks-based measurement model (Cook and Seiford, 2009; Hu and Wang, 2006; Lozano and Gutiérrez, 2011; Tone, 2001; Zhou et al., 2006).

The slack-based measure (SBM) was first introduced by Tone (2001) through theory and methodology. In contrast to the CCR and BCC measures, which are based on the proportional reduction (enlargement) of input (output), SBM deals directly with input excess and output shortfall of the DMU, called slacks. The SBM projects the DMU to the furthest point on the efficient frontier, in the sense that the objective function is to be minimized by finding the maximum slacks (Tone, 2001). Therefore, it is in principle a non-radial model. As Tone (2001) claimed, it is "units invariant and monotone decreasing with respect to input excess and output shortfall." Non-radial efficiency measures were preferably used by Zhou et al. (2006) and Hernández-Sancho et al. (2011). Using the slack-based non-radial DEA model, Zhou et al. (2006) shows that it has higher discriminatory power compared to the traditional DEA model. In the non-radial approach, inputs and outputs are not impelled to improve uniformly (Lozano and Gutiérrez, 2011). The efficiency indicator for each variable in the process can be identified in order to increase the efficiency of the DMU being studied.

Literature review in estimating environmental efficiency reveals that almost no studies exist except one conducted by Chin and Low (2010) in port sector. Even this study does not estimate the environmental efficiency based on ports' own input factors and output variable within ports' territory, but attempts to estimate the efficiency based on inter-port routes. Thus current study attempts to fill the gap in the port literature.

3. Methodology: Slacks-Based Measure DEA

Our DEA frameworks build on the slacks-based measure (SBM) developed by Tone (2001) and upgraded by Zhou et al. (2006) and Lozano and Gutiérrez (2011), by extending the model through incorporating undesirable outputs in the objective function and the constraint function.

We assume that producing more outputs relative to less input resources is a criterion for efficiency. In the presence of undesirable outputs, technologies with more good (desirable) outputs and less bad (undesirable) outputs relative to less input resources should be recognized as efficient. Suppose that there are n regions and that each has three factors—inputs, good outputs, and carbon emissions—which are respectively denoted by

three vectors - $X \in \mathbb{R}^m$, $Y \in \mathbb{R}^{s1}$ and $C \in \mathbb{R}^{s2}$. Define the matrices Y , C , and X as $Y=[y_{ij}]=[y_1, \dots, y_n] \in \mathbb{R}^{s1 \times n}$, $C=[c_{ij}]=[c_1, \dots, c_n] \in \mathbb{R}^{s2 \times n}$ and $X=[x_{ij}]=[x_1, \dots, x_n] \in \mathbb{R}^{m \times n}$. The production possibility set (PPS) can be described as follows:

$$P(x) = \{(y, c) \mid x \text{ produce } (y, c), x \geq X\lambda, y \leq Y\lambda, c \geq C\lambda, \lambda \geq 0\} \quad (1)$$

where λ is the non-negative intensity vector, indicating that the above definition corresponds to the constant returns to scale (CRS) situation.

Using Tone (2001)'s SBM model and adding undesirable outputs into both the objective function and a separate constraint function, the undesirable outputs SBM-DEA model can be measured as follows:

$$\rho_0^* = \min \frac{1 - \frac{1}{m} \sum_{i=1}^m \frac{s_{i0}^-}{x_{i0}}}{1 + \frac{1}{s_1 + s_2} \left(\sum_{r=1}^{s_1} \frac{s_{r0}^y}{y_{r0}} + \sum_{r=1}^{s_2} \frac{s_{r0}^c}{c_{r0}} \right)}$$

S.T.

$$x_0 = X\lambda + s_0^- \quad (2)$$

$$y_0 = Y\lambda - s_0^y$$

$$c_0 = C\lambda + s_0^c$$

$$s_0^- \geq 0, s_0^y \geq 0, s_0^c \geq 0, \lambda \geq 0$$

The vector s_0^y denotes the shortage of good outputs, whereas vectors s_0^- and s_0^c correspond to excesses of inputs and CO₂ outputs, respectively. The subscript 0 means a DMU whose efficiency is being estimated. The DMU is efficient in the presence of undesirable outputs if $\rho^*=1$, indicating that all the slack variables are 0, ($s^- = 0, s^y = 0, s^c = 0$) but the Model (2) is not a linear function. Using the transformation suggested by Tone (2001) and also adding undesirable outputs into both the objective function and a separate constraint function, we can establish an equivalent linear programming for t, φ, S^-, S^c and S^y as follows:

$$r_0^* = \min t - \frac{1}{m} \sum_{i=1}^m \frac{s_{i0}^-}{x_{i0}}$$

$$1 = t + 1 + \frac{1}{s_1 + s_2} \left(\sum_{r=1}^{s_1} \frac{s_{r0}^y}{y_{r0}} + \sum_{r=1}^{s_2} \frac{s_{r0}^c}{c_{r0}} \right)$$

S.T.

$$x_0 t = X\varphi + S_0^- \quad (3)$$

$$y_0 t = Y\varphi - S_0^y$$

$$c_0 t = C\varphi + S_0^c$$

$$S_0^- \geq 0, S_0^y \geq 0, S_0^c \geq 0, \varphi \geq 0, t > 0.$$

We can solve the optimal solution of linear programming Model (3) and let the solution be $(r^*, t^*, \varphi^*, S^{-*}, S^{y*}, S^{c*})$, where $\rho^* = r^*$, $\lambda^* = \frac{\varphi^*}{t^*}$, $s^{-*} = \frac{S^{-*}}{t^*}$, $s^{y*} = \frac{S^{y*}}{t^*}$, $s^{c*} = \frac{S^{c*}}{t^*}$ from Model (2). Model (3) can guarantee the solution of $(t^*, \varphi^*, S^-, S^c, S^y)$ with $t^* > 0$. A similar LP solution idea of solving undesirable SBM-DEA can be found in Zhou et al. (2006) and Lozano and Gutiérrez (2011).

4. Results and Discussions

4.1. Input and Output Variables

This study attempts to estimate environmental efficiency of Korean ports using the SBM-DEA model. For this purpose, the most recent available data was 2010's data in Korea in terms of relevant input and output variables used for the model. The decision-making unit (DMU) was individual seaport, which was involved in international trade in 2010. Input variables for the model were number of labour employed, length of quay (meter) and area of terminal (m²), energy consumed (Ton of Equivalent: TOE) in each port. The labour is a typical input factor for production function in theory and the data was collected from Korea Port Logistics Association (<http://www.kopla.or.kr>). The length of quay and area of terminal are often used as surrogate for capital factor in the literature (see Cullinane et al., 2002; Cullinane et al., 2005; Cullinane and Song, 2006; Cullinane and Wang, 2006; Cullinane et al., 2006) when data on capital costs are unavailable, which is also the Korean case. All the works done by Cullinane team used length of quay, area of terminal and number of cranes as the input variables, but did not use number of labour due to unavailability of the data. However, we use labour since we could collect the data, but exclude the number of handling equipment as the decision making unit (DMU) in this study is port not the container terminal which was DMU done by Cullinane team. Too many different types of handling equipment would be involved in the port level unlike more standardized container terminals if we include the handling equipment. Therefore, any arbitrary counting of the equipment and decision on including and excluding the equipment among various types across ports is more likely to lead to biased results. The data on quay length and area were collected from Statistical Yearbook of Korea Ministry of Land, Transport and Maritime Affairs (MLTM). The energy consumption at each port was calculated as follows. First, energy consumption at each port was collected from a report by (MLTM, 2008). This report estimated three types of energy consumption at each port, namely electricity, diesel oil and LNG. From this data, energy consumption of each port was converted into Ton Oil Equivalent (TOE) unit using the conversion ratio of the International Energy Agency between various energy sources and their Ton Oil Equivalent units. For instance, when electricity is converted into TOE, one TOE is equal to 2,150 kcal/kWh/(10⁷kcal). Likewise, the one TOE for the diesel oil and LPG is 9,050kcal/liter/(10⁷kcal) and 15,000 kcal/Nm³/(10⁷kcal), respectively. The output variables for the model were vessel tons and cargo tons handled in each port as the desirable output and CO₂ emitted (tons) as the undesirable output. The total vessel tons and cargo tons were collected from the database of MLTM (www.spidc.go.kr), which is public goods. Finally, the CO₂ emission was taken from a report by (KMI, 2009). This report estimated the amount of CO₂ emission using the guideline of the International Maritime Organization. Excluding a few ports which do not provide the input and output data, the final sampled data consist of 23 seaports in Korea. Table 1 presents the input and output data collected in the sample. Table 2 shows the descriptive statistics of the input and output variables. The average labour was 777 people ranging between 15 and 5,606 people. The average values of quay length and terminal area were 8 km and 711,144 m², respectively. The energy consumption was averaged at 12,303 TOE with the maximum being 85,926 and minimum 5 TOE. As for the output variables, ports handled 131 million vessel tons and 49 million cargo tons on average whereas they emitted 84,976 tons of CO₂.

Table 1: Inputs and Outputs Data for 23 Ports of Korea, 2010

Ports	Labor (person)	Quay length (m)	Terminal area (m ²)	Energy consumption (TOE)	Vessel (1000 tons)	Cargo handled (1000 tons)	CO ₂ emission (tons)
Busan	5,606	40,213	2,578,154	73,168	936,418	262,070	502,824
Incheon	2,528	19,484	4,138,666	61,050	339,829	149,785	236,810
Pyeongtaek	1,097	9,807	1,993,588	85,926	210,213	76,681	146,407
Donghae	536	6,147	226,378	8,354	44,161	28,030	57,967
Samcheok	49	2,164	35,713	1,764	7,808	6,201	12,016
Sokcho	15	3,314	22,300	11	2,001	75	241
Okgye	55	874	54,963	1,027	9,123	6,973	13,138
Daesan	293	896	53,577	536	104,006	66,122	77,399
Kunsan	396	6,673	1,077,557	2,000	90,066	19,262	48,037
Janghang	56	330	41,535	19	1,876	1,218	1,780

Mokpo	641	8,893	433,790	1,486	70,409	16,389	38,673
Wando	101	2,661	28,450	45	1,366	630	1,165
Yeosu	154	6,837	58,756	541	86,488	9,828	9,313
Gwangyang	1,640	19,931	2,077,302	30,525	482,240	206,691	345,172
Pohang	1,728	14,250	1,236,412	5,341	107,855	63,108	142,516
Masan	565	8,792	795,067	1,778	76,434	14,104	30,904
Samcheonpo	242	4,888	128,812	1,466	15,181	11,715	22,311
Jinhae	98	2,389	137,000	302	8,592	859	1,775
Tongyeong	25	4,829	6,860	23	3,314	310	697
Gohyun	51	524	3,492	1,060	12,911	3,014	7,468
Ulsan	1,526	18,038	1,081,729	6,517	387,227	171,664	254,026
Jeju	418	3,096	90,405	33	16,212	19,998	3,177
Seogwipo	63	2,227	55,812	5	1,017	446	636

Table 2: Descriptive Statistics Of Input And Output Variables

Category	Variable	Unit	Mean	Max	Min	Std.dev
Input	Labor	person	777	5,606	15	1,277.8
	Quay length	m	8,142	40,213	330	9,092.7
	Terminal area	m ²	711,144	4,138,666	3,492	1,047,257.3
	Energy consumption	TOE	12,303	85,926	5	24,735.5
Desirable output	Vessel	1000Ton	131,076	936,418	1,017	216,251
	Cargo handled	1000Ton	48,573	262,070	75	73,791
Undesirable output	CO ₂ emission	Ton	84,976	502,824	241	129,099.3

4.2. Results and Discussions

Correlation was estimated between input and output variables to check whether there are significant relationships between them. Table 3 shows significant correlations between them, particularly very high one, mostly over 0.9 between labour and quay length variables, and the output variables.

Finally, the efficiency scores and potential CO₂ reduction amount at each port were calculated using the SBM-DEA model. Table 4 presents the results. Out of 23 ports in Korea, five ports are SBM-efficient when considering the inputs and desirable outputs as well as undesirable outputs. The average port efficiency is 0.364. The efficient ports are Sokcho on the east coast, Daesan on the west coast, Yeosu and Gohyun on the south coast and Juju in Juju Island off the Korean peninsular. Most of the inefficient ports show very low efficiency scores when using the SBM-DEA model. The highest efficiency score among the inefficient ports is only 0.37 in Ulsan port and the lowest one is 0.048 in Wando. In addition, Table 4 presents how much CO₂ emissions can be reduced in each port. It is noteworthy that only eight ports out of 23 ports show the excess CO₂ emissions in the last column and the average reduction amount is 4,621 tons of CO₂. The maximum CO₂ reduction can be realized in Pohang by 62,253 tons, followed by Donghae port with 25,104 tons and Samcheonpo with 8,597 tons. Despite that there are only five efficient ports and efficiency scores of the inefficient ports are mostly quite low, it is notable that there are only eight ports showing excessive CO₂ emissions and the other 15 ports not having reduction potential. This requires us to further look into slacks values of all the input and output variables. The results are presented in Table 5. Most of the ports in input and output variables in the table show slack values except in CO₂ and vessel tonnage variables.

Table 3: Correlation Matrix for Inputs and Outputs

	Labor	Quay length	Terminal area	Energy consumption	Vessel	Cargo handled	CO ₂ emission
Labor	1.000						
Quay length	0.966	1.000					
Terminal area	0.777	0.786	1.000				

Energy consumption	0.739	0.698	0.831	1.000			
Vessel	0.928	0.950	0.792	0.729	1.000		
Cargo handled	0.945	0.958	0.742	0.519	0.978	1.000	
CO ₂ emission	0.883	0.916	0.787	0.503	0.989	0.960	1.000

Table 4: Results of SBM-DEA Model

Ports	Efficiency Scores	Rank	Potential CO ₂ Reduction
Busan	0.306	7	0
Incheon	0.157	16	0
Pyeongtaek	0.192	13	0
Donghae	0.087	20	25104.08
Samcheok	0.153	18	4757.74
Sokcho	1	1	0
Okgye	0.167	15	4975.12
Daesan	1	1	0
Kunsan	0.250	10	0
Janghang	0.156	17	353.48
Mokpo	0.172	14	0
Wando	0.048	23	148.89
Yeosu	1	1	0
Gwangyang	0.294	8	0
Pohang	0.079	21	62253.41
Masan	0.205	12	0
Samcheonpo	0.077	22	8597.21
Jinhae	0.127	19	0
Tongyeong	0.289	9	0
Gohyun	1	1	0
Ulsan	0.370	6	0
Jeju	1	1	0
Seogwipo	0.248	11	93.61
Mean	0.364	N/A	4621.02

Table 5: Summary of Excess in Inputs and Shortage in Outputs

Ports	Excess of labor (person)	Excess of quay length (m)	Excess of terminal area (m ²)	Excess of Energy (TOE)	Excess of CO ₂ (tons)	Shortage of vessel (1000 tons)	Shortage of cargo (1000 tons)
Busan	3,286	10,673	2,045,713	68,009	0	0	174,094
Incheon	1,598	14,777	3,959,461	59,271	0	0	53,070
Pyeongtaek	522	6,886	1,882,714	84826	0	0	48,736
Donghae	411	5,767	203,629	8,126	25,104	0	46
Samcheok	21	2,080	30,689	1,714	4,758	1,946	0
Sokcho	0	0	0	0	0	0	0
Okgye	24	780	49,313	970	4,975	1,846	0
Daesan	0	0	0	0	0	0	0
Kunsan	174	3,796	102,6262	15,03	0	0	22,422
Janghang	50	313	40,548	9	353	41	0
Mokpo	465	6,768	393,979	1,100	0	0	17,116
Wando	97	2,649	27,746	38	149	0	238
Yeosu	0	0	0	0	0	0	0
Gwangyang	305	14,261	1,825	28,017	0	0	88,657
Pohang	1,424	13,321	1,180,853	4,785	62,253	0	5,461

Masan	392	5,259	748,992	1,340	0	0	13,181
Samcheonpo	191	4,729	119,319	1,371	8,597	3,247	0
Jinhae	81	1,804	131,382	250	0	0	815
Tongyeong	19	4,605	4,696	3	0	0	346
Gohyun	0	0	0	0	0	0	0
Ulsan	492	10,924	873,450	4,464	0	0	46,514
Jeju	0	0	0	0	0	0	0
Seogwipo	52	2,147	53,308	1	94	0	0
Mean	418	4,850	634,670	14,939	4,621	308	20,466

Combining both Tables 4 and 5, it is found that low ranking inefficient ports have extremely high slack values in input variables. The most inefficient port, Wando shows that it has over ninety percents of input excess values as well as shortage of almost forty percents in cargo tonnage. It is hard to justify why this port should be sustained economically compared with other ports. Other problematic ports are Jinhae and Samcheonpo as these two ports have so much waste in labour and capital while handling too insufficient vessels or cargoes. Similarly other low ranking ports such as Incheon, Donghae, Samcheok and Pohang show that they squander labour and capital resources and Incheon has shortage in cargo tonnage as well. In addition, the second best port among the inefficient ports, Busan shows excess values of 60%, 80% and 90% in labour, terminal area and energy consumption, respectively as well as shortage of 70% in cargo tonnage.

All these excess/shortage values in input and output variables suggest some implications in research direction and policy-formulation. First of all, the average excess values in labour and quay length are 54% and 60% of their mean input values. The average excess values in terminal area and energy consumption are even worse showing over 90 % of their mean input values. The excess of the input factors can be ascribed to two types of ports: the low-ranking inefficient ports and Busan port particularly in excess labour. Most of the low-ranking ports are owned and run by central government, MTLM, and the size is small except Incheon, which is governed by state-owned port authority and the size is big. The literature shows that inefficiency is often caused by size effect (Cullinane et al., 2002; Cullinane and Song, 2006) and port governance structure even though the governance structure shows mixed conclusion (Cullinane et al., 2005; Tongzon and Heng, 2005). The governance structure of Busan and Incheon was transformed from former pure public to public/private type (Cullinane et al., 2005) by establishing respective port authorities. Even after establishing the port authorities to achieve presumable privatized efficiency, the two ports had to maintain large number of dock workers due to labour union's monopoly supply system across the country. This implies that the Korean government should strive to continuously change the governance structure from pure public to more privatized ones while merging small sized ports into more competitive large ones at the same time. In addition, they should formulate more flexible labor supply policies to reduce the excess labour.

Second, the output variables of CO₂ emissions and vessel tons show slack values in a few ports whereas the cargo tons variable shows slacks in most of the ports. This implies that overall environmental efficiency of Korean ports is deemed to be rather high and sufficient number of vessels entered the ports, but cargoes were in shortage. The cargo shortage may have been caused by global recession in the world, which affected shipping industry in 2010, resulting in low load factor of the vessels. In other words, Korean ports seem to show inefficient economic performance, but relatively efficient environmental performance based on the SBM-DEA model. Färe et al. (1996) studied how environmental and economic efficiencies can be estimated separately using input distance function. However, their model is radial one since all the input factors have to be reduced equiproportionally to reach efficient frontier. The problems of radial models are well described by (Tone, 2001; Zhou et al., 2006; Zhou et al., 2007). In addition, existing SBM-DEA models only consider the undesirable variable in constraint function and do not directly treat them in the objective function as this study attempted.

Finally, one of the limitations of this research is data compatibility between energy consumption and CO₂ emission data sets since the former and the latter were estimated by different sources, therefore there can be a degree of divergence in capturing the environmental performances between them. However, the data set were the best available sources to our research team. When carbon footprinting data are available at each port in the

future, this problem can be overcome, thus this remains the avenue of further research. Other limitations can be using one year cross-sectional data rather than multi-years panel data, which can capture intertemporal changes of the efficiencies as well as using surrogate data for capital variables since the ports do not disclose the financial data. One can also argue that the DMU of port level can be difficult or inappropriate in estimating the efficiency since ports have varying characteristics, for instance, some ports handle only specialized cargoes, whereas others handle all kinds of cargoes like Incheon and Busan, therefore, heterogeneous among the ports. In order to address this issue, we need enough number of homogeneous subgroup samples, for instance container terminals, dry bulk terminals, liquid bulk terminals, which is not the case in Korea. Thus future research can be international samples by the different subgroup provided that all the input and output data are available.

5. Conclusion

There are plentiful studies on estimating port efficiency in the literature, but no studies have been conducted yet regarding environmental efficiency. This study attempted to contribute to the literature by estimating environmental efficiency of ports using SBM-DEA model. Our SBM-DEA model is explicitly handling the undesirable variable in both the objective function and constraint function, which was not attempted in extant SBM-DEA models. 23 Korean ports were sampled with regard to labor, quay length, terminal area and energy consumption as the input variables and cargo tonnage and vessel tonnage handled at the port as the desirable output variables and CO₂ emissions as the undesirable variable. The major findings are that the SBM-DEA model can provide us with more comprehensive efficiency of combining economic performance and environmental performance and also capture how much input excess and undesirable output excess (CO₂) should be reduced and how much output shortage should be increased for a concerned DMU to be efficient. Thus the SBM-DEA model is non-radial and non-input/output oriented. Using the model and the data, it was found that Korean ports are deemed to be economically inefficient, but environmentally efficient when considering economic and environmental performances simultaneously.

Some caveats should be taken in this study. Our research team had to use two different sources in collecting energy consumption and CO₂ emission data, therefore there can be a degree of divergence in capturing the environmental performances between them since Korean ports do not estimate their carbon footprinting yet and the two data sets were the best available ones. Other limitations are using only one year cross-sectional data rather than panel data, surrogate data for capital variables and making the DMU port level rather than more homogeneous cargo-specializing terminal level. All these remain the avenue for further researches.

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Exploring Factors Influencing Port Logistics in China

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Abstract

Globalisation and increased entry of nations into the World Trade Organisation have generally increased the international trade as well as the use of ports in the past few decades. The main objective of this study is to explore the factors influencing port logistics in China, a research gap in the literature. Semi-structured interviews were conducted with 40 key port stakeholders to extract and access the interviewees' knowledge, experience and personal perceptions to address the research objective. Thematic analysis was employed for the data analysis. The study has generated an enhanced understanding of the factors that influence port logistics in China such as: customs efficiency, government support, logistics demand, politics and culture. If taken into consideration, the important factors derived from this research could result in positive improvements for strategic planners of ports in China.

Keywords: factors, influence, China, port logistics

1. Introduction

Increased entry of nations into the World Trade Organisation has generally increased its international trade in the past few decades, although the recent economic recession has seen reduced growth. Ports are playing an important role in global industrial and logistics networks, being land areas with maritime and hinterland access that have developed into a logistics centre (Notteboom and Winkelmanns 2001). They handle 90% of world trade, not only delivering value to shippers and third-party logistics (3PL) service providers, but also capturing value for ports themselves. Ports are the core strategic resource to drive the regional economy on revenue and employment. Ports are important also because they are the access to maritime logistics which provides a cheap and high volume of transport for customers (Tseng et al. 2005).

Globalization has pushed western countries to outsource their manufacturing into China due to its cheap cost of labour and raw materials. China's semi-products and end products are distributed worldwide for final consumption. With the fast development of China economy boom, increasing demand of international trade between China and other countries has caused ports in China to be critically important. A large number of studies have thus been carried out on port logistics in China. However, few studies have explored and investigated factors influencing port logistics in China employing a qualitative approach. This paper attempts to fill this gap.

2. Literature Review

Ports are the locations where road, rail and waterways start and end for cargo consolidation and distribution. Long (2003) defines a port as the intersection of different modes of transport, while De Langen (2003) defines a port as a collection of a diverse set of economic activities. Seaports are hubs in worldwide transport to ensure interactions of domestic and international markets. They witness flows of goods and services between industries and consumers from different countries. Being pivotal places for sea/land transport interface, places where ships and cargoes are handled and services are provided, nodes of shipping networks and elements in value-driven chain systems, ports have become elements and links in a global logistics and value chain (Robinson 2002). As for logistics, the researchers adopt the most widely accepted definition by the US-based

Council of Supply Chain Management Professionals (CSCMP), which defines logistics as part of supply chain management (SCM), i.e.

“that part of the supply chain process that plans, implements, and controls the efficient, effective forward and reverse flow and storage of goods, services and related information from the point of origin to the point of consumption in order to meet customers’ requirement”(http://cscmp.org).

This definition represents a supply chain orientation and integrates material management and physical distribution, including flows of materials, information and services (Lambert et al. 1998).

The globalisation of production, whose key driver is multinational companies (MNCs), has been one of the main drivers for the change in port industry. The seeking for strong brand has helped the MNCs to focus on innovation and customers instead of ownership and management of many production sites. They reduce cost by outsourcing production to the low cost developing countries, whose goods are distributed worldwide via ports. Global sourcing thus acts as a major driver of world trade and has deeply affected transportation and distribution systems (Notteboom 2006). Consequently, global sourcing and world trade has promoted ports to develop their logistics, and port logistics refers to process that plans, implements and controls the efficient and effective flow of cargos, services and information at the port areas.

Many studies have been conducted on port logistics in China, some of which are focused on the development of port strategies. For example, Liu (2007) proposed a port logistics development strategy in the context of global port competition based on a case study of Yantai; Luo and Xie (2006) demonstrated the systematic structure of port logistics and put forward the strategy on port logistics operations. Li and Wang (2007) studied the modes of port development. Wang (2007) designed the strategy for Ningbo port logistics development. Cai (2004) researched on Qingdao port logistics development scheme and strategy. Xie (2007) investigated the development obstacles of Xiamen port logistics and suggest the strategy to cope with the obstacles.

Some studies are focused on individual factors influencing port logistics in China. For example, Zhao (2007) claimed that improving port facilities can promote port logistics. Zhuang (2008) analysed how the change of global logistics environment influences port logistics. Liu and Wang (2004) identified that regional economy, hinterland economy and free trade zone policy influence port logistics. However, few researches investigate various factors influencing port logistics in China in a single study, although these factors are interrelated with each other. Based on the above review, the research objective of exploring factors that influence port logistics in China is derived.

3. Methodology

3.1. Methods choice

Table 1 presents research methods used in research of port performance and choice, most researchers have adopted quantitative research by questionnaire survey or secondary data. Interviews and case studies have also been employed in port studies, but they are not so often used as questionnaires and secondary data. Some studies have been conducted on quantifying relationships between some selected factors and port logistics to evaluate the influencing degree of those factors on port logistics in China. For example, Wu and Huang (2008) chose some influencing factors with statistical data for grey relational analysis to find out the grey relational degree between factors and port logistics of Fujian Province. They identified that the problematic factors are related to industrial development and port infrastructures such as berth and navigation channels. Peng and Yang (2009) researched on the development of three main ports in Fujian based on the principle of Balanced Scorecard. They selected some evaluation indexes and analysed the subjective index employing fuzzy-AHP and evaluated the objective index employing PCA (Principal Component Analysis). However, all the studies did not explain how the indexes were derived to evaluate port logistics.

A research philosophy is central to the process of research in all areas (Saunders et al. 2009). It is a set of

basic beliefs that defines the nature of the world and the individual's place within it and guides action, and the interpretative paradigm is viewed as qualitative, inductive and subjectivist (Denzin and Lincoln 2000). Interpretivism is a strategy of social research concerned to interpret social phenomena in terms of meanings.

Empirical methods are receiving increasing attention due to the growing calls to incorporate real world data in order to improve the relevance of business research. Strauss and Corbin (1990) indicate that primarily the choice of research approaches depends on the nature of the research problem and research purposes. As there is no well-established theoretical framework for factors determining port logistics and little research has been conducted on the factors on this in China, this research has a clear exploratory purpose, i.e., to explore factors influencing port logistics in China, which merits an inductive and qualitative approach for gathering data (Neuman 2006; Sekaran and Bougie 2010). This implies that qualitative methods are appropriate when the topic needs to be explored, and the research questions, often beginning with "how" or "what", focus on describing what is happening in this area (Creswell 1998).

Table 1: Research Methods used in Port Research

Author	Methods used				Data
	Interview	Questionnaire	Case study	Secondary data	
Yeo et al. 2008		√			AHP, port stakeholders
Islam et al. 2006		√			Delphi, local experts
Lam and Yap 2008				√	analyse annual slot capacity
Wiegmans et al. 2008	√				12 deep-sea container operators
De Langen 2007	√		√		4 port regions with various clusters
Tongzon 2007		√			Survey with manufacturers
Comtois and Dong 2007				√	Hinterlands
Ng, 2006		√			global top 30 liners
Guy and Urli 2006			√		Montreal-New York Alternative
Song and Yeo 2004		√			surveys on a group of experts
Lirn et al. 2003 2004		√			Global top 20 shipping lines
Bookbinder and Tan 2003				√	European vs. Asian logistics
Mangan et al. 2002	√	√			Irish port/ferry choice in RoRo

In qualitative data collection, the interview is the most widely used research method (Fielding and Thomas 2001). In-depth interviews and group discussions are two of the most commonly used methods for interviews, and are used to obtain a first-person description of some specific domain of experience (Cope 2005).

Interviews are conducted to allow a free range of responses to emerge in the participants' own words and produce a rich source of data (Zoltan and Laszlo 2007). Being a conversation with a purpose (Marshall and Rossman 1999), the interview encourages respondents to become involved in active interactions and talk about the research subject, leading to negotiated, contextually based results (Fontana and Frey 1998). Hence, it is an extremely flexible research tool. Saunders et al. (2009) note that a principal way of conducting exploratory research is to interview "experts" in the subject. That is why interviews were used to explore port stakeholders' views on factors influencing port logistics.

Given the research objectives posed, structured interview was rejected as it cannot explore in-sight factors. Unstructured interview was also rejected because it is too open and free for the interviewees to deviate from the research objectives. Although group discussion has some benefits of cost and time advantage, and new idea generation (Crimp 1990), this, too, was excluded from this research, given the fact that interviewees might not be willing to talk freely within groups and it would be difficult for the researchers to arrange for a

group of people to meet together. The questions were designed to be as open-ended as possible in a careful and theorizing way to gain spontaneous information, as suggested by Feilding and Thomas (2001). In-depth interviews result in a free exchange of information and enable elicitation of rich and detailed data. Silverman (2000) argues that in-depth semi-structured interview has become common parlance, having the advantages and avoiding the disadvantages of both structured-interview and unstructured interview. The interviews were employed to extract and access the interviewees' knowledge, experience and personal perceptions to address the research objectives. Before the interview, a sample interview schedule was designed. Brief and clear questions were prepared to allow lengthy and more detailed descriptions from the respondents.

3.2. *Sampling procedure and sampling frame*

The ultimate purpose of sampling is to select members from a population so that a description of those members accurately describes the whole population from which they are drawn (Vaus 1996). The researchers made the samples sufficiently accurate, free from omissions and duplications and up to date, as advised by Saunders et al. (2009). In order to ensure that the selected samples were as representative as possible, a stratified random sampling technique was adopted, which gives a greater degree of representation and decreases the probable sampling error that would occur with a simple random sample of the same size (Vaus 1996).

The aim in selecting these broad categories of interviewees was to cover port stakeholders as comprehensively as possible. The target groups that were closely related to ports were identified on the basis of literature review (Murphy et al. 1992; Murphy and Daley 1994; Notteboom and Winkelmans 2001; and Bichou and Gray 2004), previous surveys, interviews and networking with professional and trade bodies. Specifically, the sampling frame of port stakeholders was categorised into five groups: consignors/consignees, port service providers (PSPs), port managers, carriers and other port stakeholders. The reason for collecting data from various groups is that each group of port stakeholders has a distinct interest and role in the global logistics pipeline (Murphy and Daley 1994). Empirical research is likely to benefit from different groups of stakeholders who have the experience and expertise to understand port logistics. The interviewees were selected on the basis of in-depth knowledge and expertise on ports. Three criteria were used for interviewee selection: job position, working experience in the port sector and involvement in port management. Experts in various high positions from five key port stakeholders were interviewed. Forty interviews were conducted from four port regions: Qingdao, Shanghai, Xiamen and Shenzhen (ten interviewees for each region), and the number of interviewees depended on the saturate data. These four regions are representative of ports in China as they represent different geographical locations, capacities and ownships. They are important ports of China in terms of cargo volume and container TEUs. The detailed profile of interviewees is given in Table 2.

Table 2: Profile of Interview Participants

Group	Consignors/Consignee	Port service	Shipping	Port	Others	Total
	8	8	8	8	8	40
Location	Qingdao	Shanghai	Xiamen	Shenzhen		Total
	10	10	10	10		40

3.3. *Data collection*

Four exploratory interviews were conducted with port stakeholders. The issues that arose during scoping interviews were discussed and amended to become the final interview questions. Prior to the interviews, the interviewees were contacted either by email or phone call or both. The interview questions were sent to interviewees if requested. All the interviews were conducted by the researchers to build rapport, uncover possible insights and achieve a standardized approach, in order to reduce or at least systemize any interviewer effect. Thus, the interviews improved the credibility of the research.

The primary focus of this research was to explore the factors influencing port logistics to gain valuable initial insights. In order to encourage interviewees to express their views openly and freely, interviews were conducted individually, either in the interviewee's company, or at a place agreed by the researchers and the

interviewees. Most interviews were at the interviewee's own office so they did not feel detached from their working environment.

The interviews began by encouraging interviewees to talk about their company and their job roles to make them feel at ease. This was followed by an introduction to the research and some background questions to create a friendly atmosphere for free communication. Then they were motivated to speak out their views about the questions the researchers were interested in by a semi-structured interview. Their perceptions were understood as factors influencing port logistics. During the interviews, the major questions covering the prepared list of themes were asked in the same way each time, but the order of questions varied depending on the flow of the conversation, as suggested by Saunders et al. (2009). Follow-up questions that might be helpful for obtaining further information were asked to explore some of the issues under discussion, or to explore emerging issues related to the research objectives. Most of the interviews lasted for 45-90 minutes. The interviews were recorded subject to the participant's permission. After each interview, data were transcribed as soon as possible to avoid unnecessary memory loss. Each interview transcript was reviewed, and the interview schedule was altered or amended based upon the issues arising in the previous interviews.

3.4. Data analysis

The researchers employed thematic analysis for the qualitative data, following Miles and Huberman (1994) who suggest a three-stage process of qualitative data analysis: data reduction, data display and conclusion drawing and verification. The whole process was manual and inductive. The researchers printed the full verbatim interview transcripts together and read them several times to familiarise themselves with the contents. The data were reduced in Stage 1 by selecting, focusing, simplifying, abstracting and transforming the data that appeared in transcripts. The reduction activities consisted of coding, writing summaries, and identifying themes and clusters. Data display (Stage 2) allowed data to be organised and condensed in a way that permitted conclusion drawing. The purpose was to reduce complex information into selective and simplified or easily understood configurations on the transcription. Additional manually extended text, matrices, graphs and charts on transcript or other blank paper helped the researchers with themes and patterns for further analysis and conclusions. The analysis proceeded in an iterative manner, simultaneously with data collection, interpretation, and narrative report writing. Stage 3 analysis was conclusion drawing and verification. In order to provide solid proof and valuable insights into the main issues investigated, the presentation was focused on maintaining the personal meanings expressed by the interviewees, and on locating these personal meanings within the different port contexts. The researchers did not draw conclusions until the data collection was over and verified as plausible and valid, because the researchers were aware that causes and effects might not be the same as the research progressed. The iterative process helped in gradually verifying, modifying and refining the research results until finally an explicit conclusion was reached and verified. Finally, a report of the qualitative data analysis was written based on findings.

4. Findings and Discussions

The presentation and discussion of findings were elicited from empirical evidence. The data collected are presented and elaborated to be related to the research objective. For discussion purposes, the interviewees' responses are classified into eleven categories in Table 3. Row 1 gives the factors influencing port logistics raised by the interviewees. Row 2 gives the number of interviewees and Row 3 presents the percentage of interviewees raising the respective factors. The various factors are described one by one below.

Table 3: Factors Influencing Port Logistics and Number of Interviewees

Location	Gov. support	Port infr.	Trans. Inf.	ICT serv.	Customs & border service	Service	Log. Demand	Cost	Sealink	Other factors
34	32	28	22	12	19	32	36	27	14	34
85%	80%	70%	55%	30%	47.5%	80%	90%	67.5	35%	85%

4.1 Geographical location

The interviewees commonly recognised the geographical location as a very important factor for ports to develop their logistics. They explained that Qingdao's location is important because it is located close to Korea and Japan; Shanghai's location is important as it is the out-mouth of the Yangtze River; Xiamen is important because it is opposite to Taiwan; Shenzhen is well located because it is just opposite to Hongkong which is the international transshipment hub. The importance of location can be exemplified by the quotes of Interviewee 5,

"The critical point for ports to development logistics is the location, location and location!"

Not only is the geographical location important but also its political location. For example, interviewees thought Xiamen's proximity to Taiwan, Hongkong and Macao grants Xiamen unique advantages in terms of political location. The geographical proximity, common language and customs, and ethnic relationships between Taiwan and Xiamen play an irreplaceable role in promoting cross-strait economic and trade cooperation and cultural exchanges to attract Taiwan investment. Politically, Xiamen is strategically positioned to promote the peaceful reunification of Taiwan with mainland China. Among the five special economic zones (Shenzhen, Zhuhai, Shantou, Xiamen, Hainan), Xiamen is the only zone to implement certain Freeport policies. Interviewee 28 said,

"Xiamen has a strong point to develop port logistics with a Haixi (West to the Taiwan Strait) frontier position. It has both political and economic meanings."

Twelve (30%) interviewees, however, considered that location was not critically important as the ports are naturally geographical resorts and cannot be improved. To their understanding, location is beyond the control of terminal operators and port managers.

Interviewees clarified that port regions benefited from a strategic geographical location that was conducive to their port logistics. This finding is consistent with the literature (Song and Yeo 2004; De Langen et al. 2007; Yeo et al. 2008; Tongzon 2009), and particularly supports Lirn et al. (2004) who found that three out of the top five transshipment port selection sub-criteria are location-related. However, the finding also supports Lirn et al. (2004) who note that port location is a factor beyond control.

4.2 Government support

All of the forty interviewees considered that government support is important to influence port logistics, as Interviewee 20 said,

"Government support is the most important thing in China to develop port logistics. It is definite that port cannot develop without government support..."

Firstly, government support to logistics is reflected in preferential policy on tax reduction or tax exemption. Eight interviewees noted that policy on port bonded zone would promote port logistics. This point was also emphasized by Interviewee 36,

"Our company is located in the bonded zone, hence enjoys the policy of tax benefit. We save tariff and VAT (value-added tax) to reduce our cost and this makes us more competitive."

However, in many areas, existing policies were identified not to be well implemented. For example, manufacturers do not benefit from the preferential policy, as illustrated in the following comments from Interviewee 34, a manufacturer vice director,

"We have to waste time and energy to prepare more documents to meet those extra requirements as we are in the bonded area. The extra burden may drive us off the bonded area..."

Secondly, government support to logistics can be reflected in investment in physical infrastructure and port technical infrastructure, as Interviewee 17, Maersk Line Manager, explained:

“The Chinese government has invested a lot in the port physical infrastructures.”

Thirdly, government may have a logistics scheme that targets some port cities as logistics cities, such as Qingdao, Shanghai, Xiamen, Shenzhen and Ningbo. However, overinvestment in some ports was identified as a scheme problem. Xiamen has seven ports whose production capacity reached 13.8 million TEU in 2009, three times the actual shipping volume. The over-capacity of some ports has caused a serious waste of resources and higher operations cost. As one interviewee commented, Dalian and Xiamen are known as the typical ports with most overinvestment which results in fierce competition, worse profit and poorer efficiency.

Based on the interview analysis, government support to ports is complicated. On the one hand, government is trying to support port development with preferential policies. On the other hand, the support is not equal to different ports. The ports with stronger support have better logistics than those ports with weaker support. The finding that government support plays a prominent role in logistics is in line with Banomyong (2005) and Arvis et al. (2010).

4.3 Port technical infrastructure

Port technical infrastructure refers to port facilities, container terminals and the information technology status of the port (Lirn et al. 2004). Twenty-eight (70%) interviewees demonstrated that good port technical infrastructure improves port logistics. For example,

“The supply of good quality infrastructure must be ahead of the demand. Otherwise, customers cannot be attracted.” Interviewee 3, a vice director of a Port Operator

The ports in China handle different cargos, such as oil, gas, bulk and general cargos. The length of ports, number of terminals, terminals with big capacities, areas for warehousing, number of cranes, number of equipment of loading and offloading, container yards, and yards for other stocking, etc. were found satisfactory for most ports. This is because ports in China have recently been heavily invested on the infrastructure construction and facilities. As the ports were developed late, the quality of port infrastructure and facilities is good, especially compared with the ports in other developing countries, as explained by Interviewee 37, a director of a shipping company,

The port infrastructure also includes depth of navigation channel, which is a very important determinant of port competitiveness in the literature (Tongzon and Heng 2005; Tongzon 2007). Logistics at ports relies on advanced physical infrastructure and ICT (information and communication technology) systems to reinforce its influence on the port vicinity, enhance the cargo consolidation, storage and distribution. Interviewees highlighted the importance of ICT. The capability of ICT systems varies between different port regions. ICT systems of Shanghai, Shenzhen and Ningbo work well while that of Xiamen does not. The application of information system in some ports so far is limited to very basic and primary functions such as e-booking and e-billing, and even these limited functions are confined to big companies. Interviewee 26 from the manufacturing sector explained that the information system was the bottleneck of Xiamen port development. This finding is consistent with the view of Tongzon (2009) that lack of an adequate information system would slow down the documentation process and port efficiency.

4.4 Landside transport infrastructure

Ports are linked to their hinterlands by rail, road, water, air and pipeline. It was commonly understood that poor infrastructure to connect ports and hinterlands hinders port logistics. Actually, 80% interviewees commented on the landside links to ports. One 3PL Manager criticized Xiamen's poor landside transport infrastructure as below,

“Xiamen is blocked by mountains around. Currently there is only one rail to connect Xiamen and other places. Almost all of our customers would not consider railway for transport, as it is too slow. Almost all links to ports rely on road... and the highways are limited due to natural conditions.”

Interviewee 6 from Qingdao commented that

“There is hardly any virtual intermodal in China. People know it as a concept but also know it does not work in reality, because the physical infrastructure of rail and road is not generally in place yet. Many companies even do not have loading/unloading platforms for containers.”

Most of the cargoes from inland China do not come from or go to Xiamen due to lack of proper transport infrastructure. They go to Shanghai making use of the Yangtze River. Neither Xiamen nor Shanghai has sufficient cargo sources from the city itself. However, Shanghai has attracted much more cargo than Xiamen because Shanghai has good landside links such as the Yangtze River and efficient highways that bring cargos easily from hinterlands.

The transport infrastructure is important, because the size of the hinterland depends on its quality and availability. Many ports have been seeking intermodal links to expand their hinterland; however, intermodal transportation has not become true yet.

4.5 Seaside connections

Seaside connections include deep-sea shipping services and feeder services, both of which were identified as important. Most of the top 20 carriers in the world, such as Maersk, American President Lines, the Mediterranean Sea, P & O Nedlloyd, Evergreen, COSCO, and China Shipping, have set up branches or agencies in the main ports of China and the Chinese cargoes can reach over 100 countries worldwide. Interviewees gave a favourable assessment of the shipping frequencies for ports in China. Frequency of shipping lines is critically important for port logistics, as Interviewee 15 said,

“Shipping frequency is one major factor for us to consider whether we select the port or not. The ports with more shipping frequency would attract us more easily. On the contrary, ports with less shipping frequency would develop more slowly.”

The finding that shipping frequency is important for port to develop logistics is consistent with the literature by Slack (1985), De Langen (2007) and Tongzon (2009).

4.6 Logistics cost

Logistics cost at ports were generally classified into shipping prices and port charges by the interviewees. Twenty interviewees held the view that port terminal charges were critical for ports to attract shipping lines to call. Port charges were considered not very important, as all the ports in China are required to follow the same charge criteria. The details of port charges are available on official port website, including the carrier cost, agency cost, tug and pilotage, cargo loading/unloading charges, man-hour rate, rental of boat, equipment, facilities and other operations cost, domestic line carrier cost, lump sum for domestic container cost, port construction fee, and port dues. They are also visible in the lobby of most port services buildings to ensure the charge transparency. The overheads were identified cheaper in bigger ports such as Shanghai and Shenzhen than smaller ports such as Xiamen. However, for particular cost, some ports may have privilege policy to attract customers. For example, it was free to keep the empty containers at Xiamen yards. Some interviewees explained that the high cost in some ports was because of private monopoly ownership. However, it was not identified as a serious problem as most ports in China have diversified ownership.

Shipping prices were considered very important as they would determine cargo sources. As logistics cost includes a wide range, it is hard to simply tell whether logistics cost is high or low. Also, because cost is a very sensitive index, the researchers could not obtain information on the details, as the interviewees were not

allowed to disclose cost due to confidentiality. The finding that cost is a key factor that influences port logistics is in line with Murphy et al. (1991), Lirn et al. (2004), Tongzon and Heng (2005).

4.7 Logistics demand

Logistics demand is backed up by the local and hinterland economy. 90% of interviewees strongly highlighted its importance. They explained that a developed economy ensures sufficient cargo resources for the trade. Some ports had the obvious characteristics of an export-oriented economic development model (like Xiamen), some had a transshipment model (like Hongkong and Shenzhen), and some had a commercial model (like Guangzhou). Focusing on an export-oriented growth competitive strategy requires extensive port rationalization for export-led success and attracting imports. For some ports, the local economy is not strong enough to support port logistics; however, their demand is supported by hinterland economy, such as Shanghai. The demand also depends on the product range of the export/import cargoes. Some interviewees had concerns about the cargo types for trading at their own ports, for example, Interviewee 8 expressed his concerns about Xiamen future,

“One of the main products Xiamen transports is stone, which is a non-reproducible but heavy product with low value. Xiamen is the port to ship the biggest share of stones in China.”

Some interviewees were also concerned about their hinterland economy. They understood that river navigation provides cheap and convenient transport for the cargos from the broad hinterlands (Yangtze River Delta/ Pearl River Delta) to go to Shanghai or Shenzhen, but some ports are separated from the inland by mountains like Xiamen. However, most interviewees had confidence about their logistics demand due to China's economy boom and they asserted that regional economy influences port logistics.

4.8 Logistics services

The quality and availability of logistics services such as customs and border inspection services, logistics personnel skills and management levels, speed of cargo handling, port risks, port safety and other services by LSPs were identified as important for port logistics improvement. Customs service was highlighted by thirty-six (90%) interviewees as a critical factor to influence port logistics in China. The interviewees acknowledged that ports with good customs service attract more customers, and vice versa. The typical example is Xiamen. Big manufacturers such as Dell, Xiahua Electronics Group and You Da Guang Dian, which enjoyed the “green customs channel”, were happy with the customs services. However, most Xiamen interviewees strongly asserted that Xiamen's customs service was poor and some of their customers had turned to Shanghai or Shenzhen due to Xiamen's poor customs services. The interviewees thought that customs supervision now has become too strict and it has impacted the government work efficiency and slowed down the development of Xiamen. According to the interviewees, the poor customs service is not only a matter of logistics development, but also a matter of politics.

The interviewees noted that logistics skills and management levels are important for port logistics. Whether the logistics policy is implemented efficiently and effectively depends on the ability of the management team. For example, in the early 1980s, Shenzhen, Xiamen, Zhuhai and Shantou were the first four open special economic zones by the Chinese government and Xiamen actually had a better opportunity than Shenzhen. However, Xiamen has developed much slower than Shenzhen for three reasons: the political relationship between Taiwan and Xiamen, culture difference, and difference in logistics skills and management level.

Interviewees held the view that speed, contributing to port efficiency through vessel calling, departure and cargo movement, is critical in logistics services. Increasing cargo handling speed can increase the total loading/unloading speed and shorten the vessel turnaround time. Interviewees 23 and 31 highlighted this view. Sixteen interviewees realised that risk (such as congestion, delay) and safety management were explicitly important for port logistics as a common sense. The services in the investigated port areas were all identified satisfactory in terms of warehousing, freight forwarding and cargo handling.

4.9 Port Ownership and Politics

Port ownership was found important to influence port logistics. Twelve interviewees realised that ports in China have experienced the process of moving from an exclusive "complete monopoly" by the government to "oligopoly" by diversified ownerships. They considered that port services in China had improved greatly in the past 20 years, partly because diversified port owners, multiple port operators and port managers had replaced the complete monopoly in most ports. The current diversified port ownerships include the government agency, world top shipping carriers such as Maersk and world port operators such as Hutchison. The diversified ownerships contributed to improving services due to competition and this finding is consistent with the claim of Borger et al. (2008).

Politics was recognised as one important factor influencing port logistics in China. For example, Xiamen has long been regarded as a city more politically than economically important. Thirty-two interviewees considered that Xiamen's development largely depends on mainland China's political relationship with Taiwan. They held the view that the politics in Xiamen was not stable, which hindered the development of Xiamen port logistics for quite a long time. This also explains why Xiamen has not developed so well as Shenzhen and other port cities. The FDI investors had some concerns about the stability of politics, so they held investment in Xiamen. The poor landside links to the hinterland are to some extent due to political issues. The idea that political stability influences port logistics is supported by the evidence of recent Xiamen-Taiwan relationship. The literature has hardly addressed politics in port performance development. Although Tongzon (2007) and Lirn et al. (2004) mentioned that political stability was one determinant of competitiveness in logistics, they did not include this determinant in their empirical research. The current finding supports Tongzon's view and it enhances the literature by empirical analysis.

4.10 Culture

Culture was identified as important for port logistics. People who work for the customs in China are known to have an "iron rice bowl", which means secure employment and a lifelong secure job. Their jobs are secured whatever their job quality is. Employees in these positions are like the people who used to work in the China state-owned enterprises. They lack the sense of services, because they get the same salary however hard they work. This is particularly true in the public sectors, like customs and government departments, where the state-owned ideology prevails.

The slow development of logistics in Xiamen was attributed largely to the leisure culture (such as the tea culture) and culture of not appreciating change. The confrontation between immigrant culture and farming culture, the collision between farming and maritime cultures, the coexistence of contradictions in comfort and struggle constitute the character of Xiamen citizens. This contradictory character is reflected in the 30-year history of Xiamen's economic reform and opening up, and also reflected in the transfer routes to undertake foreign investment. However, the main stream of Xiamen culture is a leisure-driven instead of profit-driven economy. The Xiamen culture is quite different from that of Shenzhen. Shenzhen is a completely new city with a culture of "time is money, efficiency is life". The city has pursued transformation by advantages of land, finance and taxation, manpower, industry and business services.

The interviewees raised some other factors influencing port logistics, such as unbalanced containers due to unbalanced imports and exports, and a nearby competitor. Unbalanced international trade of China has put some ports into difficult situation to feed the empty containers, which has raised shipping cost and port customers' cost. Port image is an issue with smaller ports in China. Customers may not choose them because of bureaucratic customs procedures like Xiamen. Nearby competitors would influence port logistics, for example, Ningbo's development has impact on Shanghai's cargo volumes', and Fuzhou's upgrading has impact on Xiamen's shipping activities.

5. Conclusion

A number of factors were identified from the empirical research, which provides an unambiguous view of the factors that influence port logistics from port stakeholders' perspectives. Geographical location, government

support, logistics demand, physical infrastructure to link ports with hinterland, port infrastructure, information communication system, customs service and the port services provided by logistics service providers, logistics cost, political stability and port ownership were all identified as important factors that influence port logistics. These findings are in line with literature.

Efficient port risk and safety management would ensure the efficient management of port logistics. Some ports showed dissatisfaction with their regional logistics skills that are below the average level nationwide. Some interviewees feel somewhat disappointed about their logistics infrastructure, but most interviewees were happy with their port facilities and physical infrastructure to link ports and the hinterland.

Among those factors on which different regions have different perceptions, government support, customs service, logistics cost, and logistics demand are typical examples. For government support, some ports have gained government support more positively than others in terms of infrastructure investment, and preferential policy on tax exemption or reduction. It should be acknowledged that there is a common gap between expectation and satisfaction. What is important is to shrink the gap and make the expectation come true. This depends on the efforts of both government and ports. Port services are not as strong as they are expected in some ports, this might be because Chinese ports lack a sense of service due to the influence of a long history of “iron rice bowl”. All infrastructures are important, but intermodal is not available and waterways have not been promoted as expected in China. Regarding customs services, some port users complained about the complicated documentation and cumbersome procedures while other ports had no such concerns at all. For logistics cost and logistics demand, different ports vary, too. Xiamen port interviewees expressed strong concerns on the lack of logistics demand due to the weak local economy and small hinterland, while Shanghai, Shenzhen and Ningbo ports had no such concerns.

Some new themes have emerged from the empirical research. 1. Customs efficiency has seldom been addressed in empirical research as an important factor that influences port logistics, although it is mentioned in the literature and reported by the World Bank. The empirical finding shows that customs efficiency influences port logistics in China. 2. Logistics demand was hardly highlighted in previous empirical research due to common knowledge; however, this research has provided empirical data proving its importance. 3. Politics and culture have hardly been investigated in empirical research from the perspective of development of port logistics, nor have they been profoundly addressed in the literature. This empirical research has found they are fundamentally important in China.

The above findings have shed light on factors that influence port logistics, which enhance, extend or complement the literature by persuasive evidence from this empirical research. Building on the presentation and discussion, this paper summarised and highlighted a number of main themes. Future research is needed to investigate the descending order of the factors’ importance influencing port logistics.

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Dock Labour Systems in North-West European Seaports: How to Meet Stringent Market Requirements?

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Abstract

This paper aims at providing a deeper understanding of the dynamics behind port labour in North-West European ports. In the first section we introduce a conceptual framework on dock labour systems and arrangements following a market-driven perspective. The conceptual framework highlights that the requirements of the market players come down to a maximization of the performance of dock workers (with an optimization of the direct costs of port work as a prerequisite) and a minimization of the indirect costs of port labour. This internal organization of dock work takes place within a wider setting of legal and social conditions. The paper continues by analyzing characteristics of and key issues in dock labour systems in North-West European ports. We particularly identify elements of convergence and divergence among the dock labour arrangements in the ports considered and in the way the social partners concerned try to provide an adequate answer to the changing market environment.

Keywords: Dock labour, Europe, port competition, market dynamics

1. Introduction

Seaports are increasingly functioning not as individual places that handle ships but as turntables within global supply chains and global production networks (see e.g. Notteboom & Winkelmanns, 2001; Robinson, 2002). Pallis et al. (2011) point out that scholars have devoted an increasing number of studies on the role of ports in supply chains. Notwithstanding the increasing role of ports as key nodes in supply chains, cargo handling operations still form the core of the *raison d'être* of seaports. The efficiency and effectiveness with which loading and discharging activities in a port take place remain important cornerstones of a port's competitiveness and its ability to generate wider economic effects in terms of employment and value-added creation. As dock workers are typically responsible for loading and discharging cargo, the design and practical arrangements of the dock labour system in a port has an important role to play here.

The role of dock labour in the competitiveness of seaports and the changing face of dock labour requirements as a consequence of structural changes in the maritime and logistics environment have not received a lot of attention in academic literature. For example, port efficiency studies using data envelopment analysis (DEA) or stochastic frontier models generally tend to disregard port labour or assume a fixed relation between dock labour and the quay and yard equipment used. Existing studies on port labour tend to focus primarily on the social dimension such as the role of labour unions and the need for social dialogue (see e.g. Turnbull, 2006a; Turnbull and Wass, 2006). There is room for more economic approaches to the organization of dock work in light of changing market requirements.

This paper provides a deeper understanding of the dynamics behind port labour in North-West European ports. Competition in the North-West European port industry and the technical conditions of cargo handling bring about resemblances among ports. The general nature of the dock work and of labour relations are similar and port labour is crucial to the competitiveness of seaports. But, the organization of port labour and the associated

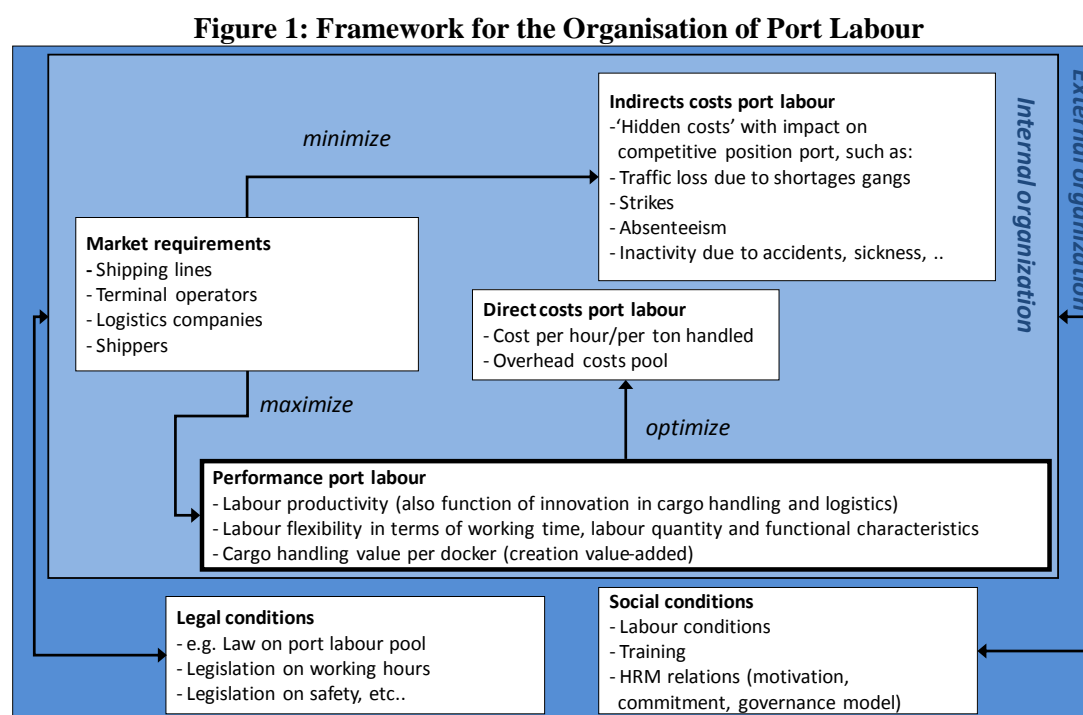
dock labour systems can vary considerably throughout North-West Europe as will be discussed in this paper. The research question put forward in this paper is the following:

To what extent and along which lines do the changing market requirements affect dock-related work in North-West European ports and the characteristics of and current issues in the design of port labour systems in North-West Europe?

The paper is structured as follows. In the first section we introduce a conceptual framework on dock labour systems and arrangements. After a detailed discussion on each of the components of the framework, the paper analyses characteristics of and key issues in port labour systems in North-West European ports with a specific focus on UK, French, German, Belgian and Dutch ports.

2. Conceptual Framework on Dock Labour

Dock labour is a key production factor of port terminals. The flexibility, productivity, quality and cost efficiency of dock workers contribute to the competitiveness of port-related and logistics companies and the wider economy. Still, the dock labour force typically represents a modest portion of total direct jobs in quite a number of ports¹. Figure 1 presents a conceptual framework on dock labour. This theoretical framework is based on a market-driven approach. Shipping companies, cargo handling and logistics companies, transport operators and shippers impose certain logistics requirements on ports and terminals based on the characteristics and the needs of the supply chains. Port terminals have to meet these market requirements if they want to bind cargo in a sustainable way and to stimulate economic growth within the port and the immediate hinterland. Broadly speaking the requirements of the market players come down to a maximization of the performance of dock workers (with an optimization of the direct costs of port work as a prerequisite) and a minimization of the indirect costs of port labour. This internal organization of dock work takes place within a wider setting of legal and social conditions. In the next sections we discuss each of the segments of the conceptual framework in detail in view of demonstrating how they interact.



Source: Own Compilation

3. Performance of Dock Labour

At the heart of the conceptual framework lies the performance of the dock labour system. The dock labour system should be designed in such a way that dock workers perform to the market requirements in terms of

labour productivity, flexibility and added value created.

Labour productivity in ports is a complex issue and cannot be narrowed down to the output per man hour or tons per gang shift since these performance indicators do not reflect the technology used to handle the cargo. Benchmarking dock labour performance thus requires indicators which combine handling rates with the technology used, for instance by looking at ‘output per man hour produced with a certain stock of fixed capital of a given technology and operational characteristics’ as suggested by Haralambides (1995). Labour productivity can thus not be treated in isolation as it is linked to a number of factors:

- *Technology used.* It is obvious that technological innovations / developments in cargo handling can dramatically increase labour productivity. A typical example is the unloading of bananas. Only a decade ago, toboggans cranes (crane equipped with a movable arm and a conveyor system) were quite common to unload individual banana boxes one by one from the hold of the reefer ship. Today, banana boxes transported by reefer vessels are palletised and handled by specially equipped pallet cages attached to a crane allowing unloading up to eight pallets in one move. Reefer containers are also commonly used which adds to labour productivity. With the introduction of pallet cages and containerization the number of banana boxes handled per minute per crane increased from 50 when using a toboggans crane to 385 for the pallet cage and 480 when pallets are containerized. The willingness to innovate among stevedoring companies in ports is partly related to the benefits at the level of port labour. If a technical innovation would in principle allow reducing the manpower per gang from 8 to 6 people, then the terminal operator will only benefit from the labour costs savings if the gangs are indeed reduced in size. If such a reduction in manpower is not possible within the contours of the port labour system then the stevedoring company will be far less eager to introduce technological innovations, which may pose a competitive disadvantage compared to other ports.
- *Training and experience levels.* Training and experience are essential in achieving a high labour productivity. Many cargo handling operations require specific skills. For example, a docker who has a lot of experience in dealing with steel does not necessarily achieve the same level of labour productivity if he would switch to another category of goods (e.g. a forest products terminal). The docker needs appropriate training and has to go through a learning curve period in order to get the same productivity than the dockers who have a long experience with the specificities of the commodity to be handled.
- *Training and career opportunities for longshoreman.* As mentioned earlier training is an essential element in achieving a high productivity. This necessitates a customized training plan in which the longshoreman have a view on a future career path based on experience and proven competence. As will be discussed later, many ports have a number of occupational categories of dock workers combined with clear rules regarding the flow from one category to another higher category. A number of ports and terminals still have a long way to go in establishing effective human resources policies and practices with recognized career patterns.
- *Quality of the influx of dockers.* The labour productivity within a port labour system is also dependent on the way the influx of new dockers is regulated. Key issues in this respect relate to the ‘screening’ of potential candidates, training facilities, the modalities for trial periods and the characteristics of labour evaluation systems.
- *Motivation and labour spirit.* The commitment and labour spirit of the docker is linked to a number of elements such as:
 - *The societal status of the profession and professional pride.* For example, the Belgian port of Antwerp has always had a strong record in attracting labourers from the city itself and the immediate surroundings to work in the port. Dock workers generally start to work as dock worker at a young age until they retire. Job loyalty and pride are high. In some other ports dock work is being regarded as a very low-status job and perceived of a temporary nature.
 - *Wages and bonus system.* It is obvious that high wages and a performance-based bonus system

stimulate or should stimulate labour productivity and job loyalty.

- *Existing industry relations between employers and employees.* When these relations focus on commitment and loyalty then dockers are stimulated to deliver a high performance. A spirit of consultation and social dialogue enhances employee-employer relationships.
- Labour productivity is also influenced by the *gang system* in place. A competitive spirit between dock worker gangs and a strong social control within a gang enhance labour productivity per shift. Strong and highly motivated foremen typically create an atmosphere of coherence and a focus on strong team work. A seamless transition from one shift to another (the so-called 'hot seat' change) results in continuous work on a ship thereby reducing idle time of the handling equipment. A high flexibility in the deployment of gangs (e.g. movement of a gang between vessels during a shift) also contributes to an optimal use of available dock workers. The existing recruitment and dispatching systems play a key role here.

Increasing productivity through dock workers is not only a matter of having them work harder. The key is not only to work harder but also to work smarter (Meletiou, 2006). Working smarter in a port context can be achieved by eliminating unnecessary tasks, developing a strong sense of teamwork, providing continuous training or giving workers more say about how to do their jobs and in problem solving. Psychosocial factors are a major source of productivity improvements in the port sector.

An objective comparison of labour productivity among ports is hardly possible due the existing diversity. A high productivity per vessel (tonnage loaded / unloaded per shift) is not always associated with a high productivity per dock worker (tonnage loaded / unloaded by port worker) as the outcome is strongly dependent on the size of the gang and the number and type of cranes and other equipment deployed to handle the vessel. Also, labour productivity should always be analyzed in relation to the labour costs.

Next to labour productivity, there is the issue of the **flexibility of dock labour**. Flexibility has many faces. First there is flexibility in working hours. A distinction should be made between passive and active flexibility. Passive flexibility implies that the employer establishes schedules (taking into account the legal provisions) and taking into account breaks, holidays, etc. Active flexibility gives a lot of initiative to the employee. A port labour system with a large number of casual workers normally generates a high degree of active flexibility. The port workers have, within certain limits, a freedom of choice for certain tasks. When the port labour system does not impose a work obligation at specific moments in time (for example for weekend work or work on holidays) finding enough volunteers is often a matter of providing generous bonuses for performing such tasks.

Secondly, there is flexibility in terms of the total labour quantity. This refers to the possibility to adapt the size of the workforce to the amount of work that needs to be done. In terminal operations that suffer from peaks in cargo handling demand, this kind of flexibility is crucial for a good business operation. One of the main incentives behind the establishment of dock labour pools in quite a number of ports is exactly to guarantee this kind of flexibility. Employers and employees then jointly determine the size of the docker workforce based on current and future needs. There is also another dimension linked to this type of flexibility: the possibility to recruit workers outside of a dock workers pool (for instance via temporary labour offices) when there are shortages.

A third type of flexibility refers to the operational deployment of dock workers or the extent to which dock workers can be used for different types of tasks (multi-skilling or multi-tasking). When dock workers are assigned to specific job categories then such flexibility is only guaranteed when a system of qualifications (based on certification or training) allows dock workers' mobility between categories. When dock workers strictly adhere to their specific professional category then the multi-skilled nature over the categories is typically low. This can lead to discrepancies whereby shortages in one category cannot be compensated by surplus dockers in other (higher ranked) categories. The multi-skilling flexibility of a dock worker can also relate to a particular professional category: for example a driver who can be deployed both at a paper terminal (forklift equipped with a paper clip) and a banana terminal (forklift equipped to deal with four pallets simultaneously). A multi-skilling orientation of dock workers classifications is a plus when the port is

confronted with large cargo flows with a highly cyclicity or seasonality. For example, dock workers of a given category who normally are deployed on a fruit terminal (e.g. citrus fruits) can shift during the low season to other terminals which might be confronted with cargo peaks.

Finally, there is flexibility in the assignment of gangs/teams, the size of the gangs and the shift system in place. In principle, the employers benefit the most when they have the widest possible freedom in switching gangs between vessels during a shift, to vary the size of the gangs to match the desired productivity per hour and to deploy every dock worker to work in the most appropriate shift. In practice, there are clear limits to such forms of flexibility. There are human and social boundaries (e.g. a frequent change of dock workers from night to day shift typically lowers concentration and thus has an impact on productivity and safety). There are also legal provisions on working and resting times and the provisions stipulated in local dock labour schemes.

The flexibility of a dock labour system can be evaluated in absolute terms (e.g. how often are shortages in gangs recorded) or in relative terms compared to benchmark ports. Employers often strive for a higher flexibility. A broad array of measures exists to marginally or substantially increase flexibility in port labour. The most straightforward way is to increase the remuneration of dock workers by raising base wages or, more commonly, by installing bonus systems linked to flexible tasking and irregular working hours. In many cases, flexibility improvements can also be achieved by better using the formal possibilities for a more flexible use of dock workers. The modernisation of job assignment systems towards electronic dispatching can facilitate the distribution of dock labour in ports or terminals which have a high demand for a flexible work force.

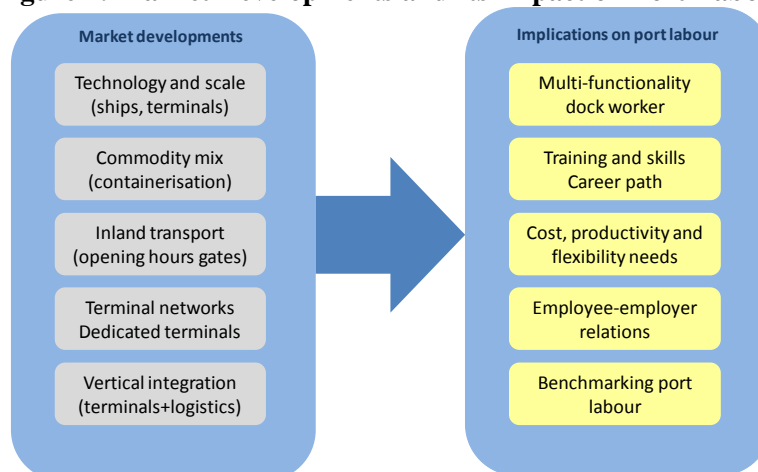
4. Market Requirements

The requirements of the market have an impact on what is expected from dock labour in terms of performance. As the market environment of seaports change, so do the requirements imposed on dock work. Figure 2 provides an overview of the main market developments and the associated implications on port labour requirements. We discuss each trend in greater detail.

4.1. Technological advances in ship types and cargo handling facilities.

Until the Second World War cargoes were mostly bundled together in pieces or units that dock workers could manipulate, i.e. the so-called ‘man load’. Examples are bags of sugar, cotton bales and drums of liquids. Dock workers carried loads of 30 to 50 kg in and out the vessels. Since the 1950s ports have been facing a ‘goods explosion model’ characterized by a shift from ‘man load’ to ‘unit load’ and bulk cargoes. The unitization of cargoes went hand in hand with the development of specialized terminal equipment (e.g. specialized quay cranes, forklifts, terminal tractors, straddle carriers, reach stackers, RMGs, RTGs, etc..) and specialized ships (e.g. container ships and ro-ro ships). Forklifts, tractors and other mechanical equipment have been around for more than seventy years.

Figure 2: Market Developments and Its Impact on Port Labour



Source: own compilation

The changing technology brought new requirements in terms of the skills of the workforce. Up to the late 1950s, dock work basically involved unskilled work requiring no or little previous training, except for the operation of the mechanical devices which at that time accounted for something like 10% of the work (Jensen, 1964). Dock workers were mainly used to manually handle various bags and other man load. The multi-skilled nature of dock workers was limited to the handling of a broad variety of man loads: bags, bales, crates, drums etc..

The ‘goods explosion model’ increased the need for skilled dock workers who have the qualifications and experience to operate more specialized handling superstructure. The new technologies made it increasingly difficult to maintain a system of gangs of a dozen or so. A whole new range of crane drivers, straddle carriers drivers and drivers of other equipment emerged. At the same time, wage systems were adjusted to face the new realities by combining basic wages and bonuses instead of only opting for time-rates or piece-rates. The dock labour force now faced increasing requirements in the field of specialized cargo knowledge and technical knowledge of dedicated and expensive handling equipment. The need for skilled dock workers was further reinforced by the increased focus of port customers on precision, damage prevention and overall quality of service.

The above developments encouraged some degree of permanent employment or at least the assignment of individual workers to always the same port terminals. The increasing specialization trend implies that the deployment of multi-skilled dock workers on different types of terminals is only possible when extra efforts are made in the field of training. Technological development in ports thus has altered the balance between the specialization degree and the multi-skilled nature of dock workers.

4.2. Scale increases in vessel size

Given the relentless search for cost savings at sea, many shipping lines’ expansion plans are heavily focused towards larger vessels, particularly in the container business. The high time costs of these large ships make that shipping companies exert strong pressure on terminals in terms of quay productivity. A ship has to turn around as quickly as possible. The high time costs of vessels also make 24h/7d operations indispensable. Shipping companies might be willing to accept higher terminal costs during weekends and at nights if these additional costs are compensated by savings in time costs of the vessel. Port labour is being scrutinized in view of finding ways to yield productivity improvements. Examples of such improvements include (1) the full use of the shift in hours instead of allowing dock workers to already wrap up before the end of the shift; (2) the ‘hot seat’ change or optimizing the seamless transition between different shifts so that the idle time of the equipment is reduced (more usable time); (3) reducing the delay between the mooring of the ship and the start of operations, etc..

Many terminal operators keep statistics on labour productivity per shift. They are used for internal purposes but also in relation to customers. Hence, contracts between terminal operators and shipping lines typically contain clauses on minimum terminal productivity guarantees. Productivity statistics can also be used to motivate and guide dock workers and to enhance a competitive spirit among the dock labour gangs.

4.3. Changes in the commodity mix: increased containerisation

The increasing containerisation of conventional general cargo is a process that started more than 50 years ago and has even accelerated in the last decades. The explosive growth in containerised trade triggered a trend toward more permanent employment at container terminals, while the shrinking conventional cargo market still relies much more on casual work. Containerisation also brought an increased pressure on the training of port workers. The most talented and skilled port workers typically aim for a high-paying job at a container terminal, thereby putting pressure on conventional general cargo terminals to keep their best dock workers. Containerisation thus brought a stronger focus on training and career planning of dock workers.

4.4. Changing inland transport requirements

Containerisation contributed to a modal separation on terminals and a disconnection between quay side and

landside operations (Rodrigue and Notteboom, 2009). This transformation led in a number of ports to a discussion on the reach of dock work. In some ports, dock labour became confined to the loading and unloading of ships while other ports followed a very broad application of dock labour including all forms of cargo handling in a designated port area, including warehousing, stuffing and stripping, loading and unloading from inland waterway vessels, trucks, railway wagons, etc..

4.5. The rise of terminal networks and dedicated terminals

The terminal operator business in Europe is marked by waves of consolidation and entrance of global terminal operators such as PSA, HPH, DP World and APM Terminals (Notteboom, 2002; Bichou and Bell, 2007; Olivier et al., 2007). These large terminal operating groups have extended their reach over more than one port. In addition large logistics players and multinational enterprises also increasingly involved in terminal operations as exemplified by investments of steel groups in bulk terminals (e.g. German steel groups Thyssen Krupp Stahl and Hüttenwerke Krupp Mannesmann are the full owners of the EECV terminal in Rotterdam; ArcelorMittal has own terminal facilities at many of its maritime steel plants), the setting-up of dedicated forest products terminals (e.g. StoraEnso) or the development of specialized fruit terminals (e.g. Dole, Chiquita). Large port customers and large cargo handling companies can exert a significant impact on port labour.

First of all, these companies often develop a strong network focus by their presence in several ports. The experience they gain at different ports is the basis for explicit or implicit port labour benchmarking exercises comparing the turnaround time in each port, terminal productivity, flexibility in working practices, cost profiles, etc.. International port companies try to apply best practices throughout their terminal network.

Secondly, the internationalization in the cargo handling industry facilitates the transfer of new technologies over a wide range of ports. Creating a competitive advantage in terms of terminal productivity is no longer only a question of operating modern terminal equipment, but more and more a matter of ensuring that the most efficient human resource system is in place to operate the terminal equipment. Empirical evidence shows that highly motivated and efficient dock worker gangs can attain cargo handling rates per container crane per shift which are two to three times higher than less motivated dock workers who are using similar cranes.

Thirdly, a loss or gain of a large customer can exert a major impact on the port and is directly reflected on the number of dock workers required. Consequently, numerical adaptations to a dock labour force are increasingly stepwise (sometimes even in the hundreds) instead of incremental.

Finally, the internationalization of cargo handling activities and the emergence of (semi-)dedicated terminals affects the traditional patronage structures in ports. Decades-old relationships between incumbent terminal operators and dock worker groups can be scrutinized by newcomers who want to implement their best practices regarding port labour. The decline of traditional patronage structures might lead to a certain level of alienation of dockers and reduced motivation. In some cases, traditional patronage structures conflict with the needs of a modern terminal management, making changes in employee-employer relations and the port labour system unavoidable.

4.6. The functional integration of terminals in logistics

Modern seaports are often home to a wide range of distribution centres. The combination of quay-related cargo-handling activities at terminals and a wide array of logistics activities at warehouses on or near the terminals has redefined and broadened port labour. Ports all over Europe were challenged to come up with a clear cut definition of what dock labour is and in some cases a distinction was made between ship-related dock labour and logistics dock labour in the port (see later).

4.7. Seaports and inland locations

Seaports are key constituents of many supply chains and prime locations for value-added logistics (VAL). Many seaports have responded by creating logistics parks inside the port area or in the immediate vicinity of

the port. However, the rise of port-based activities in the hinterland has triggered processes of port regionalization (Notteboom and Rodrigue, 2005) and dry port development and strengthened the formation of multi-port gateway regions (Notteboom, 2010). Labour costs, mentality and productivity are among the many factors determining the spatial distribution of logistics sites. The knowledge that value-adding logistical activities are increasingly 'footloose' in company-based logistics networks is a clear invitation to seaports to focus on favourable port labour conditions.

5. Direct and Indirect Costs of Dock Labour

Meeting market requirements by offering a high labour productivity and a high flexibility often comes at a high price. If high wages for dock work are not compensated by clear advantages in terms of flexibility and productivity then the port or terminal in question faces a competitive disadvantage. In other words, the dock labour system in place in a port should create an optimal balance between direct costs in terms of wages and bonuses on the one hand and performance on the other hand. In many cases, this exercise is not easy.

Port labour costs (blue collar) typically represent between 40 and 75% of total terminal operating costs of general cargo terminals. Even in the capital-intensive container handling industry, the share of port labour in total operating costs can be as high as 50%. The handling of dry bulk (i.e. major bulks such as iron ore and coal) requires less port labour due to the existence of conveyor belt systems throughout the bulk terminals. The share of labour costs in total operating costs at dry bulk terminals therefore typically ranges between 15 and 20%.

Bonuses and wage supplements are widespread in the port industry. In quite a number of cases, the base or guaranteed wage of a dock worker is only a fraction of the monthly income he can generate by collecting a wide range of bonuses and miscellaneous compensations linked to the nature, complexity and timeframe of his task.

A dock labour system should be designed in order to minimize the risk of 'hidden costs' which affect the competitiveness of the port. 'Hidden costs' can take different forms. A port or terminal can be confronted with a shortage of gangs or dock workers leading to substantial delays in vessel loading and discharging operations. Shortages can be caused by sudden non-anticipated peaks in demand or a (short-term) significant drop in the availability of dock workers (due to holiday period, weekends). Structural long-term shortages are an incentive to enlarge the number of dock workers. Cargo damage incidents can generate high hidden costs and negatively affect the reputation of a terminal or port. A high incidence of damage cases might point to a lack of training or a low commitment of the dock worker (absence of a 'we care' attitude). Short isolated strikes and long port-wide strikes by dock workers generate high hidden costs to ports and can even disrupt an entire economic system. Strikes cause port deviation costs for ship-owners, time costs for ships in port, lost revenues for inland transport operators and other port-related companies, time costs and broader logistics costs for cargo owners and potentially high costs to factories linked to major disruptions in the production line (stock-out). Strikes are typically a result of disputes regarding labour conditions with potentially detrimental long-term effects on the port's reputation. The history of the port industry has been earmarked by labour disputes. Most of the time, strikes were the result of disputes between labour unions (representing the interests of the dock workers) and employer organizations with respect to the terms and conditions for the renewal of collective bargaining agreements. A terminal or port can also be confronted with hidden costs caused by accidents. Terminals and ports often have to deal with absenteeism or the failure of workers to report when they are scheduled to work. The reasons for absenteeism can be company-related (e.g. ineffective selection and placement procedures, excessive fatigue, ineffective use of skills, poor supervision, inadequate training or promotion programs, etc..) or personal causes (e.g. dual occupation, alcoholism or drugs). As in other industries, absenteeism can relate to job satisfaction, but also as an indicator of worker's responsibility in fulfilling his/her contractual obligations. The power of absenteeism has been exercised many times by dock workers. Finally, hidden costs can also be the result of operational inefficiencies due to a lack of communication between the vessel and the stevedores, possible breakdowns of equipment or the late reception of the load plans.

6. Legal and Social Conditions

As previously stated, the internal organization of dock labour is taking place within a wider setting of legal and social conditions. The legal constraints are embedded in the appropriate port labour regulation and legislation and industry-wide labour and safety regulations. The theme of social conditions, including labour relations, is complex, difficult to delineate and hard to measure. Of paramount importance is that a port labour system from a social perspective should seek motivation and work spirit among the dockers. As previously stated motivation and work ethic are factors with an important impact on labour productivity.

As is the case in other industries, dockers feel best when they can rely on structures that defend their interests. Often these structures are organized not at company level but at the level of the whole port or the whole industry. Dock workers have a strong preference for employment systems that combine job freedom with labour conditions that are found in permanent contracts (such as job security and guaranteed wages). Dock labour pools typically combine these elements. Freedom and team spirit are generally highly valued by dockers.

As early as the 1960s scholars argued that the longshore industry, because of its peculiar nature, should be considered as a separate labour market (see e.g. Weinstein, 1963). While dock labour is confronted with specific labour challenges not commonly found in many other industries (cf. manpower utilization, job security, flexibility, demand fluctuations, etc.), we do not go so far in trying to disconnect dock labour from the principles guiding labour deployment in other industries.

Labour unions are typically very visible at the dock labour front, although major differences in union power can be observed across seaports and countries (Turnbull and Wass, 2006). Trade Unions are well organized in the hanseatic ports in Belgium, the Netherlands and Germany. These ports are among the most efficient ports in the world and their labour force is highly skilled, productive, well remunerated and union membership is high. While differences exist among these ports with respect to how and at what institutional level collective bargaining agreements are negotiated, the trade unions in these ports generally form a united front at the national level, the regional level, in the ports and at a port-company level. Social dialogue through effective bodies of joint consultation is considered as the key to a sustainable relation between employers and trade unions. A climate of constructive dialogue thus enhances social peace in ports. In 2005, the International Labour Organization published a practical guide to social dialogue in the process of structural adjustment and private sector participation in ports (see Turnbull, 2006b). Dock workers are often very direct in formulating their opinions, both internally during union meetings as towards others. Negotiators thus require specific skills in terms of understanding the differences in negotiating tactics and styles of trade unions and employers.

7. Dynamics in Dock Labour Systems in North-West European Ports

7.1. Key issues

The North-West European port industry has been undergoing port labour reform for over 100 years. Since the 1960s, most ports have witnessed a decrease or at best a stagnation of the number of dock workers. While the imperatives for change may have been the same, different countries and ports adopted quite different approaches to the change process. For example, the British government clearly chose for a ‘big bang’ approach when abolishing the National Dock Labour Scheme in 1989, while other countries have followed a more ‘incremental’ approach based on a continuous evolution (not revolution) in existing dock labour arrangements. The key issues that often appear in dock labour reform processes can be summarized as follows:

- *The (legal) status of the dock worker*

Dock workers can be civil servants in state-owned service ports, workers directly employed by a private terminal operating company or workers employed through dock labour schemes. Quite a number of port labour systems require that only registered dock workers can perform dock work in the port. This obligation can be imposed by national or regional legislation or might also be the outcome of collective bargaining agreements between port employers and trade unions. Though not ratified by a lot of Member States, Article 3

of ILO Convention 137 makes explicit reference to the registration of dock workers: “*Registers shall be established and maintained for all occupational categories of dock workers, in a manner to be determined by national law or practice*” and “*Registered dock workers shall have priority of engagement for dock work*”. In those ports where employers have to use registered dock workers, the criteria to recognize dock workers and the entities involved in the recognition process might differ among ports. Port reform processes that envisage loosening the preferential relations between registered dock workers and port employers often face fierce opposition from labour unions out of fears of undermining their position.

- *The definition of ‘dock work’*

In some European ports, dock labour is confined to the loading and unloading of ships within the port area. Other ports are confronted with a very broad application of dock labour including all forms of cargo handling in a designated port area, including warehousing, stuffing and stripping, loading and unloading from inland waterway vessels, trucks, railway wagons, etc.. . The development of logistics activities in ports typically led to discussions on the reach of the definition of ‘dock work’. For example, the port of Le Havre was hit by docker strikes in 1999 partly on the grounds that new logistics work should be classified as ‘dock work’. In Antwerp and other Belgian ports a special (cheaper) category of dock workers was created for logistics activities in port warehouses.

- *Labour pools*

A large variety in dock labour schemes can be observed among North-West European ports. Cargo-handling is performed according to different settings across the European Union and even within one Member State. Ports can depend on a dock labour scheme based on a centrally managed pool of registered dock workers. The use of registered dockers through a pool can be mandatory or not. This obligation can be de facto or imposed by law. By the 1960s or 1970s, many major ports had institutionalized, by law or by governmentally supported collective bargaining, organized systems for limiting competition in the dock labour market. The schemes generally involve three elements: (a) the designation of an “in-group” of officially registered (in effect, licensed) dock workers, (b) registered workers are not permanently employed at particular stevedoring enterprises are hired through a central pool or hiring hall, which stevedores are obligated to use for their primary source of casual labour and (c) a system of minimum pay guarantees or unemployment benefits for registered dockworkers who are left idle by a shortage of ships to be worked during a particular day, week or month.

Most port labour reforms have led to small or significant changes to labour pool arrangements in a sense that the matching of labour supply and demand in the port was altered. In an increasing number of ports, dock workers are directly employed by terminal operators, instead of contracted via ‘pools’, entities in charge of recruiting and training port workers. In some cases (such as Germany and the Netherlands) employers are able to hire permanent company employees directly from the external labour market, but any additional (casual) labour must be hired from a regulated labour pool. In some cases, recent reforms have privatized the status and operation of these labour pools (e.g. in the Netherlands in 1995). A labour pool can be organised in the form of an (autonomous) undertaking that provides labour services to port operators or workers in a pool can be hired by these operators. There is a general trend towards open and autonomous pool systems with back-up of temporary employment agencies. Over the last 50 years or so, the collective bargaining process in many ports has progressively been decentralized to the company level. The labour pools are often involved in the training of dock workers. Some ports have analyzed whether it might not be better to replace one dockers pool for all sorts of cargo handling operations by two or more specialized pools for specific commodities (for example a separate pool for container operations), thereby risking to undermine the solidarity among terminals in dealing with peaks in demand.

The status of dock labour pools and the degree of openness of some of these pools remain points of attention and contention in European port circles. When referring to pool systems the European Commission in its Communication on a European Port Policy (2007) stated that “*the Treaty rules on freedom of establishment and freedom to provide services can fully apply to the activities carried out by the pools*” and that “*such arrangements should not be used to prevent suitably qualified individuals or undertakings from providing*

cargo-handling services, or to impose, on employers, workforce that they do not need, since this could under certain circumstances fall foul of the Treaty rules on the Internal Market, and in particular of Article 43 on freedom of establishment and Article 49 on freedom to provide services". A more elaborate discussion on the current state of the complex discussions on labour pools can be found in Jerman (2009) and Verhoeven (2010).

- *Arrangements at the work floor*

While the pace of change differs among North-West European ports, there is a general tendency or push from the employers' side towards continuous working (via individual rather than collective breaks), flexible start times and variable shift lengths. Dock labour schemes show various ways in dealing with overtime, night shifts and weekend work. For example, in some ports weekend work is to some extent considered as a normal shift, while dockers in other ports have the freedom to accept weekend shifts (voluntary basis) with provisions in place for overtime money in case they do.

North-West European ports show a rather large variety in the way the respective labour systems deal with the composition of and flexibility within gangs or teams of dockers. There are systems advocating semi-autonomous and multi-skilled team-working with a high degree of freedom given to the teams to allocate tasks within specific shifts and over longer shift cycles. Other ports strongly rely on rather fixed gangs (linked to a supervisory system) as the central entities responsible for achieving a high productivity through experience, team-work and a spirit of competition among the gangs.

The hiring methods are guided by the provisions of local port labour schemes. Even in ports with a pool of registered dock workers, hiring systems can vary greatly in terms of:

- The hiring moment: e.g. hiring at fixed moments per week day or on a continuous basis;
- The persons involved in the hiring process: e.g. foreman, company officials;
- The characteristics and governance of the supervisory system;
- The interaction between docker and hiring person/entity: e.g. physical in a hiring hall or via electronic systems;
- The control given to the docker: e.g. matching on a voluntary basis or controlled externally (with or without taking into account the preferences of dockers);
- Etc..

- *Specialization/categorization/qualification of dock workers*

Dockers in port are generally not a homogenous group. Significant differences between their members can relate to the particular tasks carried out, the required skills, the way they are hired, the training arrangements, career planning, etc..

One of the foundations for categorization of dock workers is the division between permanent and non-permanent workers. International shipping lines and global terminal operators, particularly in the container business, increasingly demand direct employment for a significant number of their own workers, especially crane drivers and other operators of heavy yard equipment (the regulars). Casual workers are deployed during periods of peak demand. Even when a labour scheme is in place that includes a pool of registered casual workers, local port employers often hire a large part of the dockers on an almost continual basis (the quasi-permanent workers or semi-regulars). Labour schemes often include a 'continuity rule': a docker hired on a particular day can be rehired for the next day(s) to complete a ship without having to be rehired every one of these days in a central hiring place (the principle of 'repeat hiring'). The rule also gives the chance to new dock workers to become acquainted with the routines in a gang.

Some labour systems rely on a system of *job categories* of dockers, with varying degrees of labour mobility between categories. Other employment systems are based on *job qualifications*, allowing a (casual) docker to be deployed for any dock work as long as he has the right qualification(s). Port labour systems show various types and degrees of multi-skilling among dockers. The multi-skilling programs can be organized at company-level, by the pool or provided for by the state. Multi-skilling arrangements in some cases allow functional combinations of several jobs to be performed within the same shift.

In the following sections we discuss existing port labour practices in North-West Europe. At present, the organization of port labour and the associated dock labour systems vary considerably throughout North-West Europe. In other words, the way the elements in the conceptual framework (figure 1) are combined in a port labour system differs among ports.

7.2. The French case

France has undergone a series of port reform processes. The discussion on French ports is based on Barton and Turnbull (2002), Slack and Frémont (2005) and input provided by the port of Le Havre.

Before the national reform of 1992 the access to the job of dock work was in principle managed by the BCMO (state labour office in each port) but in practice by the trade unions. A law of 1947 made that dock work was arranged via a pool system. For example, the port of Le Havre had a casual workforce with allocation of dock workers to employers on a daily basis. Le Havre had 'professionnels' (guaranteed 300 half-day shifts per annum if they attended the hiring sessions on a daily basis) and 'occasionnels' (no guarantee and no obligation to attend work on a regular basis). The work guarantees were financed by the employers. By the mid-1980s, Le Havre suffered from a structural surplus in dock workers. All attempts to introduce more permanent employment for a proportion of the labour force failed.

The French dock labour scheme was reformed in the period 1992-1994. The aim of the 1992 reform was to abolish the 1947 Law and the system of pools but some pools still exist for casual dock workers having the status of "G card" (for example in Marseille). This status is no longer authorized for new dock workers since 1992 and will disappear before 2020. The reform of 1992 has allowed dockers to become ordinary salaried staff, but this transformation has led to numerous strikes. The reform was crucial in opening up French ports to new investors (global terminal operators and shipping lines).

In line with the port reform process initiated by Law n° 2008-660 concerning the French port reform of 4 July 2008, the port authority of Le Havre was renamed to Grand Port Maritime du Havre. Similar changes took place in the ports of Marseille, Rouen, Bordeaux, Dunkirk, La Rochelle and Nantes-Saint-Nazaire. The reform process led to labour unrest over the port's plans to transfer dock workers to stand-alone operating companies under the French government's national port reform.

The current classification of dock workers in French ports depends on their role in the gang (foreman, quay leader, reach stackers drivers, etc.). The system allows for some flexibility in the tasks but the dispatch appoints as much as possible the dock workers according to their specialisation (role in the gang and commodity). The composition of the gangs is based on negotiations between the unions and the port operators. Surplus and shortages of dock workers are managed through the temporary employment agency and labour leasing between port operators. Some port operators organize training sessions in order to avoid accidents and damages and to enhance labour productivity.

The labour system in Marseille provides a good example. The port counts some 1000 'professional' dockers and around 500 'occasional' dockers. Around 25% of the professional dockers are on the pay list of one operator and receive a monthly pay. The other 75% of professional dockers and all casual dockers are in the labour pools. They are recruited on a daily basis and can work for several operators. There are two kinds of labour pools. The first one, the Bureau Central de la Main d'Oeuvre (BCMO), is composed of "G card dockers", a historical status. This status should disappear in the medium term (around 2020). The Port Authority plays a role in the management of the BCMO. The second pool is composed of the 'new dockers' and is managed by stevedoring companies.

7.3. The UK case

The discussion on UK ports is primarily based on Barton and Turnbull (2002), Goss (1998), McNamara and Tarver (1999), Turnbull and Weston (1993) and Dempster (2010). Traditionally, dock labour in the UK has been casual in nature, allowing employers to hire and lay-off workers as and when needed. In 1967, shortly after the introduction of the container in Europe, the UK moved towards decasualization. Registered dock

workers were no longer hired on a daily basis from the National Dock Labour Board (NDLB), but got permanently assigned to an individual employer. The employment of dockers on a permanent basis led to high costs and inflexibility.

The abolition of the National Dock Labour Scheme (NDLS) in 1989 drastically changed the system of labour regulation in British ports. The NDLS became operative in 1947 and implied that all cargo handling and dock work within the designated port area had to be carried out by registered dock workers and only registered employers could employ these dockers. The NDLS applied to all 83 ports where casual labour was used. After the abolition of NDLS, the port industry revitalized. Employers now had the flexibility to employ labour as and when required and management was freed from the rigours of negotiating under the Scheme. Most stevedoring companies now employ a core workforce and run their own recruitment agencies to satisfy peaks in labour demand. They are also heavily involved in training casual staff. Some argue that the abolition is not a complete success as it led to a decrease in the welfare provisions of dock workers. The productivity of port workers in UK ports has generally increased. However, Goss (1998) states it is not at all clear how much of the productivity gains came from abolishing the Dock Labour Scheme and how much of it have been passed on to the port users and consumers. Turnbull and Weston (1993) argue that UK ports are now 'locked in a vicious spiral of cost-cutting, based predominantly on reducing labour costs'. Despite these comments, it is generally believed that the combination of privatization, increased capital investments and a plentiful supply of labour has contributed to the revitalisation of UK ports.

7.4. *The German case (Bremerhaven and Hamburg)*

The number of dock workers in the port of **Hamburg** has fallen sharply in recent years. In 1980, there were more than 11,000 dock workers in the port. In 2007 there were about 5,000 dock workers. The increasing mechanisation and containerisation are major sources of dock labour decline in Hamburg. The *Alterteilzeit* system was used to allow the inflow of younger dock workers. Under this system, older dockers (55 years) who retire can retain 85% of their salary. The government pays a portion of the salary (about 20%) and the remainder is paid by the port company.

The Gesamt Hafenbetriebs Gesellschaft (GHB) is the largest provider of port-related workers in the port of Hamburg. The "Unternehmensverband Hafen Hamburg", an association of port companies, holds 97% of the shareholding of GHB. The remaining 3% of the shares are held by members of this association. All financial risks are covered by the shareholders. GHB provides a flexible work force to companies who have to deal with peaks in port demand. The port workers in the GHB can be used virtually in all sectors and are generally well trained. There is no close cooperation between the City of Hamburg and the GHB pool.

GHB can also function as transfer point for surplus dock workers. Companies can offer excess capacity to the pool, but the pool is not obliged to take it (in practice, the pool does not take employees without own interest). Dock workers that cannot be placed elsewhere receive a guaranteed wage. In case dock workers (in the companies or in GHB) temporarily face less or no work, they receive a guaranteed wage ('freie schicht'). This salary is paid by the customers of the port through a 1.5% mark-up on the price for stevedoring services. This ensures that qualified dock workers remain in the port and can be redeployed when traffic volumes and port labour demand picks up. GHB works according to the 7d/24h principle.

In **Bremen/Bremerhaven**, there is cooperation between the City and the port. Similar to the Hamburg case, an independent pool was established now functioning under the name Gesamt Hafen Betriebs Verein im Lande Bremen E.V. (GHBV). Also this pool consists of well-trained dock workers who can be deployed for all kinds of port activities. The terminal operators communicate about the number of dock workers needed and the job qualifications required and GHBV arranges the selection and the overall supply. The workers of the pool can be full-time workers, part-time workers or can be employed as permanent staff of the stevedoring company. GHBV guarantees a minimum guaranteed income regardless of the level of employment.

Besides the pool of dock workers there is also a backup system in place based on 'rote Karte': casual workers who are standby to fulfill temporary assignments. These employees are mostly students and unemployed people who followed a course, received minimum general safety training and are subject to a selection test.

This category of people is mainly used in warehouse operations, absorbing peak activity, and for conducting logistical tasks. GHBV has its own training facilities and provides training for its workers pool, in consultation with port companies.

7.5. *The Dutch case*

Dock labour systems in Dutch ports are governed by collective bargaining agreements. Most of the collective bargaining agreements stipulate that the port employer shall only use its permanent dock workers or the dock workers of a labour pool for activities that fall under the collective bargaining agreement. Since the port employers face some cyclicity and unpredictability in cargo flows, they have worked on setting up a flexible system combining permanent employees (who have a labour contract with one terminal operator) and casual workers linked to a labour pool.

The first dock labour pool in the **port of Rotterdam**, the 'Haven Arbeids Reserve' (HAR) was founded in 1916. HAR was a joint venture between employers and the staff of HAR was to be regarded as the joint staff of the port companies. This pool was aimed at distributing the available port labour supply in an optimal way. The government paid part of the cost of idle dock workers and the cost associated with redundancy, given the great economic importance of the port of Rotterdam and in view of avoiding poor social conditions for dockers. In the period 1955-1968 the HAR was transformed into the 'Centrale voor Arbeidsvoorziening' (CVA). On January 1, 1968 CVA became a separate legal entity under the name 'Stichting Samenwerkende Havenbedrijven Rotterdam' (SSHB). The port companies jointly remained financially responsible for the state of affairs within SSHB. The employees of SSHB were employees of the joint terminal operating companies. The costs related to labour redundancy were largely financed by the government. From 1976 onward, the financial means needed were collected based on an annual financial contribution to the General Unemployment Fund ('Algemeen Werkloosheidsfonds' or AWF) which found its roots in the now expired Article 69 of the Unemployment Law.

In 1993, the Minister of Social Affairs and Employment announced that he would stop financing the pools in Dutch ports. Following the intention of Minister Melkert it was decided to reorganize SSHB. This process resulted in the 'Port Agreement' ('Akkoord Modernisering SHB Rotterdam' of November 1994) and the installation of SHB Havenpool Rotterdam B.V. (SHB) in April 1995. SHB took over most of the activities of SSHB. An agreement was reached with the Minister of Social Affairs about the financial compensation in connection with the termination of the port contribution arrangements. This agreement was captured in the Act of 20 December 1995 ('Wet tijdelijke bijdrage herstructurering arbeidsvoorziening havens' or WTH). The Act had two objectives: to end the port contribution arrangements and to allow for a temporary state contribution (till 1999) in the restructuring costs incurred by ports as a result of the installation of independent dock labour pools. SHB had incorporated many redundant workers from port companies. The average age of the workforce of SHB was relatively high which made the pool quite expensive. In the late 1990s, SHB had about 900 employees and provided approximately 15% of the dock workers in the port. An SHB Holding was founded in 1999 as an umbrella structure on top of SHB and SSHB.

The operation of SHB was structured as follows. The dock workers had a permanent employment contract with SHB and worked according to a fixed schedule. There was a wide choice of work schedules ranging from part-time, full time, weekend work, etc.. SHB guaranteed the payment of an agreed amount of tasks. A profile was drawn from SHB worker with an overview of work experience, job qualifications, past training, preference of type of work or employer, training needs, etc.. All this information was contained in a central database. The port companies sent details to SHB on a daily basis by specifying the number of dock workers needed, the required job qualifications, location, etc.. The SHB staff used their worker database to match the requested profiles. SHB pool workers were also available for non-port related activities such as logistics, project work and other types of temporary work. Depending on the nature of the activities SHB could charge a lower rate than the port-related tariff.

The Act of 1995 undermined the role of SHB and increased the importance of permanent employment with a stevedoring company, not only in Rotterdam but also in other Dutch ports. In late 2008, SHB faced serious financial problems. In January 2009, a Rotterdam court declared bankruptcy over SHB. All 440 employees

were affected, most of them working in the container handling business. In February 2009, most of the activities of SHB were revamped into Rotterdam Port Services. The new company kept 300 employees of the former SHB at work.

Rotterdam provides a structured training program for its workers. Before any person can work in the port he or she had to attend an approved course at the Port Training College, which is run by the port transport industry in collaboration with the Rotterdam Port Employee's Association, trade unions, the municipal authority and government. This training division was founded in 1949.

Also **the port of Amsterdam** has a labour pool. However, due to the above policy decision of Minister Melkert in 1995 the number of dock workers in the pool was reduced drastically from more than 400 to only 150. After 1995, the pool was transformed into an autonomous and market-oriented company: the Arbeidspool. Despite the government support of about 12 million euro the Arbeidspool went bankrupt in September 1997. Soon after, the port of Amsterdam set-up a leaner version of a pool: 'Stichting Personeelsvoorziening Amsterdam Noordzeekanaalgebied Operationeel' or SPANO. SPANO currently includes a pool of about 90 dock workers who can be hired during peak demand. If labour demand exceeds supply, private port companies are allowed to hire outside workers. In the reverse situation, when the labour supply exceeds demand, the dock workers in the pool can exceptionally be deployed at Schiphol airport. Dock workers (permanent or casual) in the port of Amsterdam are used exclusively for water-related tasks. Logistical tasks fall under the collective agreements concluded at company level.

The port labour organization in **Flushing and Terneuzen** (managed by Zeeland Seaports) is characterized by a high degree of flexibility. People with the right qualification have access to the profession of dock worker. The high degree of flexibility is also reflected in the recruitment of casual dockers, the deployment of multi-skilled dock workers (exchange of workers between different terminals during a shift), the composition of the gangs, etc.. Terminal operating companies largely rely on permanent dockers paid according to the collective bargaining agreement at company level. Wage differentiation is based on three elements: qualifications, seniority and bonuses/surcharges. The peaks in port demand can be absorbed through casual workers made available via temporary labour offices such as Tense Logistics and Labour Services Zeeland. Casual workers sign contracts with these labour offices and work according to the conditions contained therein (hourly wage, working hours, leave, allowances, etc.). The terms and provisions of the contracts between the casual worker and the temporary labour office apply (such as the start of a shift or shift duration). Permanent and casual dock workers in Flushing and Terneuzen can only be deployed exclusively for water-related tasks. Logistical tasks fall under the collective agreements which are concluded at company level.

7.6. *The Belgian case*

Antwerp, Zeebrugge, Ghent and Ostend, the main seaports of Belgium, are subject to the Act of June 8, 1972 (B.S. 10/08/1972), better known as the Major Act ('Wet Major'). Article one of the Major Act stipulates that only recognized dockers are allowed to perform dock work in the port areas. All cargo handling activities within the port area are considered as dock work, so the Major Act is not limited to the loading and unloading of ships only. Only few exceptions exist to this general rule (for instance in the framework of collective bargaining agreements): the handling of oil products and the treatment of fish brought in by fishing vessels are not subject to the compulsory use of registered dock workers.

Although the above legislation forms the basis for dock work in the Belgian seaports, there are differences among the ports in terms of port labour organization and hiring. This situation is the result of differences in regional and sectoral collective bargaining agreements which are in turn linked to the specificity of each port, its historical background and its labour relations. The collective bargaining agreements are grouped to a larger agreement: the Codex. Antwerp, Zeebrugge and Ghent each have their own Codex. The port of Ostend follows the Zeebrugge Codex. Each codex describes in detail the prevailing labour regulations applicable within the port. The codex of Antwerp is very elaborate. The codex of Zeebrugge/Ostend is rather compact while the code of Ghent is quite extensive for a medium-sized port. Each port-specific Codex contains stipulations on wages and working conditions and also includes a clear description of the geographical area for which the regulations apply. Changes and additions to a port's Codex are the responsibility of the

competent Joint Subcommittee in which representatives of both employers (terminal operators) and trade unions are represented on an equal footing.

The law of July 17, 1985 obliges port companies (who employ dock workers) to join the employers' association of the relevant port: CEPA for the port of Antwerp, CEPG for the port of Ghent, CEWEZ for the port of Zeebrugge and CWO for the port of Ostend. These employers' associations are member of the employer's federation of Belgian ports. The Royal Decree of 10/07/1986 (B.S. 13/08/1986) gave these non-profit associations the exclusive mandate to act for the employers who engage the services of dock workers in the port areas, with the purpose of fulfilling all their obligations arising from this employment pursuant to the application of the labour and social security legislation. CEPA pays all dockers' wages and other benefits in the port of Antwerp, even for regular workers. The other associations do the same in their respective ports. If an employer breaks the Codex, the association imposes a fine. The associations also take responsibility for port-wide training, ensuring high levels of competency across the entire labour force. The training centres offer obligatory professional training courses for newly registered dockers and special schooling for dockers willing to move to another job category.

Employers in a Belgian port have to employ the locally registered dock workers. Casual workers from outside the system can only be deployed in case of shortages of registered dockers (strict conditions apply). Remuneration for dockers is considered high when compared to other industries, but at the same time Belgian dockers are often cited for having a strong record when it comes to labour productivity. Union membership is very high among Belgian dock workers, partly because of the specificities of the process to get recognized as dock worker. BTB, ACV-Transcom and ACLVB are the major trade unions in the context of dock labour. The unions closely monitor the compliance of port operations to legislation and the local Codex. They have adopted a rather pragmatic approach in contract negotiations. The Belgian ports have a long tradition of social dialogue, both via formal and informal channels. In case of disputes, a disputes-resolution procedure sets in to resolve problems.

The increasing specialisation in cargo handling and the growth in port-related logistics activities lie at the heart of dock workers' categories in Antwerp, Ghent and Zeebrugge. Registered dock workers are categorized into two separate groups, namely the General Contingent and the Logistics Contingent (in Antwerp via the law of December 19, 2000 and in Zeebrugge via the Royal Decree of July 5, 2004). Dock workers of the Logistics Contingent perform dock labour in locations where, in preparation of the further distribution or forwarding of the goods, the latter undergo a transformation resulting indirectly in identifiable added value. These latter dock workers are contracted by an employer on a permanent basis. The categorization allowed for separate remuneration conditions, recognition procedures and working conditions for each of the two categories of dock workers as contained in the collective bargaining agreements. A similar arrangement exists in the port of Ghent although the names of the contingents are different.

The General Contingent in Antwerp is composed of (a) regular or permanently employed dockers (dock workers who always work for the same employer) and (b) casual workers. Private operators employ just key workers as regulars, principally to operate specialist equipment and oversee/lead operations. The casual workers form the labour pool. There are four hiring sessions per day for casual workers (day shift, morning shift, afternoon shift and night shift) held at a central hiring hall close to the city centre overseen by government officials. However, about two thirds of all casual dockers are effectively quasi-permanent or semi-regular, working for the same employer on a regular basis via a 'repeat hiring' by a regular employer. Casual dockers value the idea that they can return to the hiring hall whenever they like, even when many of them work as semi-regulars and seldom visit the hiring hall. When demand is low, terminal operators can return surplus dockers to the hiring hall. The guaranteed payments, for casuals dockers and returned semi-regular dockers confronted with a short or prolonged period of unemployment, are mainly financed by the state via an unemployment benefit and partly also by the employers via a special fund. The unemployment benefits system helps dockers who want to work but don't find work, and avoids abuse by dock workers who are not willing to work. The gang system in the port is key to the motivation and productivity of the dock workers. Each gang/team is managed by a foreman. A so-called 'ceelbaas' oversees several gangs working on the same ship. Both the foreman and ceelbaas work on a permanent basis for a certain employer (strong employer alliance) and are also union members. Other job categories for permanent dockers include a.o. the

‘conterbaas’ (responsible for hiring casual dockers), chief-tallyman, assistant chief-tallyman, container repairer and quay crane driver. The job categories of casual dockers include dockers ‘general work’, tallymen, deck men, ‘mineral’ men (for the handling of ores) and several categories of drivers of mechanical equipment. The job categories used in other Belgian ports differ only slightly.

Despite the existence of a common legal framework in Belgium (Major Act), there are quite a number of differences between local port regulations (Codex) as demonstrated by the following examples. First of all, the hiring system for casual dockers differs among ports. For example, employers in the port of Antwerp are bound to fixed shift hours (day, morning, afternoon and night shift) connected to four daily sessions at a central hiring hall. Ghent has two hiring sessions per weekday, Zeebrugge only one. Half shifts or continuous hiring (starting a shift at a preferred moment in time) are not possible in Antwerp. Under certain conditions, half shifts and slight changes to shift hours are possible in Zeebrugge and Ghent. Second, there is the issue of the determination of the number of required registered dock workers. Employers' organizations and trade unions carefully monitor the need for any extension or suspension of recruitment. Particularly in Antwerp, the many job categories of dock workers, the limited mobility between job categories and the fact that dock workers are assigned to the same shift for longer periods of time can complicate matters. A shortage in one job category and shift may not easily be compensated by surpluses in other categories or shifts. Third, there are small differences in the recognition process of new dockers. Fourth, about 85% of the dockers in Zeebrugge work according to a ‘timetable system’. Employers allocate port workers for a certain period. The dockers have to attain an average number of shifts during that period. The remaining 15% of workers have to come to the hiring hall (unemployment possible). Fifth, there are differences in how weekend work is approached (in Antwerp on a voluntary basis).

8. Conclusions

While the economic effects of ports are far-reaching, cargo handling operations lie at the core of the *raison d’être* of ports. The efficiency and effectiveness, with which loading and discharging activities take place in a port, are important to the port’s competitiveness and its ability to generate wider economic effects in terms of employment and value-added creation. Dock labour systems have an important role to play in this context.

Technological advances and scale increases in ship types and terminals, increased containerisation, changes in inland transport requirements, the rise of terminal networks and the functional integration of terminals in supply chain management practices and broader logistics poles have led to renewed market requirements on dock labour. Market players demand a maximization of the performance of dock workers (with an optimization of the direct costs of port work as a prerequisite) and a minimization of the indirect costs of port labour. The response to changing market requirements takes place within a wider setting of legal and social conditions.

Since the 1960s, most ports in North-West Europe have witnessed a decrease or at best a stagnation of the number of dock workers. The organization of port labour and the associated dock labour systems vary considerably throughout Europe. In other words, ports across Europe are different in the way the dock labour system tries to provide an answer to the market needs in terms of flexibility, productivity, quality and cost efficiency of dock workers. The key issues that often appear in labour reform processes relate to the definition of dock work, the legal status of the dock worker, the functioning of labour pools, practical arrangements at the work floor and the categorization and qualification of dock workers.

While the pace of change differs among North-West European ports, there is a general trend towards open and autonomous pool systems with back-up of temporary employment agencies and a general tendency or push from the employers’ side towards continuous working, flexible start times and variable shift lengths. North-West European ports show a rather large variety in the way the respective labour systems deal with the composition of and flexibility within gangs or teams of dockers. One of the foundations for categorization of dock workers is the division between permanent and non-permanent workers. Labour schemes often include a ‘continuity rule’ via the principle of ‘repeat hiring’. Such arrangements created quasi-permanent or semi-regular dockers. Some labour systems rely on a system of job categories of dockers, with varying degrees of

labour mobility between categories. Other employment systems are based on job qualifications, allowing a (casual) docker to be deployed for any dock work as long as he has the right qualification(s).

Labour unions remain very present in North-West European seaports, no matter the dock labour system in place. Social dialogue through effective bodies of joint consultation at the level considered appropriate by the social partners (e.g. regional, national) is considered as the key to a sustainable relation between employers and trade unions.

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Endnote

ⁱ For example, in 2008 there were 8,836 registered dock workers in the Belgian seaports (Antwerp, Ghent, Zeebrugge and Ostend) on a total direct port employment of 108,818 FTE (figures Flemish Ports Commission, 2009 and National Bank of Belgium, 2009). Dock workers thus represent a modest 8.1% of total direct employment in the Belgian seaports. For the individual ports the shares were 10.5% in Antwerp, 1.6% in Ghent, 13.6% in Zeebrugge and 1.4% in Ostend.

How Small and Medium-Sized Ports (SMPs) Compete in Multi-Ports Gateway Regions: The Case Study of Zhuhai Port in Pearl River Delta Region (PRD) of China

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Abstract

This paper focuses on how SMPs can survive and become competitive in multi-ports gateway regions by introducing the case study of Zhuhai Port in Pearl River Delta region (PRD) of China, the most prominent container multi-port gateway region in the world characterized by intensified competition. We will illustrate port hierarchy system and competition in PRD and demonstrate that by transforming the strategic position of Zhuhai port through a differentiated market segment strategy, the construction of a sea-river port to expand the hinterland and the development of specialized docks, Zhuhai port exhibits an external port growth path, which is more applicable for SMPs worldwide. Conclusions are drawn with respect to how SMPs can compete in multi-port gateway regions and improve networking through their internal (based on previous studies on SMPs) and external growth and how they can transform port competition in the region.

Keywords: Pearl River Delta region (PRD), Zhuhai port, SMPs, multi-port gateway

1. Introduction

The new economic background characterized by slower economic growth and highly volatile demand for international trade provides new opportunities for small and medium-sized ports (SMPs) that often are very responsive in dealing with supply chain dynamics and related logistics systems. However, there is no academic work on how SMPs grow and compete in multi-ports gateway regions, a concept introduced by Notteboom (2009; 2010). This paper focuses on how SMPs can survive and become competitive in multi-ports gateway regions by introducing the case study of Zhuhai Port.

Defining SMPs demands a multifaceted approach. Often, the scale or size of a port is measured by the single variable of cargo throughput. Thus, small ports usually refer to ports with a total cargo throughput (volume) below a certain threshold value. Feng and Notteboom (2011) defined SMPs by proposing a seven-dimension method which takes into account the port's competitive position in its port cluster region: (a) volume/market share, (b) international connectivity, (c) hinterland capture area, (d) Gross Domestic Product (GDP) of the port city, (e) GDP of the hinterland, (f) relative cluster position, and (g) logistics and distribution function. Veldman and Bückmann (2003) developed a model on container port competition and port choice in the Antwerp–Hamburg range. The study excluded the port of Amsterdam and Zeebrugge due to their smaller market share. In recent models on port system development, SMPs are seen as instrumental to the “peripheral port challenge” (and thus port system deconcentration, see e.g. Slack and Wang, 2002 and Notteboom, 2005). Moreover, SMPs also function more in “port regionalization” processes (Notteboom and Rodrigue, 2005) and are key to the formation of “multi-port gateway regions” (Notteboom, 2010) characterized by routing flexibility and inter-port competition and coordination. In contrast to bigger ports, small ports show a slightly larger variance in growth rate (Ding, 2005). SMPs develop in an independent way, which requires ports to find their specific competitive advantage, or in a cooperative way, which seeks cooperation with neighboring bigger ports of the same multi-ports gateway region. In competing with bigger ports, SMPs' strategies can

focus on the hinterland connections. Feng and Notteboom (2011) studied the empirical case of Yingkou port in the logistics system of the Bohai Sea of China, which puts Yingkou port into a more competitive position compared to dominant ports in such area. Second, SMPs often look for a cost advantage in specific niche markets. Clark et al. (2001) demonstrated how small ports could compete with big ports in specialized markets. Third, SMPs might also secure growth by serving the dominant ports in the multi-ports gateway region. Such a strategy demands close cooperation between ports.

This paper focuses on how SMPs can survive and become competitive in multi-gateway port regions by introducing the case study of Zhuhai Port in China. In the next section, the paper provides an in-depth analysis on Zhuhai port, which is a medium-sized port in Pearl River Delta (PRD), the most prominent container multi-port gateway region in the world characterized by intensified competition. By transforming the strategic position of Zhuhai port through a differentiated market segment strategy, the construction of a sea-river port to expand the hinterland and the development of specialized docks, Zhuhai port exhibits an external port growth path, which is more applicable for SMPs worldwide. Conclusions are drawn with respect to how SMPs can compete in multi-port gateway regions and improve networking through their internal and external growth and how they can transform port competition in such region.

2. Port Hierarchy System and Competition in Pearl River Delta (PRD) of China

2.1 Seaports competition mechanism in Pearl River Delta region (PRD)

The Pearl River Delta region (PRD) can be defined from two dimensions: the smaller PRD refers to the Guangdong province that is confined to the mainland of China, while the greater PRD refers to the Guangdong province and the SARs of Hong Kong and Macao. In this paper, we adopt the broader PRD concept. The PRD has been the most economically dynamic region creating an economic gateway for China. Manufacturing industry and foreign trade mainly drive the economy in PRD, which drives the fast development of the shipping industry. From shipping perspective, the PRD is characterized by intense port competition with a large number of ports (throughout the paper, ports refer to seaports) vying for the same or neighboring hinterland. Fourteen cities have seaports including Hong Kong and Macao and inland ports are distributed in fourteen cities. Wang and Ng (2009) once proposed the port category by analyzing Chinese ports and their international connectivity, by adopting cases in PRD area, further, ports-foreland system could define port evolution more accurately owing to the more buyer-driven nature of port choice. The inter-port competition between hub ports (Hong Kong, Shenzhen and Guangzhou port) and peripheral ports in PRD also received attention from academic field. (Slack and Wang, 2002, Wang, Wang and Ducruet, 2012). As discussed, port competition has come to the fifth stage of Hayuth Model (1981), characterized of peripheral challenge brought by new emerging ports in the same ports cluster, which was also known as the decentralization stage. In this paper the measurement of port competition in PRD is to compare their volume growth, as well as their connections with international shipping routes and a port's role in this hub-and-spoke system. Most literatures focus on hub ports and how their growth transforms competition in the whole port region; in contrast, research into a small to medium sized port has relatively remained scarce.

The presumption for possibility of a port's development is basic geographical and nautical condition that supports port expansion. In PRD, five deepwater ports are distributed around Hong Kong (Kwai Chung port), Guangzhou (Huangpu and Nansha port), Shenzhen (Yantian, Shekou, Mawan and Chiwan port) and Zhuhai (Gaolan port) and all these ports are located in the centre of PRD (figure 1). For the rest ports, there are 14 shallow-water ports: 11 of these ports are in the west of the PRD serving the hinterland and domestic trade of China. The other three shallow-water ports mainly handle transshipment from Shenzhen and Hong Kong ports. This highly competitive port cluster requires all participating ports, especially the SMPs to develop their specific competitive advantage supporting their survival and growth. In PRD area, 14 ports are our research objective (table 1). In these ports, total cargo volume, cargo traffic in international trade, container traffic data are available in China port year book that is authentic. Accordingly, we calculate the data of cargo traffic in domestic trade and corresponding share.

Table 1: Port Rank, Cargo Volume and Container Traffic in PRD 2010 of Port Cargo Volume

Rank	Port (City/region)	Total cargo volume (A)	Market share (A/1389.07)	Cargo traffic in int. trade (B)	Share of int. trade traffic (B/A)	Cargo traffic in domestic trade (C)	Share of domestic trade traffic (C/A)	Container traffic TEUs in millions (D)
1	Guangzhou	425.26	30.61%	90.93	21.38%	334.33	78.62%	12.70
2	Hong Kong	267.80	19.28%	118.60	44.29%	149.20	55.71%	23.70
3	Shenzhen	220.98	15.91%	171.06	77.41%	49.91	22.59%	22.51
4	Zhanjian	136.38	9.82%	47.60	34.90%	88.78	65.10%	0.32
5	Zhuhai	60.56	4.36%	16.79	27.72%	43.78	72.28%	0.70
6	Dongwan	56.57	4.07%	13.02	23.02%	43.55	76.98%	0.50
7	Jiangmen	49.65	3.57%	4.61	9.29%	45.03	90.71%	0.71
8	Zhongshan	47.98	3.45%	7.29	15.20%	40.68	84.80%	1.25
9	Huizhou	46.73	3.36%	21.14	45.24%	25.58	54.76%	NA
10	Shantou	35.09	2.53%	10.01	28.52%	25.09	71.48%	0.94
11	Maoming	22.84	1.64%	10.70	46.83%	12.14	53.17%	0.04
12	Yangjiang	7.99	0.57%	2.42	30.32%	5.56	69.68%	0.00
13	Chaozhou	6.35	0.46%	3.30	51.90%	3.06	48.10%	0.03
14	Shanwei	4.89	0.35%	0.36	7.39%	4.53	92.61%	0.04
Total		1389.07	100.00%	424.43	30.56%	798.14	57.46%	43.60

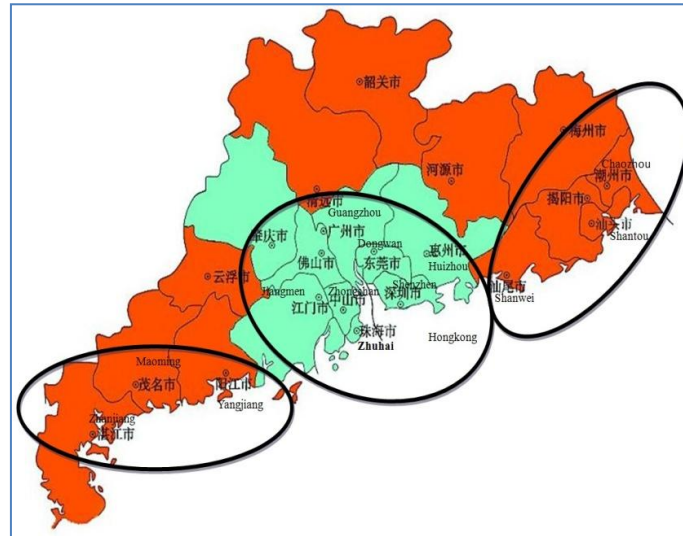
Table 2: Centralization Degree

Rank	Port (City/region)	Market share ¹	Centralization degree ²
1	Guangzhou	36.18%	78.00%
2	Hong Kong	22.78%	
3	Shenzhen	18.80%	
4	Zhuhai	5.15%	22.00%
5	Dongwan	4.81%	
6	Jiangmen	4.22%	
7	Zhongshan	4.08%	
8	Huizhou	3.97%	
total in centre PRD		84.63%	
1	Zhanjian	81.56%	81.56%
2	Maoming	13.66%	18.44%
3	Yangjiang	4.78%	
total in west PRD		12.04%	
1	Shantou	75.73%	75.73%
2	Chaozhou	13.71%	24.27%
3	Shanwei	10.56%	
total in east PRD		3.34%	
total		100%	

Metric tons except noted. Hong Kong: cargo traffic in domestic trade in Hong Kong refers to transshipment. market share ¹: cargo volume in each port / total cargo volume in each region. Source: author's elaboration on China port year book 2011.

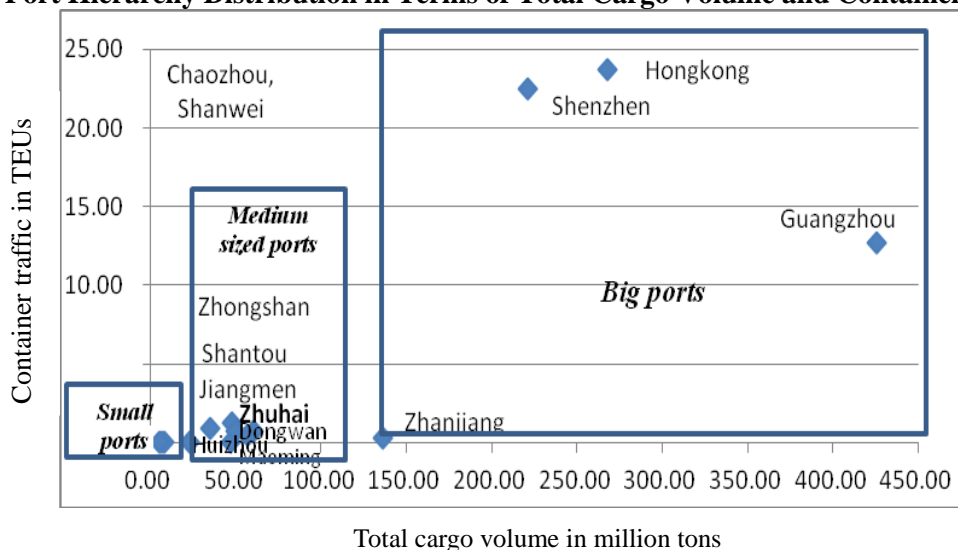
Among all 14 ports in PRD area, three ports (Shantou, Shanwei and Chaozhou) are located in the east of PRD with relatively small market shares; another three ports, including Zhanjiang, Maoming and Yangjiang serve the west of PRD. The rest eight ports compete for the overlapping hinterland in the centre of PRD, as often discussed in academic field. However, centralization degree of these three sub-regions varies (table 2). Centralization of ports competition in three sub-PRD regions is measured by their corresponding market shares in each region. About 84.63% of cargo volume is highly centralized and handled by ports in the centre of PRD, 12.04% in the west and 3.34% in the east respectively. To some extent, SMPs decentralize this concentration. Guangzhou, Hong Kong and Shenzhen, known as hub ports in the central PRD, handle about 78% of cargoes; in contrast, five SMPs take up 22% of the rest market share, averaging of 4% of each. The “periphery challenge” by SMPs can be verified in PRD accordingly.

Figure 1: Ports Distribution in Terms of Geographical Location



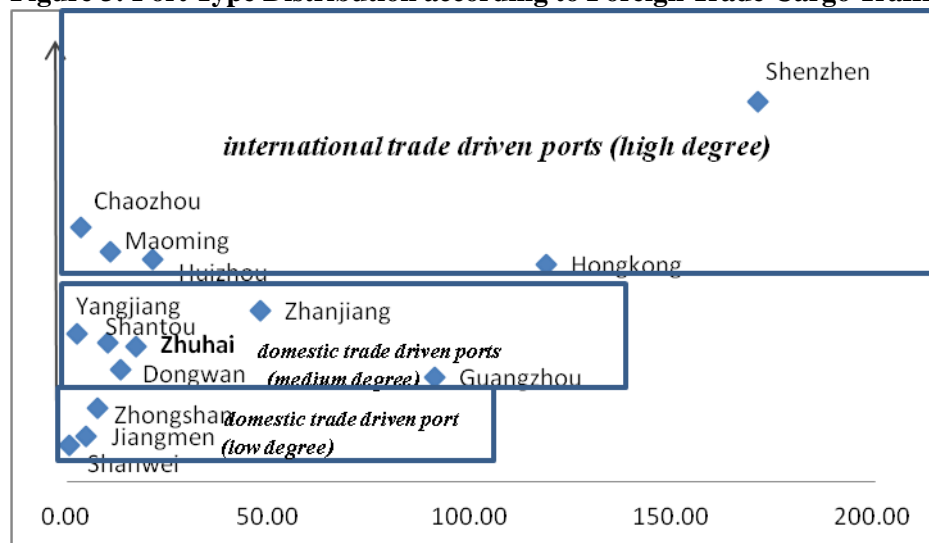
By using two dimensions (X axis as total cargo volume, Y axis as container traffic), we outline port hierarchy system in PRD (figure 2). Top four big seaports are Guangzhou, Hong Kong, Shenzhen and Zhanjiang, among which, the first three ports are well known as hub ports and load centers of PRD, while Zhanjiang, in most literature, is neglected. Guangzhou with 425.62 million tons of total cargo volume is three times of Zhanjiang. The possible reason is why Zhanjiang is hardly discussed is that it locates in the west of PRD and hinterland is southwest of China that are mainly driven by domestic trade, basically, it has no direct competition with other three hub ports. In addition, container traffic in Zhanjiang is quite limited as prevalent researches in PRD ports group focus on containership. We define this layer as big ports group rather than hub ports because indicators we employ can only measure the size of a port. Even Zhanjiang port has occupied 9.82% of total market share in PRD, it can't be defined as a hub port or load centre because it has few connection with foreland or worldwide hub-and-spoke system. These four ports occupy 76% of market share in total freight with high degree of centralization. The second layer is constituted of medium-sized ports in PRD, including Zhuhai, Dongwan, Jiangmen, Zhongshan, Huizhou, Shantou and Maoming. Excluding Shantou and Maoming that are located in the east of PRD, all the rest medium-sized ports are ranging from 46.73 to 60.56 million tons of total cargo volume and their market shares reach to 23% of whole, less centralized and location-distributed compared to big ports layer. The third layer is conceptualized as small ports, including Yangjiang, Chaozhou and Shanwei with 3.34% of total market freight share. Small ports in PRD, especially those ports in the east of PRD receive intense competition with neighboring ports, such as Xiamen in Fujian province.

Figure 2: Port Hierarchy Distribution in Terms of Total Cargo Volume and Container Traffic



If not considering size of a port, we classify ports into three hierarchies from cargo source (figure 3). By measuring level of international trade cargo percentage, Shenzhen, Chaozhou, Maoming, Huizhou and Hong Kong are with high degree of connection with international trade, i.e., highest of Shenzhen with 77.41% and comparatively low of Hong Kong 44.29%. However, we need to draw attention that Hong Kong port in this hierarchy is a special case because the more than 50% of cargoes are for transshipment that still has strong connectivity with worldwide hub-and-spoke system rather than domestic trade. Port competition in this layer is decentralized due to scattered location of each port except for Shenzhen and Hong Kong, i.e., Chaozhou and Maoming are located in west and east respectively, and far from centre of PRD. Even located closely to Shenzhen, however, Huizhou can't compete directly with these hub ports because of its small size. We define the second layer of ports as domestic trade driven ports with medium degree of international connectivity. The hub port in this layer is Guangzhou, with 78.62% of cargo depending on domestic trade. Next to it are Zhuhai and Dongwan. In the west of PRD, Zhanjiang together with Yangjiang deals with average 66% of domestic trade cargoes. Moreover, the third layer composed of Zhongshan, Jiangmen and Shanwei are domestic trade driven ports with comparatively low degree of international connectiveness.

Figure 3: Port Type Distribution according to Foreign Trade Cargo Traffic



2.2 Zhuhai port's role as a SMP in the PRD multi-port gateway region

The role of Zhuhai port in PRD multi-ports gateway region can be defined as a typical SMP that confronts the intense competition from neighboring hub ports, such as Guangzhou, Shenzhen and Hong Kong, as well as small ports. Methodology applied in measuring a SMP will be multiple variables as follows. In terms of each dimension, a port is scored from min. 1 to max. 10 degree.

- Volume/market share (V): total cargo handling throughput within a port and its market share in multi-port gateway region
- International connectivity (I): ratio of international trade cargo to domestic trade cargo, and numbers of shipping routes (international)
- Hinterland capture area (H)
- Gross Domestic Product (GDP) of the port city (GP)
- GDP of hinterland (GH)
- Relative port cluster position (R): frequency of calling ports, number of shipping routes and transshipment and container shipping freight
- Logistics and distribution function (L): numbers of inland port, distribution centre, intermodel connectivity

By applying the total cargo handling throughput, Zhuhai port ranks 5 in total 14 ports in PRD (table 1) functioning as a medium-sized even big port. However, if we apply market share indicator measuring the scale

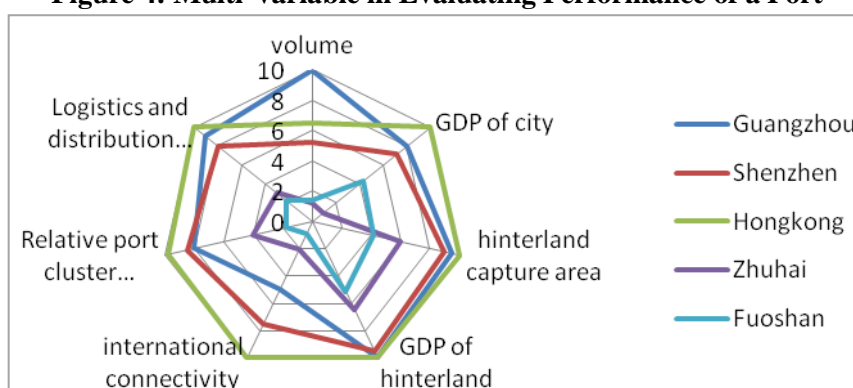
of a port, we will find that Zhuhai port can only be classified as a SMP. Zhuhai port's cargo throughput is 60.56 million tons, which is one-seventh of freight in Guangzhou. Although it is one of the top five ports in PRD, but compared with the first four ports in terms of total cargo volume, Zhuhai port's distance with those ports is too much to be named as a big port. Besides, container throughput in Zhuhai port is below the average level as most cargoes handled by Zhuhai are in bulk. The reason is Zhuhai port's intention to decrease operating cost and compete with other ports in form of bulk cargo rather than containership and most newly built yards and berths serve for bulk shipping only.

International connectivity usually describes a port's handling capacity in terms of international trade cargo and its connection with foreland. In terms of international trade cargo handling, about 27.72% of cargos depend on international trade of Zhuhai port with 16.79 million metric tons. This illustrates that Zhuhai port depends most on domestic trade in China and lack of utility of its seaborne resource despite of good access to global spoke-and-hub system. A port's international connectivity can be also measured by international shipping routes, taking Hong Kong, Shenzhen and Guangzhou ports for instance, until now three ports obtain 450, 186, 40 shipping routes respectively, while Zhuhai port started managing the first international shipping route (between South America and Zhuhai) in March 2010 and until now has been operating two international routes.

Thirdly, hinterland of Zhuhai port usually refers to Zhuhai city and west area of PRD. Zhuhai city serving as the direct hinterland of Zhuhai port is the smallest city in Guangdong province, in 2011, GDP of Zhuhai city ranks 8 among 9 cities in PRD. Despite of the fact that Zhuhai is one of cities with high foreign trade dependence, dominating industries in Zhuhai is hi-tech industry instead of manufacturing, which produces less demand for Zhuhai port. Moreover, economy in the west of PRD is less developed compared to the central area. Fourthly, SMPs' function in multi-ports gateway regions can be identified by relative cluster position. We adopt the total shipping routes and frequency of calling ports to evaluate their position in competing with other ports. Until 2011, Zhuhai port has four domestic trade and two international shipping routes, much less compared to adjacent hub ports, even less than neighboring SMPs of Dongwan. In competing with other ports, Zhuhai lacks competitiveness in container shipping. In addition, most containers are sub-transshipment from Hong Kong. Even in the background that manufacturing industries in PRD will be internally shifted to more inland areas, Zhuhai's geographical location determines it can't compete with Guangzhou or Dongwan that are closer and more convenient to middle inland area of China.

The last dimension is logistics and distribution function that connects a SMP and hinterland and may expand or restrict s SMP development. Among all ports in PRD, Zhuhai port together with Shenzhen port, have no river transport function to distribute cargo to inland area even Zhuhai port is close to Xijiang river. However, Shenzhen port can depend its solid land transportation and better access to neighboring hinterland, while there is almost no railway around Zhuhai port and several new-launched hi-speed roads are still on construction. The distance between deep-water port (Gaolan port) and Zhuhai city (direct hinterland city) is longer than average distance in other cities, while the lack of land logistics distribution system, to some extent, restricts the cargo transportation between Zhuhai port and hinterland. General evaluation in this multi-variable method referring to Zhuhai port is comparatively low in comparing to neighboring big ports. (Figure 4).

Figure 4: Multi-Variable in Evaluating Performance of a Port



3. Zhuhai Port Competition Strategy

Port competition strategies vary in hub ports and SMPs. Hub ports can seek greater operational coverage & economy of scale by deploying bigger vessels and constructing new container yards, as well as increasing frequency of liner schedule. In theory, ports owned by the same port authority won't be considered with inter port competition, i.e. Shenzhen, now owns four container ports, Yantian international container terminals (YICT), Shekou container terminals (SCT), Chiwan container terminal (CCT) and Da Chan bay (DCB). Even operated by different operators, these ports serve clear-differentiated functions and don't form competition. This strategy is to maximize market share, as well as economy of scale. However, SMPs, due to size and investment limit, are unlikely to deploy this strategy. Most SMPs in PRD, as discussed in previous section serve as specialized port and seek cost advantage in port competition. By introducing case of Zhuhai port, we analyzed how a port strategy could enhance competitiveness and increase port choice in multi-ports gateway region.

3.1 Methodology

Law of universal gravitation (eq.1) is to describe the attractiveness between two masses. However, a port's potential to attract cargo is determined by multi-variable rather than single. Therefore, here we made some adjustments on this equation with the aim to measure how a SMP could survive in a multi-ports gateway region and how corresponding strategies are employed.

$$F = g \cdot \frac{m_1 \cdot m_2}{p^2} \quad (1)$$

where: F is the force between the masses; g is the gravitational constant; m_1 is the first mass; m_2 is the second mass; p is the distance between the centers of the masses. By transforming the Eq. 1, we'll get Eq.2. It describes freight of a port is determined by attractiveness between port and cargo and distance in between two locations.

$$F_{i,j,p} = k \cdot \frac{P_i \cdot C_{j,p}}{d_{i,j}^x} \quad (2)$$

$F_{i,j,p}$: freight of port i to attract cargo p from j venue;

k : constant; P_i : port i ($i=1,2,...n$); $C_{j,p}$: cargo p from j venue ($p=1,2,...n, j=1,2,...n$)

$d_{i,j}$: distance from j venue to choose port p ;

$d_{i,j}^x$: effectiveness of distance from j venue to port p , $x = x_1, x_2, ..., x_n$;

$$d_{i,j}^x = TLC_{i,j}^x \quad (3)$$

$TLC_{i,j}$: total logistics cost from j venue to port p , here total logistics cost contains multi-model costs: cost in land transportation and cost in seaborne side.

By integrating seven-dimensions variable $f(I, H, GP, GH, R, L)$ in the above section and formula of Eq.3, we can get the formula (4) as:

$$F_{i,j,p} = k \cdot \frac{f(I, H, GP, GH, R, L)}{TLC_{i,j}^x} \quad (4)$$

Attractiveness of cargo to a port is illustrated in Eq. 4. As explained the second section, each port will be assessed with seven-dimension variables and marked from 0 to 10 degree, while total logistics cost in the whole process of transportation plays as a negative factor in port choice.

For each port, it serves certain function, thus in a result, weight of each variable will vary. For instance, Zhuhai port, most freight are from domestic trade, in competing with other foreign trade driven ports, Zhuhai port has no competitive advantage. Besides, cargoes handled by Zhuhai port come from wider hinterland area, such as Zhongshan city, rather than direct Zhuhai port city, therefore it increases TLC of Zhuhai port. As a result, variable of R and GP are neglected in evaluating port attractiveness of Zhuhai port. The equation is as:

$$F_{i,j,p} = k \cdot \frac{f(H, I, GH, L)}{TLC_{i,j}^x} \quad (5)$$

Four factors determine function more in Zhuhai port's role in PRD region: hinterland capture area (H) and GDP of hinterland (GH), international connectivity (I) and logistics system (L) of Zhuhai port. TLC, as a common factor, also affects Zhuhai port cargo attractiveness.

3.2 Zhuhai port competition strategy

Most inter-port competitions in multi-ports gateway region are for: first, the competition over hinterland or cargo resource. Due to the geographically adjacent location and containerization management of the port, SMPs confronts more intensified competition directly from neighboring big ports. SMPs without advantage of location will serve only as assisting or feeder ports to hub ports, as a result, need for securing and maintaining stable and cargo plays a key in SMPs' strategy. In PRD, the overlapping hinterland in the southeast of China serves port of Hong Kong, Shenzhen and Guangzhou, as well as Zhuhai and other SMPs. Most cargoes are manufactured in this area and transported for export. The newly built Nansha (Guangzhou) port is located at the estuary of Pearl River trying to capture cargo in Zhongshan, which is the neighboring city to Zhuhai. If expanding hinterland, Zhuhai has no advantage in either nautical location or size of the port in contrast to hub ports. However, Zhuhai's easier accessibility to hinterland can be realized by following strategies: river-sea connection and city-synchronizing (Zhuhai and Zhongshan city) strategy (Gu, 2011, Sun, 2010, Wang & He, 2011). To identify hinterland for Zhuhai port, it could utilize the advantage of connection with Pearl River (four estuaries of Pearl River are around Zhuhai port) that will provide more than 60 waterways for river shipping and create connection between river and sea shipping. River-sea strategy that exploits the intermodal transportation functions of Xijiang River (inland connection) by connecting west of Guangdong province, with which Zhuhai port could avoid the lack of multi-model transportation system and relatively short of sea transportation demand directly from Zhuhai city. Until 2011, "Xijiang river strategic alliance", led by Zhuhai port, has come into establishment. The partners include six port authorities along the river, three shipping lines in charge of liner and short-sea shipping and feeder shipping, two terminal operators providing cross-port terminal operating services, one logistics company responsible for land transportation along Xijiang River, one shipping investment company and one pharmaceutical company. Furthermore, river-sea strategy will help Zhuhai port expand hinterland to the west of PRD, where coal and petroleum are exploited, moreover, it will connect Zhuhai port with CAFTA (China and ASEAN Free Trade Area), the cargo exported from ASEAN area could be shipped by Xijiang River to Zhuhai port and distributed to other areas. When employing this strategy, Zhuhai port is also establishing its own feeder companies and trying to form monopolistic position and first-mover advantage as Xijiang River channel is still at the start of construction. The problem of hinterland extension may introduce future possible competitors, such as Saigon (Vietnam).

The other way to capture hinterland is by adopting city-synchronizing (Zhuhai and Zhongshan city) strategy. Zhuhai port's handling capacity is limited by lack of logistics support; in addition, GDP of Zhuhai city is rather small. City-synchronizing strategy by "borrowing" the manufacturing industry advantage of neighboring city, Zhongshan, further to Jiangmen (triangle in fig.1), can avoid the above restrictions. Zhuhai, together with Zhongshan and Jiangmen, is along Xijiang River. Although Zhongshan has its own seaport, the shipping capacity is limited to 1,000 tons due to the lack of deep-water condition, and ships over 3,000 tons can pass only with waiting for tide time; in contrast, Zhuhai port is one of deep-water ports in PRD. Besides,

bonded area in Zhongshan can function as important distribution node in the whole logistics system around Zhuhai port. The domestic cargo volume between Zhongshan and Zhuhai port can be regarded as “intra-yard transportation” with reinforcing more convenient agreement and efficient customs clearance for foreign trade cargo. As introduced, Zhuhai port is a domestic trade-driven port but with medium level of international connectivity, while Zhongshan and Jiangmen depend less on international trade, thus, strategic alliances in between adjacent ports is seen as a counter-strategic option against their counterparts. If we look at PRD multi-ports gateway region, city-synchronizing strategy of Zhuhai port can avoid direct competition with hub ports like Shenzhen, Hong Kong and Guangzhou. In general, Zhuhai port can maintain four layers of hinterland, direct port city (Zhuhai city); while by adopting river-sea strategy, hinterland expands to cities along Xijiang River, furthermore, city-synchronizing strategy will broaden hinterland to cover most west areas in PRD. The maximum hinterland that Zhuhai port could achieve is between China and ASEAN Free Trade Area. This strategy can also increase Zhuhai port’s competitive advantage in international connectivity. Alliance with adjacent cities of Zhongshan and Jiangmen may strengthen Zhuhai port’s competitive advantage in intermodal transportation. Compared to location of Zhuhai city, the other two cities are more close to inland area. If choosing inland connection node, it’s better to be in these cities rather than Zhuhai city. Furthermore, Hong Kong-Zhuhai-Macao Bridge will accelerate the cargo transferring between Hong Kong and Zhuhai, thus form foreland for Zhuhai port and expand its international connectivity. The other strategy is to concentrate on specification niche markets such as tanker, bulk, etc. transportation in Zhuhai port.

Table 3: Cargo Traffic and Maximum Operating Capacity of Zhuhai Port in 2010

	Ore	Coal	Oil	Container (1000 TEUs)
Maximum loading and unloading capacity	1. 82	8. 64	26. 18	139
Cargo traffic	2. 6588	13. 2433	12. 0999	70.27

Metric tons except noted. Source: Author’s elaboration of the Zhuhai port annual report 2010 By analyzing the cargo category of Zhuhai port, ore and coal traffic volume exceed the maximum transportation capacity (table 3), while containers and oil account for half of the maximum capacity respectively. Obviously, Zhuhai port’s specification should focus on ore and coal transportation and manage the empty capacity for oil and container. By focusing on specification, Zhuhai port could save cost and investment in terminalization process. Moreover, terminal operating efficiency plays a more important role in SMPs compared to big ports. For this reason, SMPs usually depend on big terminal operators. For example, at early stage of development, Zhuhai port cooperated with Hutchison (Hong Kong) to operate terminal with the aim to utilize Hutchison’s international resource and learn advanced terminal operating experiences, but at the beginning of their cooperation, Zhuhai port, as a SMP, is regarded as a quite small even sunk investment among Hutchison’s international operating business. To better utilize Hutchison’s operation services, Zhuhai port find “more than single big clients” to ensure regular liner schedule and stable cargo volume. To some extent, these joint clients also increase Zhuhai port’s market power in cooperating with Hutchison. For example, Sinopec Group (China) agrees to invest in Zhuhai port and provide more than half of oil traffic annually, which buffers the impact of external downturn. The partnership with big clients by SMPs may produce another dilemma that SMPs only obtain small bargaining power due to their small size, thus the port authority usually cooperates with more than one big clients in the same context to increase market power.

4. Conclusions

Ports competition in PRD is experiencing plausible paradox process, impeded with both centralization and decentralization. Centralization exists in each independent layer of big ports (hub ports), medium-sized ports and small ports. However, we didn’t see a clue that the incumbent SMPs can threaten the dominant position of hub ports, i.e. Shenzhen challenges Hong Kong ports in hub port position, but few data supports that the SMPs around Shenzhen threaten its dominant role. Even SMPs are expanding their market shares in total cargo volume, the neighboring ports, i.e. Guangzhou and Dongwan, Shenzhen and Zhuhai have differentiated port functions either serving international trade or domestic trade. This “inbetweeness” phenomenon is more obvious from geographical point of view. In the centre of PRD, centralization degree is much higher in

contrast to the east and west. Ports in the east of PRD are average small to medium size and the market is rather decentralized, while in the west of PRD, polarization of Zhanjiang is emerging with high degree of centralization. Reasons behind are quite different. Ports in the east of PRD receive intense competition from neighboring hub ports in Fujian province. In comparison, there is no external port competition in the west of PRD. This “inbetweeness” phenomenon has been transformed since 2011 because external demand from European and American market is volatile and ports previously depending on international trade are endeavoring for capturing domestic trade cargos. Moreover, the increasing labor and resource cost in the southeast of China force more Chinese companies, as well as joint ventures moving their factories to more inland area. From institutional view, Chinese government initiated policies in stimulating domestic demand. All these factors will complex ports hierarchy system in PRD and the current competition lays may be broken, as SMPs will receive more challenges from hub ports that previously handle international trade cargoes.

To identify SMPs in multi-ports gateway regions employs multi-variable method. In this paper, SMPs share certain similarities that are generally with highly international dependence and low level in container traffic. Being in a disadvantageous position in terms of cargo volume, SMPs’ capture for cargo or hinterland usually depends more on their institutional reform, especially with reinforcing certain competition strategies and agreements, SMPs can find niche market while avoiding direct competition with dominant hub ports. However, these strategies are more dynamic and environment derived. In addition, the growth and evolution of SMPs in a region will either drive the port cluster to a more bonded group or intensify the competition. In this paper, we defined Zhuhai port by seven indicators. It illustrates the characteristics of Zhuhai port in competition and major barriers restricting its evolution into advanced level. We proposed ways for Zhuhai to enhance competitiveness through river-sea intermodal strategy, city-synchronizing and specialization. To decrease TLD’s negative role in port choice, Zhuhai port improves its efficiency through intra-port strategies usually referring to the cooperation between port authority and terminal operator or shipping lines. However, the generalized application of these strategies needs to be justified by including more cases. Accuracy of equations and concept of TLCs employed in this paper also needs future tremendous research, especially quantitative methods to identify weight of each factor and their influence on SMPs.

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Identifying Crucial Sustainability Assessment Criteria for International Ports

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Abstract

The objective of this research is to identify crucial sustainability assessment criteria in the context of international port sector. Data collection was based on a questionnaire survey from 135 managers and supervisors at major international ports in Taiwan including Keelung, Taichung, and Kaohsiung. A total of 31 important sustainable assessment criteria were adapted from previous studies in terms of environmental, economic and social issues. Results revealed that social issues with respect to staff job security and safety was ranked as the most important sustainability assessment criterion, followed by environmental protection when handling cargo, facilitation of economic activities, port traffic accidents prevention, and cargo handled safely and effectively. In contrary, respondents revealed their less importance in the criteria, namely, mitigating light influence on neighboring residents, considering the arrangement of vehicles when constructing port transportation system, avoiding using unpolluted land in port area, hiring minority groups and consulting interests groups when making port projects. Four sustainability assessment dimensions were identified, namely: environmental material, economic issue, environmental practices and social concerns. The research findings indicated that economic issue was deemed as the most important dimension of sustainability assessment criteria from a port operator's perspective, followed by environmental practices, social concerns and environmental material. Practical implications for port sustainability assessment were discussed in this research.

Keywords: Sustainability Assessment, Port, Factor Analysis,

1. Introduction

With the rapid development of economic activities and unlimited-waste of natural resources, the environment where we dwelled is facing serious deterioration. Consciousness of environmental protection has dramatically raised by government and enterprises over the past decades. World Commission on Environment and Development (WCED) has been addressed growing concerns on the deterioration of the human environment and natural resources, and the consequences of that deterioration for economic and social development in the Brundtland Commission in 1987 (World Commission on Environment and Development, 1987). In addition, an important decision from the UN climate change conference held in Copenhagen, Denmark in 2009 required developed countries to facilitate regulations or laws for decreasing the total amount of emission of carbon dioxide (The UN Global Compact, 2010). Also, the issues of labor safety and community development had drawn much attention and been discussed in the conference. In 2009, 106 UN members have been recognized to establish their national sustainable development policies (The UN Global Compact, 2010). Therefore, business organizations play an important role towards ensuring sustainability includes environment, social,

and economic.

Ports stand at a vital position between sea and land transportation of a crucial role of supply chain, in which a large number of people and operational activities involved. Waterborne commerce is increasing rapidly and presenting ports with challenges that could not have been imagined even two decades ago. In 2011, the total volume of cargo shipped by sea reached 16,786 millions of tons and is double that of 1990 volumes (UNCTAD, 2011). To accommodate increases in trade volume, increases in the size of cargo and ships, and services requirements, many ports are investing billions of dollars in infrastructure improvements such as deeper channels, larger cranes, and other facility and property enhancements. While many of these investments facilitate improvements in the operational efficiency of existing port operations, many ports also need to physically expand to meet business demands. Even the ports that have traditionally viewed themselves as environmental stewards of coastal resources are finding it challenging to balance economic, environmental, and social issues, i.e., to grow sustainably.

Since port corporations are main operators, an understanding of port operators' sustainability can provide useful information for government to establish criteria to enhance sustainable development. Nevertheless, sustainability assessment measurement is problematic due to the difficulty of assessing and measuring port accidents or incidents in complex environments. There seems no single measure of sustainability assessment or performance that is unambiguous and wholly resistant to abuse. Therefore, the perceptions of port operators, such as managers, supervisors, and senior employees, can offer an alternatives means for assessing sustainability in the port sector. Accordingly, the objectives of this study are to provide an empirically validated approach to identify sustainability assessment criteria in the international port context and to ascertain whether differences exist between ports.

This research focuses on major international container ports in Taiwan. Taiwan is an island-economic entity which is highly dependent on foreign trade. Efficient maritime transport and port operation are essential for ensuring the development of economical activities. According to the Ministry of Transportation and Communications (2012) in Taiwan, more than 99 percent of annual trade is carried by maritime transport and handled through sea ports. Taiwan's international commercial ports, which originally were administered by the four Port Authorities (Keelung, Taichung, Kaohsiung, Hualien) to the Ministry of Transportation and Communications of the R.O.C., fulfilled the responsibilities of operating port and exercising the public power of shipping, navigation and harbor. In order to enhance the competitiveness of Taiwan's international commercial ports, Maritime and Port Bureau, MOTC and Ports Corporation came into being respectively, which the former takes charge of the public power of shipping, navigation and harbor, and the latter is in charge of port operation on March 1 2012. Maritime administration covers both administrative supervision and operations. The mission of the Maritime and Port Bureau (MPB) under the Ministry of Transportation and Communication (MOTC) is to enhance the competitiveness of Taiwan's international commercial ports, instill entrepreneurialism into operations, and realize government reorganization priorities. The MPB handles Taiwan's maritime and port affairs. Its former authority over Taiwan's several Harbor Bureaus has been reassigned to the new Taiwan International Ports Corporation (TIPC). TIPC' four subsidiaries include the former port authorities of Keelung, Taichung, Kaohsiung and Hualien. The company is tasked to handle comprehensive port operations, enhance operational efficiencies and responsiveness, raise the international profile of Taiwan's international commercial ports, and economic growth.

There are five sections in this study. After the introduction section to the study, a review of the literature on criterion of sustainable assessment is presented in Section 2. Section 3 describes the research methodology, including questionnaire survey, sampling technique, and analysis methods. Section 4 presents the analytical results of important sustainable assessment criteria. Conclusions drawn from the research findings and their implications for port operation corporations are discussed in the final section.

2. Literature Review

2.1 Definition of sustainability

The definition of sustainability had been developed by many of researches. In 1987, UN conference defined sustainability as those that "meet present needs without compromising the ability of future generations to meet their needs"(WECD, 1987). From IUCN, UNEP, WWF (1991), sustainability was defined as "Improving the quality of human life while living within the carrying capacity of supporting ecosystems". Pronk and Haq (1992) suggested that sustainability is to provide a fair opportunity to achieve economic growth, which without further depleting the natural resources and environmental capacity, for the whole human beings but not for some particular interests groups. Pezzey (1992) utilized cost/benefit analysis to evaluate environmental policy for enhancing the protection of environment and the welfare of human beings. UNCSD (1993) indicated that human beings possess the right of living in a way of harmonious to enjoy the healthy and wealthy and to meet the requirement of developing and environmental protection in all generations. Pearce and Warford (1993) indicated that developing sustainability can ensure the increasing of this generation and simultaneously not decrease the welfare of next generation.

Accordingly, sustainability means under the principle of not exceeding the capacity of environment, avoiding the depletion of natural systems and resources, both on quality and quantity to pursue the sustainable development by enhancing the efficiency of technology, society and economic effects. Sustainability provides an integrated framework which not only including environmental policy, but also the development to improve the welfare of human beings in the whole eco-system.

2.2 *Sustainability assessment criteria*

A number of international organizations (e.g. The UN Global Compact, OECD, The OECD Guidelines for Multinational Enterprises) have proposed the relevant principles. Sustainability assessment criteria with respect to environmental, safety and regulation have been developed by international ports. The ISO (International Standard Organization) 14001 evaluated sustainability from five major factors, namely, environmental policy, evaluation of environment, regulation and self-evaluation mechanism, management system and organizational auditing and reporting system(ISO, 2011). However, the assessment is inconsistent among those countries. Previous studies on sustainability assessment have focused on the aspects of environment and security. Social responsibility also need to be considered, includes the issues of human right, labor interests and social involvement (Marlow, 2008). ISO proposed eight aspects to investigate the effects of social responsibility which consist of human right, work place and staff (safety and security) anti-competing affairs, bribing, corruption, organization government, environment, marketing and consumer issue, community involvement, and society development (McIntosh et al., 2003). Accordingly, sustainability assessment can be evaluated includes three dimensions, namely, economical, social and environmental issues.

2.3 *Sustainability assessment criteria in the port sector*

Several international ports have formed roles and principles for developing sustainability. Sydney ports corporation of Port of Sydney proposed sustainable development projects focusing on consumption of resources (e.g. selection of material, waste management, control of water consumption, control of energy, traffic) and quality of environment (indoor environment, emission control, water quality, land utilization, environmental management) in port areas. Port of Los Angeles set up "sustainability assessment and plan formulation" to concern the impacts of port operation on environment, personnel and surrounding environment, whereas, Port of Long Beach developed eight major objectives for executing the sustainability assessment. The UK department of Transport of indicated that the proceeding of port sustainable development policy was classified into three steps in its "National Policy Statement for Ports in 2009. These steps include sustainable policy set up background and goal, definition of sustainable development, and identify major crucial sustainability assessment issues.

Seuring and Muller (2008) found previous studies primarily focus on environmental issue, there seems relative little research have simultaneously considered these three sustainable dimensions such as environmental, social and economical concerns. In the aspect of environmental issue, the related assessment items include air quality, green gas emission, soil and land resources, waste and recycling, coast line sightseeing, lighting, noise, creature diversity, CO2 emission, climate change, water quality. Regard to the economical issue, consists of assessment items such as the benefits of port operators, economic activities

development, fair competition, infrastructure construction, employment and local development, leisure and tourism and investment. As for social issue, assessment items relevant to population, port accessibility, security and safety, neighboring interaction and communication were emphasized. Accordingly, a total of 31 important sustainable assessment criteria were adapted from previous studies which were divided into environmental, economic and social dimensions were used in this study.

3. Methodology

This research was accomplished by conducting a questionnaire survey. First, the selection of sustainability assessment criteria by referring to the literatures and on sustainable development researches and reports (Department of Transport (UK), 2009; Marlow, 2008; OECD, 1994; OECD, 1990; Pearce & Warford, 1993), followed by the design of the questionnaire, personal interviews with port managers. The questionnaire design followed the stages outlined by Iacobucci & Churchill (2010). Information sought was first specified, and then the following issues were settled: type of questionnaire and its method of administration, contents of individual questions, form of response to and wording of each question, sequence of questions, and physical characteristics of the questionnaire. Moreover, the content validity of the questionnaire in this study was tested through a literature review and interviews with 10 port managers who worked at Taiwan International Port Corporations. Interviews with practitioners resulted in minor modifications to the wording and examples provided in some measurement items, which were finally accepted as possessing content validity. For each item, respondents were asked to indicate the extent to which they agreed the item described its prospective content domain. A five-point rating scale was used for each item (1 = very unimportant, 2 = unimportant, 3 = neither agree nor disagree, 4 = important, 5 = very important) to identify the ranking of importance of perceived sustainability assessment criteria. The analysis was carried out using the SPSS 18.0 for windows statistical packages.

The study population comprised managers or supervisors in three major international container ports in Taiwan. The directors for these three major international ports were from Keelung, Taichung, and Kaohsiung in Taiwan. A total of 300 questionnaire survey (each port sent 100 copies) was sent to managers or supervisors of these three port corporations in June 2011. Non-response test was conducted to ensure the valid representation of returning questionnaire to population (Armstrong and Overton, 1977). The result revealed the chi-square was not significant among all variables (occupation, title, department, seniority), which stand the sample in this study can represent the research population. Keelung port returned a total of 37 questionnaires, 36 questionnaires were returned from Taichung, and 62 questionnaires were returned from Kaohsiung. Ultimately, the total usable responses were 135 out of 300 and the overall response rate for this study was approximately 45 percent.

Several research methods were employed in this study. Descriptive statistics and exploratory factor analysis was conducted in order to identify and summarize a large number of sustainability criteria into a smaller, manageable set of underlying factors or dimensions (Hair et al., 2010). Further, a reliability test was conducted to assess whether these safety dimensions were adequate. Confirmatory factor analysis (CFA) was then conducted to verify measurement models. This involved the use of structural equation modelling software AMOS 18.0 to analyze measurement models, assess psychometric properties, and to specify relationships among the latent variables and the proposed measures. Finally, ANOVA was used to examine whether difference existed between three international ports of the level of importance of the sustainability assessment dimensions.

4. Results of Analyses

4.1 Profile of respondents

Results of respondents' profiles and characteristics showed a vast majority of survey participants (53.3%) were supervisors, followed by first line managers (29.6%) and 14.1% were senior supervisors. Only a few respondents held the positions of director/vice director (1.5%) and Chief secretary/Chief Engineer/harbor master (1.5%), respectively. This study attempted to evaluate the importance of perceived sustainable criteria in all aspects of sustainable dimensions, therefore, the views of managers or supervisors were considered more

useful than those of managers, director/vice directors or above.

Descriptive results indicated that a majority of respondents (59.5%) served more than 20 years in port, whereas 31.9% of respondents have been working between 15 to 20 years. Only 8.6 % of respondents have been working in ports less than 10 years. Furthermore, the results also revealed that 40.8% of respondents had worked in operation relevant departments, whereas 12.6% of respondents served in warehousing department, 11.1% in secretary department, 9.6% in harbor affairs department, 8.9% in information department, 6.7% in harbor construction department, 4.4% in human resource department , 3.7% in navigation administration, and 2.2% in research department.

4.2 *Relative importance of port sustainability assessment criteria*

This study investigated crucial port sustainability assessment criteria among three sustainable dimensions, namely, economical, social and environmental. Respondents were asked to provide information about their perceived sustainable criteria. 31 perceived sustainable criteria were ranked. According to their aggregated scores for agreement with the 31 sustainable criteria, respondents' perceptions ranged from 3.56 to 4.56, which suggested that the issues of sustainability are very important in port operations (see Table 1). Results revealed that social issues with respect to staff job security and safety was ranked as the most important sustainable assessment criterion, followed by considering environmental protection when handling cargo, facilitating to economic activities, port traffic accidents prevention and ensuring cargo handled safely and effectively, since these items' mean scores were over 4.48.

In contrast, respondents showed their less importance in the five sustainable items, namely, mitigating light influence on neighboring residents, considering the arrangement of vehicles when constructing port transportation system, avoiding using unpolluted land in port area, hiring minority groups, and consulting interests groups when making port projects, which their mean scores were below 3.7. Accordingly, the research finding reflect that port corporations have emphasized on the sustainability assessment criteria such as staff work environmental safety and impacts on environment when handling cargo in port operations.

4.3 *Factor analysis and reliability test*

This study used a factor analysis method to summarize a large number of sustainability assessment criteria into a smaller number of underlying dimensions called critical factors. VARIMAX rotation technique was applied to transform a set of interrelated variables into a set of unrelated linear combinations of these variables. The data were deemed appropriate for analysis, according to the Kaiser-Meyer-Olkin sampling adequacy value of 0.918 (Hair et al., 2010). The Bartlett Test of Sphericity was significant ($\chi^2 = 4,104$, $P < 0.00$), and well above the recommended level. Only variables with a factor loading than 0.5 were extracted to aid interpretation (Hair et al., 2010). Having eigenvalues greater than one was used as the criterion to determine the number of factors in each data set (Iacobucci and Churchill, 2010). In addition, a reliability test based on Cronbach's α was employed to test the internal consistency of questionnaire responses. The larger the absolute size of the factor loading, the more important the loading is in interpreting the factor matrix. However, the interpretability of this solution was rendered problematic due to one items being loaded on two factors, and their factor loading being less than 0.5. This items, which was subsequently removed from further analysis, was "considering the arrangement of vehicles when constructing port transportation system".

Table 1: Importance of Port Sustainability Assessment Criteria

Port sustainability assessment criterion	Mean ¹	S.D ²	Rank
Staff job security and safety	4.56	0.73	1
Considering environmental protection when handling cargo	4.55	0.71	2
Facilitating to economic activities	4.50	0.72	3
Port traffic accidents prevention	4.48	0.70	4
Ensuring cargo handled safely and effectively	4.48	0.74	5
Ensuring port area safety and orders	4.44	0.71	6
Developing approaches against rapid climate change	4.43	0.82	7

Disposing of effluents	4.39	0.73	8
Establishing port development funding	4.35	0.77	9
Maintaining air quality	4.33	0.76	10
Strengthening port infrastructure construction	4.32	0.85	11
Concerning on benefits of port operators	4.31	0.70	12
Offering employment opportunities	4.27	0.77	13
Maintaining water quality	4.22	0.83	14
Decreasing green house gas emission	4.18	0.87	15
Landscape improvement	4.16	0.76	16
Encouraging foreign direct investment (FDI)	4.13	0.84	17
Flood avoidance in land side operation area	4.07	0.91	18
Avoiding environmental destruction when dredging	4.05	0.85	19
Decreasing noise pollution	4.04	0.90	20
Using environmental-friendly material in port construction	3.97	0.92	21
Encouraging using recyclable material	3.96	0.86	22
Supporting tourism industry development	3.93	0.87	23
Ecological environment protection in port area	3.90	0.91	24
Recognizing requirements of neighboring community	3.88	0.81	25
Historic relics protection	3.71	0.92	26
Mitigating light influence on neighboring residents	3.70	0.93	27
Considering the arrangement of vehicles when constructing port transportation system	3.64	0.89	28
Avoiding using unpolluted land in port area	3.64	1.09	29
Hiring minority groups	3.62	0.79	30
Consulting interests groups when making port projects	3.56	0.83	31

Note: 1. The ratings were based on the mean scores obtained from a Likert scale ranging from 1 (very unimportant) to 5(very important). 2. S.D. = standard deviation.

Subsequent analysis of the 30 remaining items yielded four factors or dimensions, which accounted for approximately 64.251 % of the total variance. A reliability test based on a Cronbach's Alpha statistic was used to test whether these factors were consistent and reliable. The reliability factor of each factor was well above the value of 0.85, considered to indicate a satisfactory level of reliability in a basic research (Nunnally, 1978; Hair et al., 2010). The factors were described as below:

- (1) Factor 1, environmental material, consisted of 11 items, namely, historic relics protection, avoiding using unpolluted land in port area, using environmental-friendly material in port construction, encouraging using recyclable material, ecological environment protection in port area, mitigating light influence on neighboring residents, landscape improvement, avoiding environmental destruction when dredging, disposing of effluents, decreasing noise pollution and maintaining water quality. Historic relics protection had the highest factor loading ($=0.753$) on this dimension and accounted for 44.698% of the total variance. These items are port environmental material related activities. Therefore, the factor was identified as environmental material dimension.
- (2) Factor 2, economic issue, consisted of six items: facilitating to economic activities, concerning on benefits of port operators, ensuring cargo handled safely and effectively, establishing port development funding, supporting tourism industry development, offering employment opportunities and encouraging foreign direct investment (FDI). Facilitating to economic activities had highest factor loading ($=0.875$) on this dimension and accounted for 8.806% of the total variance. These items are economical related activities. Therefore, the factor was identified as economic issue dimensions.
- (3) Factor 3, environmental practices factor, consisted of six items: strengthening port infrastructure construction, developing approaches against rapid climate change, flood avoidance in land side operation area, maintaining air quality, decreasing green house gas emission, considering environmental protection when handling cargo. Strengthening port infrastructure construction scored the highest factor loading

(=0.812) on this dimension and accounted for 6.320% of the total variance. These items are environmental practice related activities. Therefore, the factor was identified as environmental practices dimensions.

- (4) Factor 4, social concerns, consisted of six items: recognizing requirements of neighboring community, staff job security and safety, port traffic accidents prevention, ensuring port area safety and orders, hiring minority groups, consulting interests groups when making port project. Recognizing requirements of neighboring community had the highest factor loading on this dimension (=0.782) and accounted for 4.158% of the total variance. These items are social related activities. Therefore, the factor was identified as social concern dimensions. As indicated in Table 4, factor 2, economic issue, had the highest average score (mean=4.6), and this was perceived by respondents to be the most important of these four factors.

4.4 Confirmatory factor analysis (CFA)

Confirmatory factor analysis allows tests to be conducted for unidimensionality, convergent validity, and divergent validity of the scales employed in a study. Unidimensionality can be described as the existence of one construct (or latent variable) underlying a set of items. One of the loadings in each construct can be set to a fixed value of 1.0 in order to make the construct comparable (Koufteros, 1999). A confirmatory factor analysis, CFA, using AMOS 18.0 was performed to ensure the validity of the measurement scale (Anderson and Gerbing, 1988).

Table 2: Factor Analysis of Sustainability Indicator

Items	Factor 1	Factor 2	Factor 3	Factor 4
Historic relics protection	0.753	0.115	0.170	0.230
Avoiding using unpolluted land in port area	0.752	0.065	0.155	0.253
Using environmental-friendly material in port construction	0.747	0.046	0.214	0.166
Encouraging using recyclable material	0.737	0.112	0.240	0.141
Ecological environment protection in port area	0.732	0.125	0.276	0.289
Mitigating light influence on neighboring residents	0.679	0.208	0.225	0.260
Landscape improvement	0.665	0.305	0.195	0.274
Avoiding environmental destruction when dredging	0.659	0.259	0.388	0.190
Disposing of effluents	0.596	0.286	0.327	0.317
Decreasing noise pollution	0.566	0.407	0.266	0.229
Maintaining water quality	0.557	0.209	0.332	0.211
Facilitating to economic activities	0.055	0.875	0.122	0.178
Concerning on benefits of port operators	0.208	0.850	0.054	0.173
Ensuring cargo handled safely and effectively	0.167	0.670	0.142	0.284
Establishing port development funding	0.210	0.633	0.250	0.142
Supporting tourism industry development	0.240	0.619	0.071	0.151
Offering employment opportunities	0.260	0.590	0.195	0.315
Encouraging foreign direct investment (FDI)	-0.044	0.556	0.237	0.152
Strengthening port infrastructure construction	0.229	0.179	0.812	0.133
Developing approaches against rapid climate change	0.203	0.211	0.803	0.092
Flood avoidance in land side operation area	0.395	0.047	0.723	0.196
Maintaining air quality	0.385	0.204	0.670	0.116
Decreasing green house gas emission	0.444	0.165	0.653	0.140
Considering environmental protection when handling cargo	0.256	0.321	0.624	0.233
Recognizing requirements of neighboring community	0.296	0.179	0.118	0.782
Staff job security and safety	0.245	0.296	0.148	0.739
Port traffic accidents prevention	0.233	0.292	0.191	0.726
Ensuring port area safety and orders	0.193	0.272	0.246	0.722
Hiring minority groups	0.365	0.135	0.084	0.642
Consulting interests groups when making port projects	0.265	0.248	0.085	0.635

Mean	3.962	4.344	4.318	4.096
S.D.	0.234	0.126	0.173	0.254
Eigenvalues	13.490	2.642	1.896	1.247
Percentage variance (%)	44.698	8.806	6.320	4.158
Accumulated percentage variance (%)	44.698	53.774	60.093	64.251
Cronbach's Alpha	0.939	0.871	0.905	0.894

A number of goodness-of-fit indices recommended by many researchers were used to assess the fit and unidimensionality of the measurement model (Bagozzi and Yi, 1988; Hu and Bentler, 1995; Kline, 1998; Koufteros, 1999). The resulting, as shown in Table 3, provided an adequate model fit ($\chi^2/df = 1.80$; GFI = 0.91; AGFI = 0.87; TLI = 0.95; NFI=0.91; RMR = 0.02; RMSEA = 0.07), indicating that the proposed model was purified and credible. (Bollen, 1989; Hair et al., 2010).

Table 3: Goodness of Fit Indicator

SEM indicator	Criteria	Results
χ^2 (Chi-square)	-	151.76
χ^2/df	< 2	1.80
P value	> 0.05	0.00
GFI	> 0.9	0.91
AGFI	> 0.9	0.87
TLI	> 0.9	0.95
NFI	> 0.9	0.91
RMR	Close to 0	0.02
RMSEA	< 0.08	0.07

Note: GFI: goodness of fit index; AGFI: adjusted goodness-of-fit index; TLI: Tucker-Lewis index; NFI: normed fit index; RMR: root mean square residual; RMSEA: root mean square error of approximation.

Convergent validity can be tested by t-values that are all statistically significant on the factor loadings. The t-value, in the AMOS output result indicates the critical ratio (C.R.), which represents the parameter estimated divided by its standard error. As a rule of thumb, the value of C.R. needs to be greater than 2.00 or smaller than -2.00 for the estimate to be acceptable (Koufteros, 1999; Byrne, 2001 Hair et al., 2010). Results showed that all C.R. values of each measurements were significant at the 0.05 level, in effect confirming that all criteria measured the same construct and providing satisfactory evidence of the convergent validity and unidimensionality of each construct (Anderson and Gerbing, 1988). Moreover, item reliability (R^2) can be used to measure the reliability of a particular observed variable or item (Koufteros, 1999). Results revealed that all R^2 values were greater than 0.5, providing evidence of convergent validity (Carr and Pearson, 1999; Hair et al., 2010). Discriminate validity was assessed by comparing the average variance extracted (AVE) with the squared correlation between constructs. Discriminate 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).

As shown in Table 4, results indicated that the highest squared correlation was 0.477, which observed between carrier collaboration and supplier collaboration. The value was significantly lower than their individual AVE value of 0.500 and 0.520, respectively. The results demonstrated evidence of discriminate validity for the study variables.

Composite reliability provides a measure of the internal consistency and homogeneity of the items comprising a scale (Iacobucci and Churchill, 2010). It means that a set of latent criteria of construct are consistent in their measurement. The reliability of construct can be estimated using AMOS output results. This reliability is the degree to which a set of two or more criteria share the measurement of a construct. Highly reliable constructs are those in which the criteria are highly inter-correlated, indicating that they are all measuring the same latent construct. The range of values for reliability is between 0 and 1. Results also indicated that the reliability of the constructs of environmental material, economic issue, environmental practices and social concerns were 0.904, 0.867, 0.863 and 0.858, respectively. All constructs exceeded the recommended level of 0.60 (Bagozzi

and Yi, 1988; Sanchez-Rodriguez et al., 2005; Hair et al., 2010).

Table 4: Assessment of Discriminate Validity

Dimensions	AVE ^a	Environmental material	Economic issue	Environmental practices	Social concern
Environmental material	0.501	1			
Economic issue	0.500	0.577** (0.332) ^b	1		
Environmental practices	0.520	0.691** (0.477)	0.548** (0.300)	1	
Social concern	0.503	0.657** (0.431)	0.691** (0.477)	0.607** (0.368)	1

a: Average variance extracted (AVE) = (sum of squared standardized loadings) / [(sum of squared standardized loadings) + (sum of indicator measurement error)];

b: Squared correlation

***:* Correlation is significant at the 0.01 level.

4.5 Differences in port corporations' perceptions of sustainability assessment criteria

To examine the perceived differences of sustainability assessment dimensions between Keelung port, Taichung port and Kaohsiung port, one-way analysis of variance (ANOVA) was performed based on Scheffe tests. As shown in Table 5, mean scores of all sustainability assessment dimensions were found to have significantly difference for three international ports. Respondents from the Keelung port in the dimensions of environmental material (mean = 4.26), economic issue (mean = 4.44) and social concern (mean = 4.29) tended to gain higher mean scores than those of Taichung and Kaohsiung ports. Taichung had slightly higher mean score than those of Keelung and Kaohsiung port on environmental practices dimension.

Table 5: One-Way ANOVA of Differences between Port Corporations

Sustainability assessment dimensions	Groups			F Ratio
	Keelung port	Taichung port	Kaohsiung port	
Environmental material	4.26 (0.60)	3.96 (0.72)	3.82 (0.70)	1.54**
Economic issue	4.44 (0.41)	4.20 (0.64)	4.24 (0.60)	1.85**
Environmental practices	4.38 (0.71)	4.39 (0.69)	4.22 (0.66)	1.39**
Social concern	4.29 (0.51)	4.14 (0.61)	3.95 (0.59)	2.19**

*Note: **p<0.01, *p<0.05*

5. Conclusion and Implications

The objective of this research is to identify crucial sustainability criteria and examine sustainability assessment dimensions in the context of international port. Data collection was based on a questionnaire survey from 135 managers or supervisors at major international port corporations including Keelung, Taichung, and Kaohsiung in Taiwan. A total of 31 important sustainable assessment criteria were adapted from previous studies which were related to environmental, economic and social dimensions. Results revealed that social issues with respect to staff job security and safety was ranked as the most important sustainable assessment criterion, followed by considering environmental protection when handling cargo, facilitating to economic activities, port traffic accidents prevention and ensuring cargo handled safely and effectively, etc.

Nevertheless, respondents showed their less importance in the five sustainable items, namely, mitigating light influence on neighboring residents, considering the arrangement of vehicles when constructing port transportation system, avoiding using unpolluted land in port area, hiring minority groups and consulting interests groups when making port projects. Four sustainability assessment factors were identified as environmental material, economic issue, environmental practices and social concerns. The research findings indicated that economic issue was deemed as the most important dimension in the international port sustainability assessment context in Taiwan, followed by environmental practices, social concern, and environmental material.

Theoretical and practical implications from the results findings for port sustainability assessment were discussed in this research. First, while a majority of previous studies on sustainability assessment have been discussed, there is still a lack of investigation of sustainability assessment in the context of port sector. This study not only develops sustainability assessment attributes but also to highlight the important criteria of sustainability assessment. Further, this study identified four crucial sustainability assessment factors, which provide helpful information for port corporations to identify important criteria and policy of sustainability assessment.

However, this research has limited on an evaluation of sustainability assessment criteria. Future research could conduct an effect-and-cause analysis and consider enablers (e.g. management support, internal and external collaboration) and dependable variables (e.g. organizational performance and sustainable performance) of sustainability. Moreover, this study identified crucial sustainability assessment criteria from a port operator's perspective, future research could consider the perceptions of stakeholders include local people, community, stevedoring companies and carriers. In addition this research only focused on Taiwan international port corporations. Future research could apply this approach in other countries or areas.

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A Note on the Civil Liability Regime of Maritime Piracy – Caused Oil Pollution

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Abstract

Maritime piracy and the environment are two issues which have drawn considerable attention from international community, and there is a linkage between them. When attacked by pirates, the attached vessel will encounter the danger of cargo leaking (notably tanker oil), or even worse, grounded and become wreck. Hence, there is a growing concern that it is only a matter of time before the occurrence of such a marine pollution tragedy. However, the existing civil liability regime for oil pollution has largely remained silent due to the rather implicit nature of oil pollution and the lack of motivation of coastal states located at the piracy prone areas, not helped by the general scarcity of research addressing this issue. Based on such understanding, this paper critically examines the risk of oil pollution posed by maritime piracy through the analysis of piracy's modern trends, and how they would pose hazards to the marine environment. Our study reveals that the current liability regime has a number of significant drawbacks and proposes feasible and realistic solutions after evaluating several possible reforms.

Keywords: Environment, Oil Pollution, Civil Liability, Maritime Piracy

1. Introduction

During the last decades, there is a phenomenal increase in maritime piracy attacks. There are 445 reported incidents in the year 2010 from IMB's annual piracy report. Maritime piracy is a threat to navigation security, which is crucial to the growing international trade volume and the guard of seamen's security. The increasing frequency of piracy attack brings hardship to maritime transportation players. Various participants in shipping industries have to bear additional cost such as extra premium, ransom payment, re-routing cost, security equipment cost etc. It is roughly estimated that the total cost of piracy is USD 7 to 12 billion per year (Hurlburt et al., 2010).

Despite those explicit costs, maritime piracy would also pose dangers to marine environment. Ships suffered damage during the maritime piracy attacks may leak cargoes, e.g. tanker oil, dangerous cargoes, etc., or bunker oils into the ocean, or even unfortunately, founder and become wreck. Therefore the environmental damage posed by maritime piracy could not be ignored. Although there is no reported case mainly regarding environment damage caused by maritime piracy so far, there is a growing concern that it is only a matter of time before the occurrence of a major pollution incident caused by an act of maritime piracy. However, the international legal and policy instruments are inadequate in addressing oil pollution liabilities. Indeed, pollution has never been the focus of maritime piracy issues because of the rather implicit nature of oil pollution (cf. Ng and Song, 2010) and the lack of motivation of coastal states among piracy prone areas. This is not helped by the general scarcity of research investigating the interrelationship between these two issues. With such understanding, this paper aims to investigate the environmental risks posed by maritime piracy,

identify the gaps between existing international legal instruments in addressing the environmental civil liabilities posed by piracy and recommend feasible and realistic solutions after evaluating several possible reform approaches. We believe that this paper offers valuable insight on the dynamics between these two critical issues which would pose significant impacts on the future efficiency, safety and security of international shipping.

After this introductory section, Section 2 examines the oil pollution risks posed by maritime piracy, followed by a critical review on the current legal framework in Section 3. Finally, Section 4 will conclude the paper, and provide feasible and realistic solutions after evaluating several possible reforms.

2. Oil Pollution Risks Posed by Maritime Piracy

2.1. Maritime Piracy, Trends and Oil Pollution Risks

Maritime transportation bears approximately 80% of international trade volume and maritime security is indispensable to guarantee the sustainable development of international trade. However, maritime piracy is taken as the biggest threat to maritime security. In the last few decades, maritime piracy has developed its new trends and caught the attention of general public.

According the *ICC-IMB Piracy and Armed Robbery against Ships Annual Reports* (hereinafter called IMB Annual Report 2010), several modern trends can be identified. Firstly, maritime piracy is more active nowadays, as reflected by the frequency and geographic range of reported incidents. The number of actual and attempted attacks in the year 2010 is 445 while it is nearly half of that in the year 2006 (IMO, 2010, Table 1). In 2011 (IMO, 2011, Table 1) the number, while still remains high, has a flat decrease due to the navy's safeguard. Besides, the action of pirates becomes less predictable in terms of active region. Maritime piracy on the high seas increased largely comparing with armed robbery in coastal waters. For Somali pirates, who contribute over 30% to total reported attacks, are travelling further. They are no longer using the small and old fishing ships, but large ships as the 'mother ships' which carry small boats or skiffs to off coast waters. These skiffs allow pirates to have a wide scope of activities. Indeed, many attacks took place more than 1,000 nautical miles from the Somali coast (IMO, 2011). This wilder active scope indicates an even implicit oil leaking arising from maritime piracy attack.

Secondly, modern pirates are well-equipped and they are less reluctant to take violent actions. Many pirates are well-equipped with weapons such as riffles, AK47 or even cannons (IMO, 2010). More than half of them are equipped with guns (IMO, 2010). Lethal weapons allow them to control vessels through boarding and firing, thus hijack vessels and crew members so as to extort ransom. Historical data shows that 24% of targeted vessels are attacked by firing upon (IMO, 2010). Huge danger of marine pollution is created by such violent actions. Besides, many ships encountered different extent of damage during maritime piracy attacks or during escaping. For example, a chemical tanker, *Rising Sun*, escaped from a Somali pirates attack. However, it suffered significant physical damages caused by rocket propelled grenades (IMO, 2010).

Thirdly, pirates clearly have preferential vessel types, notably high-value vessels, or vessels with high-value cargoes, which would allow pirates to negotiate a higher ransom amount. Unfortunately, it is also those vessels that pose more environmental pollution. According to the IMB Annual Report 2010, the total number of vessel attacked is 445. Among them, 33% are tankers, including chemical tankers, tankers, product tankers, LPG tankers, bitumen tankers and LNG tanker. Cargoes carried on those vessels are usually the source of considerable maritime pollution.

2.2. Oil Pollution Liabilities

Approximately four percent of the world's oil supplies travel via the Gulf of Aden annually (Jeffrey, 2010). Most maritime piracy prone areas are located along the 'chokepoints' of shipping routes (cf. Nincic, 2002; Rodrigue, 2004). Vessels travelling through are facing high danger of piracy attacks. Even though it is not hard to imagine the risk of causing oil pollution hazard, there is no such reported case. It is mainly because of the rather implicit nature of oil pollution comparing with the eye-catching news about hijacking and murder.

Another reason might be the lack of incentive for the international society to pay attention. It is so because many attacks happened within the territory of countries in turmoil or beyond the territory of any countries. For those coastal countries, they do not have powerful infrastructures for prosecution. As the IMB Annual Report 2010 shows, nearly half of incidents happened in the regions around Gulf of Aden and Somalia. Those are the areas in turmoil and without effective government supervision. Taking Somalia as an example, there are three main political powers. The poverty and turbulence there make it a perfect nursery for pirates. People even take piracy as a serious and profitable business, instead of a type of crime (Fairplay, 2009 and 2011). Or even if the incident happened in the country with a powerful political infrastructure, most of piracy attacks happen far off the coastal areas or in the public sea. Their impact is relatively less comparing with those happened in the coastal areas.

There is a growing concern that it is only a matter of time before the occurrence of a big pollution incident caused by maritime piracy. Even there are international conventions regarding civil liability of marine pollution, they may not be adequate to solve oil pollution liabilities containing piracy element. Or, the regime itself has many drawbacks. Unfortunately, however, leaps in international legislation are often propelled by large environment disasters. The *Torrey Canyon* disaster in 1967 was the catalyst for working on liability and compensation. Two years after the tragedy happens, IMO first adopted International Convention on Civil Liability on Oil Pollution Damage. Another example is *Exxon Valdez* happened in 1989. This incident was the incentive for the promulgation of the US Oil Pollution Act (1990). Marine disasters keep showing the significance of compensation rules in oil pollution damage. Apart from administrative and possible criminal liabilities, polluting parties bore civil liabilities towards claimants who suffered damage in the pollution incidents. Compensation rules would identify the liable parties, their exclusion of liabilities, maximum liability amount and other financial aids for implementation.

3. The Current Legal Framework and its Inadequacy

There are two systems of law governing oil pollution liabilities issues. One is domestic laws, possibly laws of the flag state or agreed laws in a related contract. Flag state jurisdiction is a traditional and important type of maritime jurisdiction. It is justified by the statement that vessels are the floating territory of the flag state. Thus, certain disputes happened regarding the vessel should be under the manipulation of its flag state and governed by its domestic laws. While this paper focuses more on the international regime, the role of laws of flag state should not be overlooked. Another applicable law is international conventions. But their big limit is that international conventions will only be applicable when the damage is happened within the agreed scope of application, for example, within the Exclusive Economic Zone (EEZ) of the contracting states. The coastal states of piracy borne areas has less developed legal infrastructure and they ratified rather limited number of international conventions on environmental liabilities. For example, Somalia ratified none of the follow-mentioned conventions. That being said, the following critical review is based on the assumption that those international conventions are initially applicable.

3.1. Critical Review on International Legal Framework

On an international level, civil liability for marine pollution is governed by a package of international conventions adopted by IMO: *International Convention on Civil Liability for Oil Pollution Damage 1992* (CLC 92) dealing with oil spills from laden tanker and the *International Convention on Civil Liability for Bunker Oil Pollution Damage 2001* (Bunker Convention) for bunker oil damage.

Those conventions share common features. The most distinguishing one is that they treat shipowners of the polluting vessel the liable party. This rule stems from an old principle, the "the polluter pays" principle. However, the extent to which civil liability makes the polluter pay for environmental damage depends on a variety of factors (cf. Birdnie and Boyle, 2002) and it even has had a big revolution in the Bunker Convention (Zhu, 2007). For example, liability basis will influence the compensation of environment pollution. IMO liability package adopted strict liability basis, under which shipowners shall be liable regardless of their fault. One reason for the adoption of strict liability principle is that it is very difficult for the plaintiff to prove the fault of the defendant. Another reason is that, quoting EC (2000), *someone who is carrying out an inherently hazardous activity should bear the risk if damage it caused by it*. Moreover, shipowners are in a better

position to take precautionary actions to prevent oil pollution comparing with cargo owners (Zhu, 2007) Apart from identify the liable parties, conventions within this package also deal with issues like compulsory insurance, certification, limitation of liability and their respective funds.

Besides the foresaid two conventions, several mechanisms are to achieve the full compensation and reallocate the liability among ship and cargo interests. It includes International Oil Pollution Convention (IOPC) Fund, Small Tanker Oil Pollution Indemnification Agreement 2006 (STOPIA) and Tanker Oil Pollution Indemnification Agreement 2006 (TOPIA).

3.2. Major Drawbacks

The EC Communications (2000a) have listed three criteria for a well-functioning civil liability and compensation regime. They are certainty, promptness and sufficiency. However, the current framework is unsatisfactory in achieving those goals. Ambiguous and insufficiency can be summarized as two drawbacks of the current legal instruments. They are embodied in the ambiguous application and exclusion scope, and insufficient level of liability.

3.2.1. Ambiguous Application scope

As foresaid, the precondition of analyzing those conventions is that they should be applicable. The civil liability instruments initially mainly functioned within the territorial sea of contracting states (1969 CLC, Article II). It was a rather straight-forward rule. But being straightforward could also means inflexibility. With rigidly being applied to this rule, this IMO package would encounter limited application scope because most countries in high piracy risk areas did not ratify, or fully ratify, those conventions. The inclusion of ‘preventive measures’ and the revision made in later conventions could be a possible tool to avoid the rigid application scopes of those international conventions. However, there is no geographic restriction for ‘preventive measures’ even for incidents happened on high seas. As long as the requirements of preventive measures are met, claimants are entitled to refer rules from this package without concerning about where the incidents happened. The absence of an authentic explanation of the ‘preventive measures’ ensures that the application scope of the liability regime would remain ambiguous.

The definition of ‘preventive measure’ could be found in Art I (7) of CLC and Bunker Convention. It means any reasonable measures taken by any person after the incident has occurred to prevent or minimize pollution damage. As a tool to avoid the drawbacks of rigid application scope of the foresaid conventions, the meaning of ‘preventive measure’ should be deliberately explained.

Protective booming is an example of preventive measures. When the pollution ship noticed suspicious vessel or is actually attacked by the pirates, it is possible that this incident would cause pollution damage or create a grave and imminent threat of causing oil pollution. The noticing of suspicious vessel or actual attacking by pirates is the incident in Art I (8) as long as it causing pollution damage or creates a grave and imminent threat of causing such damage. The preventive measures do not required measures to be taken after the actual oil pollution. It is subject to the reasonableness test. The word ‘prevent’ demonstrates that the preventive measures could be taken even before the incident has occurred when there is a grave and imminent threat of causing oil pollution. If there is merely a threat of causing oil pollution, then the nearest causation of pollution is carried out by the pollution vessel, rather than the pirates’ action. For example, if the pollution vessel is leaking oil from the bullet hole shot by the pirates, the pollution is then not caused by the preventive measures. However, if the polluting vessel is leaking oil because it went ground during its way to evade from pirates, the cause of pollution is preventive measures. Still, the top principle is there should be a grave and imminent threat of causing oil pollution. On the other hand, the test for the so-called ‘grave and imminent threat’ is also rather subjective. If the Master, after exercising good seamanship, reasonably believed the existence of grave and imminent threat of causing oil pollution, cost of avoiding such threat should be recoverable. (CMLR, 2010, p.231) However, the test of reasonableness is objective and it should be a cost-effective measure. (Oosterveen, 2004)

Even though there is no express geographic restriction of ‘preventive measures’, the word ‘caused’ and

‘reasonable’ largely restrict its scope of application. On one hand, ‘caused’ means proximately caused. According to the judgment of *Leyland Shipping* (AC, 1918, p.350), ‘proximate cause is an expression referring to the efficiency as an operating factor upon the result’. It requires that the incident should be the most dominant and effective cause of oil pollution. Oil pollution with piracy elements could be caused by various reasons. On the other hand, measures taken should be reasonable considering all the circumstances at the time of incidents. No hindsight is allowed. Maritime piracy is an extreme case. In response, shipowners should be allowed to take special preventive measures to prevent or minimized pollution damage. Looser interpretation on the term ‘grave and imminent threat’, ‘reasonable’ should be adopted for piracy posed environment liabilities.

3.2.2. *Ambiguous Exclusion Scope*

There are certain exclusion clauses, according to which shipowners could exempt their liabilities wholly or partially. Typical excluded liabilities are those caused by act of god, act of war, third party sabotage, governmental negligence and they are so provided in CLC 92, Bunker convention. Since those conventions share basically the same exclusion clauses, this project would use CLC 92 as an example to further examine how far these exclusion clauses could be used under the environmental liability posed by maritime piracy.

Firstly, the owner can exclude his liability if he/she proves that the damage is resulted from an act of war and act of god. Act of war requires a political motivation. But piracy should be committed for private ends or financial gain. (McCullough, 1986, p.53) However, the boundary between political demand and financial gain could be rather blurring. If the target of pirates discriminate the person and property from different stats, the action is terrorism rather than piracy. (KB, 1909, p.785)

Secondly, when the damage was wholly caused by an act or omission done with intent to cause damage by a third party, shipowners of the polluting vessel could also exclude from his liability. Obviously, pirates in this case are third party. If the damage is (either wholly or partially) caused by their intentional acts, shipowners would wholly or partially exempt their liabilities. However, the main restriction of applying this exclusion clause is that damages must be caused by pirates’ intentional acts. It should be examined whether the ‘damage’ in Art III 2(b) is the same ‘pollution damage’ in Art I (6)(a), namely whether the pollution should be wholly caused by the third party's intentional act in order to exclude shipowners’ liability. If so, then there is a huge restriction to apply this article because most of the pirates would intentionally hijack vessels rather than destroy them for ransom. Aiming at ransom, they are quite unlikely to pollute the environment intentionally. This subjective criterion seems to be too high for the ‘merchant’ pirates to achieve.

Meanwhile, if ‘damage’ in Art III (2)(b) simply means any types of damage on the ship hull, spares and other property on board, it would be easier for shipowners to exempt their liabilities comparing with the first. However, it is still uneasy to prove that pirates intentionally cause damages. As discussed earlier, most pirates aim at hijacking vessels and crew members so as to demand ransoms, and thus, under normal circumstances, unlikely to deliberately cause physical damages or destroy the vessel. If ‘damage’ can be extended to economic components such as the loss of freight (or reduction from initial freight values), then Art III (2)(b) would become a public key for the polluting shipowners to escape from their liability cage. Judges would also likely restrict the meaning of ‘damage’ when interpreting it. Otherwise, it will open the floodgate to the claims from all over the world.

Lastly, shipowner's liability could be excluded by the negligence or other wrongful act of any government or other authorities responsible for the navigational aids in the exercise of their duties. This situation is not rare in piracy scenario. Many states have arranged naval forces to safeguard the passage of vessels in maritime piracy-prone areas. Despite this, there are many other organizations, e.g., IRTA, MSCHOA, NATO, etc. Also, the subjective criterion has a lower threshold comparing with it in third party sabotage. Negligence of government shall be sufficient. The two only constraints include: (1) the authority should be responsible for the navigational aids; and (2) the negligence or wrongful act is taken in exercise of that function. Nevertheless, whether the duty of authorities such as MOSCHOA is to provide the navigational aid remains a question yet to be answered satisfactorily. The convention uses the maintenance of lights as one example of navigational

aids. However, the duty of MOSCHOA is to monitor the vessels transiting through the Gulf of Aden. There is a big difference between providing safeguard and providing buoys maintenance.

3.2.3. *Limited Liability*

In the shipping industry, damage is not always impaired in full amount. Nowadays, although it faces some controversies, the doctrine of limitation of liability is reflected in almost all international maritime liability conventions. Current IMO liability package offers special protection for shipowners including the right to limit liabilities. This doctrine is justified by the fact that carriers face tremendous navigation risks to provide services to the general public. However, navigation risks are constrained by the application of advanced equipment and updated seaman skills. Accordingly, the proper limitation amount needs to be re-examined.

(i) Insufficient Limitation Amount

In the tanker oil pollution liability regime, the limitation amount is calculated according to Art V (1) of CLC 92. In bunker oil pollution liability regime, the limitation amount depends on the state country's national law or ratified international convention, such as the LLMC as amended. Maximum liability is summarized without considering of LLMC convention, which may further limit the final amount. Limitation amounts set by those conventions are insufficient to provide protection for victims. In early 2003, the total bill for the *Prestige* accident was estimated at 1,100 million Euros (IOPC, 2003). P&I clubs would eventually indemnify liabilities of shipowners. However, their compensation capacity is far more than this limitation amount. P&I groups could afford USD 4.25 billion and for oil pollution damage, while the P&I insurance is limited to USD 1 billion (Westterstein, 2004) which is ten times less than the maximum liability under CLC 92. Furthermore, as argued by Wetterstein (2004), P&I club's compensation capacity is highly dynamic and can easily be adapted to increasing compensation needs. Increasing shipowners' limitation amount might be easier to be implemented, comparing with reforming cargo receiver's liability regime.

From the above comparison between the maximum limitation amount and P&I club's compensation capacity, it is not hard to conclude that shipowners could provide sufficient compensation for claimants. However, current limitation cap is far under their compensation capacity. For claimants of bunker pollution, the maximum amount in Bunker convention is all they can get, in absence of any supplemented fund to ensure their full and adequate compensation. For victims of tanker oil pollution, extra protection tools, e.g., IOPC fund, STOPIA, TOPIA, etc., cannot guarantee the full compensation. Ironically, it is exactly the reason why they are needed from the very beginning.

(ii) Lose of Limitation

There are certain conditions when shipowner's limitation of liability could be broke. However, the threshold is so high that the limitation of liability is practically unreachable. This high threshold is a compromise to shipowner's consent of raising liability amount. According to V(2) of CLC, owners would lose their right to limit if it is proved that the damage resulted from the personal act or omission of the owner, committed with the intent to cause such damage, or recklessly and with knowledge that such damage would probably result. It is extremely difficult to break the right of limitation. To make matters worse, the burden of proof is on victims. The usual victims are fishermen who lived from the polluted sea, coastal states etc. Those are the parties who cannot control the vessel and it is unreasonable to let them to bear the onus of prove.

Therefore, the threshold should be lowered so that at least the proven gross negligence of the liable party should result in unlimited liability. It has been suggested that the requirement for unlimited liability should be lowered, even to the extent that a return to the 'actual fault or privities' requirement as laid down in CLC 1969 (Gauci, 1997).

4. **Conclusions**

Maritime piracy is a new threat faced by the maritime industry nowadays. It threatens navigation security, brings additional cost and cause many new legal issues. However, most legal disputes relating to piracy are on the

legality of ransom payment, or off-hire in charter party. Environment risk pose by maritime piracy is lack of international community's attention but could not be ignored. It is a matter of time before such tragedy occurs. The value of this paper is to arouse the public attention, identify the research gap in addressing this problem, and provide a realistic solution to multi-players in shipping industry to constrain such risk. The international civil liability framework on pollution caused by ships is clearly inadequate in solving the stated problem. Ambiguous and insufficiency can be summarized as two drawbacks of current legal framework. It is embodied in the ambiguous definition of piracy, inconsistency with the "polluter pays" principle and insufficient of liability amount.

Therefore, we propose three possible solutions, international legislation, compulsory insurance, and fund. We hold a rather conservative opinion on the implementation of recommended solutions. Firstly, setting up a new international legislation is quite a fancy approach. The idea of setting up an 'umbrella convention' may solve the problem of inconsistency, ambiguous and insufficient by including different types of pollution liabilities, introducing a more specific definition of 'preventive measure', fitting maritime piracy into one of the liability exclusion clause and increasing the first tier of limitation amount. The 'umbrella convention' would provide a unique convention containing provisions on strict liability, compulsory insurance and direct claims from the various liability conventions.

However, adopting a whole new convention is a very long process full of the endless diplomatic bargains. Moreover, liability is always a very sensitive topic when making international conventions. The recommended 'umbrella convention' would deal with civil liabilities for different types of oil and substances such as tanker oil, bunker oil or even HNS pollution. States would be more resistant when signing or ratifying it. Since, for example, CLC 92, Bunker Convention, and Fund convention have very different contracting states. Moreover, IMO has more than 160 states with various political and economic backgrounds. Compromises reached at the diplomatic conferences often do not satisfy countries giving more emphasis on environmental protection. It is quite hard to make a widely acceptable compromise and strike a balance between ship and cargo interest. Creating a new huge international mechanism is not a quick solution to close the gap of current framework in addressing the environmental liabilities posed by piracy. It is, instead, a goal to strive for.

Alternatively, compulsory insurance could offer a sufficient and promptness compensation regime. Environmental compulsory insurance market has already been well built in economic advanced countries. Nevertheless, it must be realized that this is a rather step-by-step work since the environment danger posed by piracy does not receive much attention from international community. Such a demand insurance market is nearly rare and there is no motivation for the insurers to develop such product. Therefore, for countries with aggressive view on environment protection, compulsory insurance is always an option in the absence of commercial one. For example, EU is a leader in the reform of environmental liability regime. There is a gradual development in insurance market providing environment liability insurance. The Netherlands has a new type of policy covering the cleanup costs (EC Communications, 2000b). It is realistic to expect the insurance market to develop an insurance policy, which would cover the possible third party liabilities arising from the piracy action when shipowners lose their protection of exclusion clause. Motivation is clearly the key issue. Maybe a better timing to establish compulsory insurance is when the international community shows enough attention, perhaps after a tragic environment hazard.

Also, the implementation of compulsory environmental insurance regime is difficult because of three reasons. Firstly, the acceptability of legislative intervention will partly depend on the terms of the policy. Thus, the terms concerning loss and damage being covered, measurement of damage, duty of mitigation, possibility of risks and tariff calculation should be well drafted or assessed. Environmental damage cost is rather hard to predict. This no doubtfully adds resistance to build a well-functioned insurance regime. The non-transparency and inconsistent situation of current international legal framework definitely make it even harder. Also, the insurers may be reluctant to be associated with existing pollution facilities and take their responsibilities as compulsory insurer. If so, the government might need to offer financial inducements. Finally, the capability of compulsory insurer must be carefully judged. Necessary risk management skills, sufficient financial capability and quick response time of the service provider should be taken into considerations.

In view of the long-term process of developing compulsory environmental insurance, it is recommended that

the liability regime should not put an obligation to obtain financial security, in order to allow the necessary flexibility and experience to be accumulated. For fund reforms, a number of scholars believe that the adaption of the fund regime would be required (for example: Richardson, 2003). Unlike building the 'umbrella convention', establishing a unified fund regime seems a more realistic alternative. The way those two mechanisms function are rather different. The application of liability convention is the EEZ of its contracting states. Therefore, countries like Somalia would hardly ratify this convention. On the contrary, fund is for the oil importing states. Those are usually the countries with a strong passion in environment protection and would easily ratify this convention.

In our opinion, the current OIPC fund is too optimistic. Quoting to a report from 1999 International Oil Spill Conference (Grey, 1999), *the total amount of compensation available under Fund 92 should be sufficient to deal with the vast majority of cases, provided that costs of individual incidents do not continue to increase*. Indeed, it is a little bit hindsight to criticize the limited amount in 1992 Fund Convention. With the increasing cleanup cost and preventive measures cost, liabilities nowadays would more likely break the ceiling of the 1992 Fund Convention, or even the supplementary fund. In October 2003, the total bill for the accident of *Prestige* was estimated at 1,100 million Euros, more than the STOPIA fund's compensation ceiling (IOPC Fund, 2011). Therefore, the new fund should have a high ceiling to ensure sufficient compensation.

Financing the fund would be an interest gambling between oil industry participants and shipowners. New compensation fund should ensure oil majors contribute their share without largely violate the polluter pays principle. It should also reflect a balance between the responsibilities of the players concerned and their exposure to liability (EC Communications, 2000a). As 58% incidents are caused by human errors (IOPC Fund, 2003), shipowners, as the stakeholder who control the carriage of vessels, should take the major and initial responsibilities. Besides, letting shipowner bear the major risks is a way to alert them and an incentive for them to perform their duties. However, such an argument is based on the condition that the first-tier liability regime is sufficiently high. The second tier, i.e., the fund, can thus be triggered less frequently.

Oil receivers benefit the most from this high-risk industry, especially in cargo oil trades. Therefore, they should bear part of the responsibilities for potential environment liabilities. Fund is normally a way to switch part of shipowners' liability to oil receivers and contributed by large oil receivers. The critical question is the location of first ceiling, i.e., to what amount the fund should be triggered. Historical report shows that the cost of least expensive incidents has only contributed a small part of the aggregated cost. For example, in 1999, 15% fund incidents account for 83% of the total incidents (Grey, 1999). These demonstrate that the costs of incidents are normally distributed. Hence, the fund should have a higher threshold whilst the limited amount of shipowners' liability should also accordingly increase. The key to the success of fund depends largely on the reasonable proportion. To conclude, policymakers should always bear in mind the compensation capability of shipowners and oil majors along with the degree of faults involved in the incidents.

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Green Port Strategy for Sustainable Growth and Development

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Abstract

The recent years have seen growing interest in the environmental impact of port operations and development due to pressing global issues such as climate change and energy consumption. The port industry is facing increasing challenges since it is subject to closer scrutiny in terms of environmental regulatory compliance. The focus on environmental issues is especially felt at the level of vessel and cargo handling operations, port extension projects and hinterland accessibility. At the same time, providing adequate capacity, quality services and cost-effective solutions are essential. As such, devising a green port strategy fulfilling both economic and environmental objectives would be desirable and contributes to the port's sustainable growth and development. The literature to-date has yet to fulfill the much desired industry demand. The study aims to fill the gap by formulating a framework in green and sustainable port strategy. The research objective is firstly achieved by comprehensive literature review and conceptual development. Then three port case studies from North America, Europe and Asia, namely Los Angeles/ Long Beach, Antwerp and Hong Kong are chosen due to the high shipping traffic and cargo volume handled, as well as adopting greener approach in recent years. The case studies are presented with the aim to relate the concepts to policies and industry practices. The case studies also add value by representing an international perspective from the major ports in the three key geographical regions. Accordingly, an original framework in green and sustainable port strategy and propositions have been developed. The framework is built on key constructs of stakeholder involvement, green market development, cost effective green policy as well as sustainable port operations and development. Practical and research implications will be discussed.

Keywords: green port, port strategy, sustainable development, stakeholder analysis, green market development

1. Introduction

After long pursuing trade growth, industrialisation and the associated economic benefits since the modern era of globalisation, the society started to concern about environmental and social issues such as resource depletion, climate change and pollution. Maritime trade and the port industry have experienced phenomenal growth over the past decades. Having acted as trade facilitators, ports are important players in the global economic system. While port efficiency, connectivity and capacity have always been important topics, the recent years have seen growing interest in the environmental impact of port operations and development due to pressing global ecological issues. The port industry is facing increasing challenges since it is subject to closer scrutiny in terms of environmental regulatory compliance. The focus on environmental issues is especially felt at the level of vessel and cargo handling operations, port extension projects and hinterland accessibility. At the same time, providing adequate capacity, quality services and cost-effective solutions is essential. The critical issue is to strike the right balance among economic, social and environmental values in order to achieve sustainable development of the port and the local community.

Other than the reason of environmental legislation enforcement, enterprises start to make business decisions based on the need for sustainability and turn in to its potential marketing value. A recent survey showed that around 82% of businesses are willing to increase spending on green marketing (Environmental Leader, 2009) since the enterprises recognise the opportunity to charge higher price due to the enviable green image. Those who manage to translate sustainability into sources of competitive advantage and a key value driver for their customers, stakeholders and, ultimately, their bottom lines, will emerge as winner in this new competitive landscape (Esty & Winston, 2006; KPMG International, 2011). As such, devising a green port strategy fulfilling both economic and environmental objectives would be desirable and contributes to the port's sustainable growth and development. The literature to-date has yet to fulfill the much desired industry demand.

The study aims to fill the gap by formulating a framework in green and sustainable port strategy. The research objective will be firstly achieved by comprehensive literature review and conceptual development. Next, three port case studies from North America, Europe and Asia, namely Los Angeles/ Long Beach (LA/LB), Antwerp (ANT) and Hong Kong (HK) are conducted due to the high shipping traffic and cargo volume handled, as well as adopting greener approach in recent years. The case studies will be presented with the aim to relate the concepts to policies and industry practices. The key constructs and propositions will be established accordingly.

2. Literature Review

2.1 Sustainable development

The central notion of sustainable development is that the goals of environmental preservation and the goals of business need not be disparate and conflicting (Barbier, 1987). The concept of sustainability can be defined in terms of the triple bottom line (3BL): economic prosperity, environmental quality and social justice (Elkington, 1997). In relation to corporate performance, Savitz and Weber (2006) noted that sustainability means operating a business in a way that causes minimal harm to living creatures. Sustainability is regarded as the integration of environmental, social and economic criteria and keeping an equitable balance among the three aspects that supports an organization for long-term competitiveness (Sikdar, 2003; Carter and Rogers, 2008). To be sustainable in business, any green measures should contribute to the commercial aspect in improving economic performance (Rao and Holt, 2005). The importance of sustainable development has been recognized over the years. It is strategic to a firm since it affects the firm's core business and its growth, profitability and even survival (Corbett and Klassen, 2006; Kolk and Pinkse, 2008).

In terms of how to achieve sustainable development, Elkington (1997) examined sustainability in relation to corporate governance and argued that the key to establishing the triple bottom line is stakeholder consultation. Carter and Jennings (2004) analyzed the role of purchasing in corporate social responsibility and claimed that external pressures from customers such as request to choose environmentally responsible suppliers must be taken into account. Anderson and Brodin (2005) highlighted the importance of effective customer participation in order to understand customers' requirements and expectation in ecological concerns. Dougill et al. (2006) echoed and stated that by taking local interests and concerns into account at an early stage, it would enhance the project design and increase the likelihood that local needs and priorities are successfully met. Other than stakeholder and customer participation, there is evidence that linking sustainability goals and measures to corporate strategy helps to integrate sustainability into what the organization does (Wagner, 2011). Corporate proactive stance and tangible commitment, often in the form of a written environmental policy is a significant contributor to sustainability (Ramus and Steger, 2000).

There have been an increasing number of studies on sustainable development. In recent years we see a trend in establishing holistic frameworks encompassing sustainable strategies and practices particularly in the field of supply chain management (SCM). Zhu and Sarkis (2004) presented a model consisting of the components of green SCM, empirically validated by a survey on Chinese manufacturing firms. Carter and Rogers (2008) developed a framework of sustainable SCM based on literature review and conceptual theory building. They demonstrated the relationships among environmental, social and economic performance in the supply chain context. At the intersection of the three aspects, there are activities that organizations can engage in which not only positively affect the natural environment and society, but which also contribute to the long-term

economic benefits of the firm. Also founded on literature survey, Seuring and Muller (2008) presented a conceptual framework addressing more on supplier management and product development. Pagell and Wu (2009) performed case studies of ten exemplar firms from various industry sectors for building a testable model of the elements necessary to create a sustainable supply chain. Shang et al. (2010) identified 6 green SCM dimensions, namely green manufacturing and packaging, environmental participation, green marketing, green suppliers, green stock and green ecodesign, and carried out an empirical investigation in electronics-related manufacturing firms in Taiwan. Sharma et al.'s (2010) and Lee and Lam (2012) developed their respective framework focusing on industrial marketing. Based on literature review, the former developed a sustainable market framework in the supply chain context for achieving environmental sustainability objectives, while the latter demonstrated a framework integrated with sustainable operations management by studying a case of a medical product manufacturer.

2.2 *Environmental issues in ports*

Port research has also been increasingly addressing ecological issues. It is found that studies in earlier years were driven by environmental legislation. Bateman (1996) discussed Australia's environmental regulations and their impacts on the ports and maritime industry. The concern on higher costs of environmental protection to the stage that such costs would become a community responsibility rather than an industry one was raised. Hence Bateman suggested public consultation and more coordinated approach in maritime and oceans policy. Wooldridge et al. (1999) studied how the UK ports sector responded to environmental legislation. The paper focused on the importance of monitoring mechanism for ports and harbours in maintaining their environmental sustainability. Biological indicators such as presence/absence of individual marine species and abundance of dominant species for monitoring purpose were suggested. Also related to monitoring, Darbra et al. (2009) studied 26 European ports' requirements for environmental information via interviews. The major environmental parameters that ports required to be monitored were marine related issues, water quality, meteorological parameters, turbidity and sediment processes.

One of the major environmental impacts generated by ports is air pollution and there are several studies which specifically addressed this aspect. Liao et al. (2010) analysed the impact of using Taipei Port in Taiwan on the carbon dioxide emissions CO₂ of inland container transport. Via activity-based method, the estimation results showed that there are greater reductions in CO₂ when transshipment routes are changed from other major ports in Taiwan to Taipei. In addition to CO₂, dominate emissions from ships at ports include SO₂, NO_x, PM₁₀, PM_{2.5}, HC, CO and VOC. Studying Taiwan's case also, tankers and container ships were found to be the first and second largest groups of ships emitting such pollutants in Kaohsiung Port (Berechman and Tseng, 2012). The health effects to residents of the local community include asthma, other respiratory diseases, cardiovascular disease, lung cancer and premature mortality (Bailey and Solomon, 2004).

Another major environmental concern is water pollution and the effect on marine ecosystems. Ng and Song (2010) assessed the environmental impacts generated by routine shipping operations on ports, and conducted an empirical analysis on Port of Rotterdam. Water pollution comes from ballast water, fuel oil residue and waste disposal from ship operations as well as cargo residue. The need for upgrading and maintenance of navigation channels at port waters would lead to contaminated sludge from dredging. There may also be a need to alter the sea floor and natural geographical feature causing disruptive impact on marine ecosystems due to dredging and civil works (Peris-Mora et al., 2005). A case study on the port of Valencia in Spain was conducted.

The above studies led to a better understanding of ecological issues in ports. Nevertheless, their scope did not directly cover port strategy and did not involve any strategic framework. There was no theoretical development or analysis on the appropriate constructs which can holistically address these ecological issues. There is also a gap in the literature to integrate economic and social aspects with environmental concerns to address port's sustainable growth and development. With regards to empirical investigation or case study, it is observed that prior studies are mostly devoted to a local situation or at best regional focus, i.e. Darbra et al (2009)'s analysis on Europe. Our research adds value to the literature by filling these four major gaps identified.

3. Research Methodology

Considering the target of theory building, this study is based on literature review and three comprehensive port case studies. Case studies can contribute to improved validity and reliability by providing qualitative evidence for understanding the underlying rationale or theory (Yin, 2002). Another advantage of using case study is the inherent flexibility of the method (Dubois & Araujo, 2007) which fits the nature of the complex, dynamic relationships and interactions in the port industry.

The ports that are chosen should be international and major ports having high shipping traffic and cargo volume handled hence the cases would be comparable. We define this by limiting the possible ports to one of the top ranking ports in their respective region, namely Europe, Asia and North America, in terms of total cargo throughput in tons. The three regions are selected for the similar reason that they are the top regions in the world in terms of maritime trade volume. There is no fixed rule suggested by the literature for the appropriate number of cases to use in multiple case research. But a maximum of seven cases were stated by Eisenhardt (1989) for the reason of human's limitation in mental process. We also agree that a relatively low number is preferable since too many cases will defeat the purpose of conducting case study which is meant to be in-depth for each object. For those previous port researches utilising multiple case study, the number of cases mostly ranged from two to four. Since very little was found in terms of green port strategy in the literature, three cases, i.e. one major port from each geographic region would be a good attempt.

Data and information collection for case studies was conducted from the second quarter of 2011 to the first quarter of 2012 at the three port locations through various methods, namely interviews, field visits to each of the ports and searching library and credible internet sources. The research design is to achieve the benefits from triangulation, whereby multiple data collection methods can mitigate biases and lead to stronger substantiation of constructs and hypotheses (Eisenhardt, 1989). One interview was performed for each port targeted at a management executive related to sustainability profile of a terminal operator which would be at the most appropriate position interfacing public authorities, commercial customers and various stakeholders for the purpose of the study topic. The field visits which were hosted by different personnel provided authors with a thorough understanding of the port's practice. As suggested by Carter and Rogers (2008), a profound understanding of the motivations of case object's practices and strategies can be obtained through ethnographic inquiry. This approach enables an experimental investigation into organisational phenomena, including management philosophy, environmental measures and processes, port performance and shortcomings. The cases greatly strengthen the industrial inputs for the research. In addition to previous studies, the conceptual framework and propositions are based on the analysis of the cases, enhancing the research relevancy to the port industry.

This study utilizes qualitative approach involving compilation, summary, comparison, classification and analysis of the data, information and opinion. Specifically, the process can be divided into two parts. First, within case analysis was performed as a data reduction and organisation technique. Each port's data and information became more structured and usable. The second procedure involved cross case analysis which was concerned with pattern recognition and matching across the various ports (Miles and Huberman, 1994). Table format will be used for presenting the case comparison.

4. Case Analysis and Discussion

The importance of stakeholder involvement was established in generic sustainability literature. Various stakeholders are concerned with port operations and they also play a vital role in the development of a green port. We classify various stakeholders into four categories, namely market players, public policy makers, internal stakeholders and community. In order to identify the patterns across the three ports, the key is to analyse the level of stakeholder involvement and the type of environmental projects involved, i.e. the 'who' and 'what'. Considering various ecological aspects of air and water pollution, energy consumption and waste treatment during port operations, expansion and hinterland connection, seven types of projects are studied in focus. The findings are summarized in table 1 and the analysis is discussed below.

Table 1: Stakeholder Involvement and Type of Environmental Projects Involved in the 3 Ports

			ANT	HK	LA/LB
Stakeholders Involved (Who)	Market players	Shipping companies	Y	Y	Y
		Logistics/Inland transport operators	Y	N	Y
	Public policy makers	Port authority	Y	L	Y
		Environmental department	Y	Y	Y
	Internal Stakeholders	Employees	Y	Y	Y
	Community	Non-government organisations (NGO) & Environmental groups	Y	Y	Y
		Residents	Y	Y	Y
Specific projects involved with stakeholders (What)	Lower emission and low sulphur fuel for ships		Y	Y	Y
	Onshore power supply for ships		L	L	Y
	Clean truck (at port)		Y	Y	Y
	Green multimodal connection (to inland)		Y	L	Y
	Renewable and conservation of energy		Y	Y	Y
	Waste management		Y	Y	Y

Note: Y = yes, engage in the activity significantly; N= no engagement; L= limited engagement.

Source: Authors, based on various primary and secondary sources (see section 3)

4.1 Market players

The fundamental function of a port is a connection or ‘interface’ point where market players transact and interact. All the ports in the three cases collaborate with major customers, i.e. shipping companies in reducing air pollution. They all adopt schemes to reduce greenhouse gas (GHG) emissions and to switch to low-sulphur fuel for ships. One of the programs implemented by LA/LB called Green Flag Speed Reduction Program (Port of LB, 2009) is cost-effective for shipping companies. By slowing down, ships can reduce emissions and shipowners in return get discounted fees the following year as an incentive, hence the scheme combines environmental protection with economic benefits. ANT and HK do not adopt similar project but they use other measures. In terms of HK, in addition to government initiatives, shipowners under Hong Kong Shipowners Association supported to adopt a lower global sulphur cap of 0.5%. Craft operators also take initiatives to reduce vessels’ fuel consumption. Hong Kong’s largest tugboat operator the HUD Group commits to become the world’s first tug company being completely carbon neutral (Galbraith et al., 2008) which is a huge step taken in the tug industry. ANT also introduced low-sulphur fuel for the Port Authority’s own tug and dredger fleet (Port of Antwerp, 2010). Hence, such move is not market players’ initiative. Furthermore, the three ports started/planned to implement the onshore power supply scheme by which ships get electricity on shore. Ships are recommended to install converters that incur additional cost for shipping companies. This also incurs higher cost for ports on power stations. LA/LB is by far more aggressive in this aspect which aims to have 100% onshore power supply (IHS Fairplay, 2011) while ANT and HK implement such projects only for barge and cruise terminals respectively.

Other than shipping companies, truckers, logistics and other inland transport operators are also involved in green port initiatives. The three ports have clean truck programmes which require vehicles to switch to low-sulphur diesel. Both ANT and LA/LB take active initiatives to cooperate with inland transport sectors like rail track operator and build a green multimodal connection to hinterland. The two ports are on the way to increase the proportion of barge and rail in modal split since the two modes generate lower GHG emissions than trucks. In HK, we do not see stakeholder involvement directly in this area. But 60% of traffic coming into HK from its hinterland Mainland China is already via barge (Galbraith et al., 2008).

4.2 Public policy makers

Viewing ports as strategic assets in a country, public policy makers represented by government departments and agencies act as a central party and need to be actively involved in decision-making. The involvement of public policy makers will ensure that the green port strategy is aligned with the country’s interest and such

strategy can have a better chance of being sustained. In the three cases, the governments are all involved in the development of green port, however, the level of involvement and governing area differs.

ANT's Port Authority intends to act as a "responsible householder" (Port of Antwerp, 2010). On one hand, it monitors the overall situation and will take corrective actions wherever possible. On the other hand, it aims to develop into a centre of knowledge for environmental matters related to port activities, such as the evaluation of water quality. As for LA/LB, the port authorities serve as the driving force in ports' environmental protection. The cross-city partnership driven by the governments between the two neighbouring ports serves as a good model. The ports jointly adopt the San Pedro Bay Ports Clean Air Action Plan successfully reducing air pollution to a large degree. Supported by South Coast Air Quality Management District, California Air Resources Board and other related departments, this programme is also considered as an innovative attempt. As different from the other two ports, HK's green initiative is currently led by the industry largely due to *laissez-faire* policy adopted (Schiffer, 1991) which means transactions between private entities are free from government intervention. The port and stakeholders such as shipowners may invite government representatives to attend the meetings held by them and gradually expand the involvement of the government. Action has also gradually been taken by the government to form the cross-city partnership with Shenzhen learning from USA as mentioned above. However, to incorporate ecological concepts in port development such as in land reclamation, dredging, terminal redesign and terminal construction, the government has to play a more active role in such issues since they are beyond the maritime sector's control to involve urban planning and coastal management.

4.3 *Internal stakeholders*

We consider employees as a major category of internal stakeholders of a port. The employees' knowledge, understanding as well as enthusiasm towards a green port have a great impact on the port's development. The governing board of the port needs to take green education into account during the transformation. The three ports have taken steps to actively involve employees from top management to front-end staff in the process. For instance, they provide training on waste management and conservation of energy to employees so that they can handle such issues more proficiently. ANT has adopted a people-centric policy. In order to improve internal communication, an internal communication officer was appointed in 2010 in the Port Authority (Port of Antwerp, 2010). Practical measures have been taken by the internal communication department, such as proposed green port projects are discussed across various functions in the Port Authority. Associated information is also disseminated via the intranet which is tailored to its employees. HK also emphasized that employee engagement is one of the keys to the implementation of green port strategy. Similar to the above discussion, initiatives are led by the private sector. For example, Hongkong International Terminals, the largest terminal operator in HK communicates environmental objectives throughout the whole company. Managing Directors, General Managers and Department Heads are all members of the HIT Environmental Steering Committee. LA also pursues employee involvement and provided various training programmes to over 900 employees at the Harbor Departments (Port of LA, 2011). LA/LB incorporate a sustainability ethic into all port activities and communicate this ethic to employees and seek commitment accordingly. It is highlighted that being green also means protecting employees' rights since their working environment and health issues will be taken care of in green port strategy.

4.4 *Community*

Environment conservation is a public issue. Hence, when building a green port, the involvement with the public is not only indispensable but also beneficial for port image and sustainable development. In the three cases, all ports have made efforts to outreach to the public. They all form a relationship with NGOs and environmental institutes dedicating to pollution reduction and environmental research. ANT and LB go further and set natural conservation areas to protect wildlife with other organizations. Another common factor is that they all engage in community development by providing educational trips to the young, holding open house and so on. Strategies may vary from port to port.

ANT focuses on ecological port development with NGOs. Now the port has a 400 ha nature conservation area equipped with ecological infrastructure that provides a safe habitat for species commonly found in ports (Port

of Antwerp, 2010). HK tends to lay special emphasis on reducing the effects of pollution on the residents. Various measures to combat GHG emissions are explained above. An example on improving water quality is marine department's maritime oil spill response plan and anti-oil pollution operations (Marine Department, 2012). As for LA, it stresses on education for the young. It provides School Boat Tour Program and Speaker Series to the young in order to raise public awareness (Port of LA, 2012). Port of LB, on the other hand, attaches importance to publicize on green port using different marketing strategies. There are Open House and television programs featuring their green port branding (Port of LB, 2005).

4.5 Overall comparison

The case studies add value by representing an international perspective from the major ports in the three key geographical regions. The analysis above shows even though the ports adopt different schemes, various stakeholders are extensively involved in their green efforts. Further as the results in the table shows, when comparing the engagement with various stakeholders, LA/LB and ANT are more committed to adopting green port strategy. It can be explained as Hong Kong started fairly late and is learning from USA and Europe. Furthermore, the government's non-intervention policy accounts for HK's slower green development compared with the other two ports. Stakeholders have diverse interests and needs, but they must collaborate as a whole for the port's sustainable growth and development. Such collaboration could be formed through joint projects and technological innovation which are preferably coordinated and supported by public policy makers who play a central role in strategic planning and development. They are also the most suitable party to resolve conflicts, offer monitoring, incentives and enforcement in environmental issues.

5. Green and Sustainable Port Framework and Propositions

Based on the literature review and case studies, the following constructs are proposed to be included in the green and sustainable port framework as shown in figure 1.

Figure 1: Green and Sustainable Port Framework



Source: Authors

Stakeholder involvement: Ports cannot act alone while carrying out any green port strategies and they need collaborations from stakeholders of all four categories including market players, public policy makers, internal stakeholders and community, because most strategies are not unilateral. Apart from functional requirements on ports, social and ecological responsibility is one of the concerns of port stakeholders. Only through the efforts made by every group of stakeholders can the objective of a green port be achieved.

Green market development: Having understood the stakeholders' requirements, ports are required to define the market segment based on environmental consciousness of these stakeholders, especially customers in order to achieve economic, social and environmental sustainability simultaneously. Realizing competitors' competency and examining strengths and weaknesses of the port can devise the appropriate tactics for segment target. By utilising appropriate marketing campaign, services can be promoted and green culture can further facilitate green market development.

Cost effective green policy: Cost is a key concern for any commercial decision. Thorough cost and benefit

analysis (CBA) will enable port decision makers to determine the feasibility of environmental investment projects by calculating the expected costs and benefits. To achieve sustainable development, ports can adopt a cost effective green policy which is to compare projects by CBA and select those with higher net benefits.

Sustainable port operations and development: While port's social-economic contributions are recognised, there are financial strain and negative social and ecological effects brought by port activities and investment. In addition to green projects to reduce pollution, existing port operations should optimise space and productivity to avoid unnecessary terminal expansion. Also in view of market volatility, mindful and gradual terminal expansion in an ecological approach would be a sustainable strategy in port development.

Stakeholder involvement is crucial in devising and implementing green port strategy. This enables understanding and prioritization of stakeholders' needs and in turn facilitate green market development. Specifically, conducting stakeholder analysis and consultation can identify the green driving forces such as green port service demand and willingness to pay a premium (Lee and Lam, 2012). Furthermore, CBA can be conducted accordingly leading to more optimal cost effective green policy. Our port case studies indicate that the more active the stakeholders are involved, the more efficient the environmental programmes will be. The outcomes in terms of both marketing and cost effectiveness tend to be more promising. For example, the relatively lower rate of adoption in onshore power supply for ships compared to other green measures is largely due to the costs incurred by customers (shipping companies). Hence, the first two propositions are:

Proposition 1: Proper stakeholder involvement has a positive effect on green market development.

Proposition 2: Proper stakeholder involvement has a positive effect on cost effective green policy.

Sustainability requires a greater focus on integrating marketing and other corporate functions, including eco-design operations (Sharma et al., 2010). Tactics of green marketing will lead to the development of green logistics, waste management and green alliances (Polonsky and Rosenberger, 2001). Together with CBA, sustainable operations and development plans can be carried out with the aim to maximise higher net benefits for the port. The three ports demonstrate that environmental protection efforts go hand in hand with commercial tactics including marketing and costing so that the triple bottom line is met. As a whole, green port strategy consisting of green market development and cost effective green policy should contribute to sustainable outcomes on port operations and development, which lead to:

Proposition 3: Green market development has a positive effect on sustainable port operations and development.

Proposition 4: Cost effective green policy has a positive effect on sustainable port operations and development.

Empirical evidence suggests that ecologically-conscious policies lead to better customer retention which leads to better organizational performance including profitability (Sisodia et al., 2007). Commercial, ecological and social objectives can be compatible. A truly sustainable corporation is one that creates shareholder value while protecting the environment and improving the lives of those with whom it interacts (Savitz and Weber, 2006). The three ports endeavor to grow and be greener at the same time. Their customers and other stakeholders are generally supportive of the green measures, and in turn leading to customer retention. As discussed in the case, Hong Kong Shipowners Association, for example, even went for an extra mile to adopt green policy voluntarily. The fifth proposition is envisaged as:

Proposition 5: A green port will lead to positive outcome on port's customer retention and economic performance.

6. Conclusions

An original green and sustainable port framework has been proposed which contributes to theoretical exploration in green port strategy. The framework was built on key constructs of stakeholder involvement, green market development, cost effective green policy as well as sustainable port operations and development.

The case studies on Antwerp, Hong Kong and Los Angeles/Long Beach illustrated their green port policy and practice in comparative light. Particularly, the involvement of four stakeholder groups and seven types of environmental protection projects involved were analysed. The study provided guidelines for ports as they adopt a greener strategy for sustainability. For instance, ports can take reference from the details of stakeholder involvement to improve their green market development in achieving customer acquisition. Ports are also recommended to conduct cost and benefit analysis for formulating cost effective green policy. Appropriate resources in green solutions fulfilling stakeholders' priority can be deployed. This would lead to more sustainable outcome of environmental protection, social responsibility and economic performance simultaneously. Through the analysis, port stakeholders are also able to better understand the respective port's status and practices in environmental efforts.

The paper addressed a subject of immense public concern but little has been researched to date. For future research, a confirmatory factor analysis can be performed to analyse the measurement properties of the four research constructs to determine how well the items represent the latent factors. The next step would be performing examination of the propositions put forth. Although three port cases are regarded as good attempt in an exploratory work, more case studies from other countries can be conducted. Also, other methods can be employed for empirical investigation in the future. For instance, empirical test can be done in a larger scale facilitated by surveys so as to enhance research validity. It is also interesting to study more about the externalities generated by port operations and development, and the issue of internalizing the externalities through a market process.

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Rough Set Approach to Marine Cargo Risk Analysis

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Abstract

Considering the complication of shipping techniques, high mobility of cargoes and poor condition and uncertainty during the voyage, there are numerous risks in the transportation process. With the burgeoning of shipping volumes, the occurrence of accidents and disruptive events could bring huge losses. Despite of regulatory control such as the establishment of International Safety Management (ISM) Code, the rate of shipping accidents has not been reduced to the desired levels. Therefore, it is paramount to establish an effective risk quantification and management mechanism for shipping companies and to improve risk control process in order to cover the various components of the operating system. This paper provides a systematic and practical rough-set-based marine cargo risk analysis approach with the aim to find out the influential risk factors. Together with industry inputs, a comprehensive set of risk evaluation indicators considering various factors affecting shipping operations is developed. The study uses Rough Set method to classify and judge the safety attributes related to marine cargo and vessel. The method which is based on intelligent knowledge acquisition provides an innovative way for evaluating marine cargo risk. As illustrated by an example of a shipping company, we are able to calculate the significance of each factor and the relative risk exposure based on the original data without assigning the weight subjectively. Risk mitigation strategies can be formulated accordingly.

Keywords: marine cargo, shipping, risk analysis, safety, rough set

1. Introduction

Acting as trade facilitator, maritime transport plays a significant role in the contemporary world economy. However, shipping and marine cargo have been challenged by considerable increase in maritime risks. Events such as natural catastrophe, ship collision and piracy continue to appear in news headlines. Over the last decades, there has been an increase in the number of natural hazards and catastrophic events (EMDAT, 2012). Munich Re reported that the overall earthquakes and weather-related catastrophes in 2011 is the costliest year ever, recorded a total natural catastrophe losses at about US\$380 billion and total insured losses of US\$ 105 billion (Munich Re, 2012). A recent example is the Tohoku earthquake and tsunami in March 2011 which damaged Japanese seaports and marine cargoes. In terms of man-made incidents, piracy crisis in the Gulf of Aden, off the coast of Somalia, and in the wider Indian Ocean, has worsened since 2008 (MSC, 2012). Despite of regulatory control such as the establishment of International Safety Management (ISM) Code, the rate of shipping accidents has not been reduced to the desired levels (Celik et al, 2010; Knapp and Franses, 2010).

Considering the complication of shipping techniques, high mobility of cargoes and poor condition and uncertainty during the voyage, there are numerous risks in the transportation process. With the burgeoning of shipping volumes, the occurrence of accidents and disruptive events could bring huge losses. Furthermore, while precautionary measures such as insurance coverage could be adopted, hidden risks such as business interruption and loss of reputation that operators fail to identify will accumulate with the expansion in scale of business. Shipping companies could suffer from significant losses and financial difficulty. Therefore, it is paramount to establish an effective risk quantification and management mechanism for shipping companies and to improve risk control process in order to cover the various components of the operating system.

Building a risk assessment system, identifying and evaluating risks before hazards happen, dividing the risk level, conducting a feasibility study and formulating a risk mitigation plan (Manuj and Mentzer, 2008) is the major process to reduce the risks of shipping industry's stakeholders. The first and foremost point is, however, how to scientifically identify the core indicators that lead to shipping risk exposure among the numerous and complex factors, which has not been addressed in existing literature.

This paper, from a risk management perspective, focusing on the issue of marine cargo risk analysis, provides a systematic and practical rough-set-based approach with the aim to find out the influential risk factors in the shipping process. The study uses Rough Set method to classify and judge the safety attributes related to marine cargo and vessel. The focal point of this paper is to quantify the importance degree of each factor, and to build a mathematical model that comprehensively evaluates the risk exposure of marine cargo. After a literature review, the paper will present the methodology and the set of marine cargo risk evaluation indicators. Then the modeling process will be demonstrated by an example of a shipping company. The results and implications will be discussed thereafter.

2. Literature Review

2.1 Shipping risk analysis

A number of studies considered ships' technical features as causes of shipping risks. Roberts and Marlow (2002) conducted descriptive statistical analysis of the structural failure of bulk carriers based on Lloyd's of London casualty records over 1963–1996. Improvement in ship design such as strengthening bulkheads was suggested to reduce vessel and cargo damage. Celik (2008) analysed the design-based deficiencies in shipboard systems by referring to experimental surveys and ship deficiency reports. A shipyard-centered information network on monitoring design-based failures was proposed. Focusing on engineering perspective, Wang et al. (2002) developed a model to measure the structural performance of a ship in an accident. Some other scholars focused on navigation environment (Judson and Shortreed, 1999; MacDonald, 1999). Toffoli et al. (2005) conducted an investigation of shipping accidents particularly reported as being due to bad weather conditions. Based on frequency and severity of accidents, Hu et al (2007) performed a formal safety assessment by quantifying risks in ship navigation, particularly harbor pilotage. The human factor is another main concern investigated in the literature. Fatigue, stress, teamwork, communication and safety culture were found to be important human factors influencing maritime safety (Hetherington et al., 2006). The analysis of accidents in container ships showed that safety management practices, safety training and job safety are the most significant factors (Lu and Tsai, 2008). Celik and Cebi (2009) conducted a comprehensive study applying the Fuzzy Analytical Hierarchy Process (AHP) method for human factors analysis and classification. Skill-based errors, personnel factors such as coordination and communication, as well as shortfalls in the execution of organizational processes as root causes were the key factors.

While the literature provides good references on shipping risks, the major limitation of the above studies is that they mainly focused on one kind of factor. Few efforts have been extended to conduct risk analysis considering multiple factors. Antão and Guedes Soares (2008) analysed a chain of events leading to shipping accidents. The associated causal factors for ocean-going commercial vessels and high-speed crafts were examined. Human error, daily operation, ship equipment, management and resources parameters were included. Nevertheless, only descriptive statistics were presented which would not be able assess the significance of the factors. More rigorous analysis included the work done by Ventikos and Psarafitis (2004) which developed the event-decision network and related it with International Maritime Organization (IMO)'s formal safety assessment for oil spill accidents. Major factors considered were human, vessels and environmental conditions. The ship, crew's qualification, the environment and meteorology were included in Balmat and Lafont's (2009) study on individual ship risk factor using fuzzy logic evaluation. Centered on shipping accident investigation, Celik et al (2010) combined the effects of organizational faults and shipboard technical system failures in their modeling approach using a fuzzy extended fault tree analysis. However, these studies did not directly relate to cargo damage/loss and the associated risk analysis. Skjong and Guedes Soares (2008) suggested that there is an urgent need for improvements in methodological approaches in order to enhance shipping safety. This paper contributes by addressing these gaps in the existing literature.

2.2. *Rough set theory*

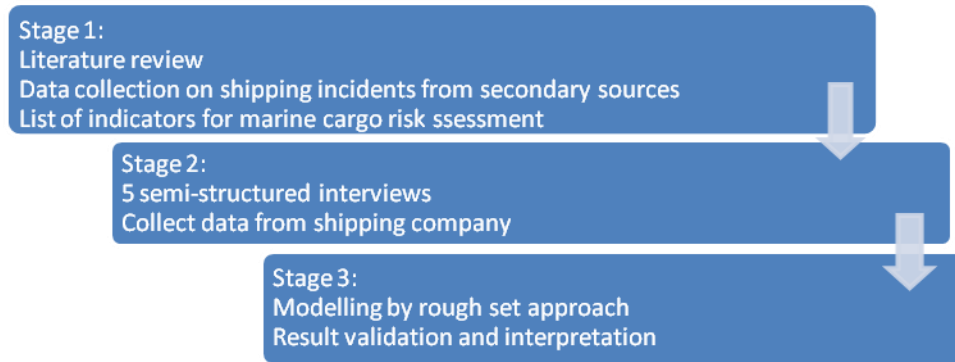
This paper studies marine cargo risk in the international shipping setting, which faces high uncertainty and dynamism in a multi-facet environment. After a comprehensive literature review, we propose the Rough Set approach firstly introduced by Z. Pawlak (Pawlak, 1982) as a new solution tool, which has successful applications in data mining, prediction, control, pattern recognition and classification, mechanism learning, and decision analysis and support in other domains, such as finance (Dimitras et al, 1999), marketing (Kumar et al, 2005), human resource management (Chien and Chen, 2007), image processing (Wojcik, 1994) and engineering (Shen et al, 2000). The method classifies the study objects into similarity classes containing objects that are indiscernible, i.e. possess the same properties. The classification features form the basic concepts of knowledge about the subject matter.

Rough set theory (RST), which is based on knowledge acquisition and discovery, would have brilliant application prospect in the research topic. In many practical systems, there are various degrees of uncertainty, especially in the data collection process which often contains inaccurate and missing data. RST is a suitable mathematical tool to deal with vagueness and uncertainty (Pawlak, 1995). Considering marine cargo transportation, the most important task is to ensure safe and timely cargo arrival at the port of destination. Based on this concern, evaluating the elements along the shipping path directly and the root cause of risks would be the most appropriate approach. The condition of marine cargo transportation is usually dynamic and hard to predict, which leads to difficulty in finding pre-requisite knowledge. A major advantage of RST is that the weight of the factors is not assigned subjectively like what is done in AHP method. Also, RST does not require any preliminary or additional information about the data, unlike requiring grade of membership or the value of possibility in fuzzy set theory used in previous maritime risk studies (Grzymala-Busse, 1988; Pawlak and Slowinski, 1994; Kusiak, 2001).

3. **Research Methodology**

The research process is divided into three stages as shown in figure 1. Stage 1 involves secondary research in which literature review has been conducted to understand the state of the existing scholarly work related to the topic of interest. Also, various sources such as company annual reports, trade journals, databases and the internet were consulted for collecting data and information especially on shipping incidents. The deliverable of the first stage is a tentative list of indicators for marine cargo risk assessment. The second stage is primary research with the main objective to verify the proposed indicators and data collection. Five semi-structured interviews were carried out in 2011 to gather opinion and information from the industry. The interviews were targeted at the management personnel of two shipping companies and two insurance companies which are the most relevant for the study topic. Shipping companies represent a natural choice since they are carriers of marine cargoes and are in charge of the voyage. The companies have domain knowledge in shipping management including the handling of the associated marine cargo risks. As for insurance companies, they are professional organisations in managing risks by underwriting insurance policies, thus being able to provide relevant information and opinion on the subject matter. A maritime professional who has worked in various sectors in the maritime industry for over 30 years was also consulted for a neutral and balanced view. Though the interviews were performed in Singapore, the organisations involved are all international entities serving a wide coverage of the global market. The organisations are among the world's largest in their respective industry sector. The interview setting was not limited to local specificity. The interviewees have given information and opinion on the indicators for marine cargo risk analysis. Minor adjustment was made to the list of indicators according to the interview outcome of Stage 2. Then Stage 3 involves modeling by rough set approach. Through a numerical example, RST is applied for obtaining the importance degree of each indicator in quantitative characterization, that is, to obtain the weight vector of each indicator. Finally, based on the output of the evaluation model, result interpretation and judgment on risk mitigation as well as validation are demonstrated. Details of the rough set approach will be presented later in section 5.

Figure 1: Research Process



4. Marine Cargo Risk Evaluation Indicators

This study takes reference from the literature and incident records as explained above for developing a comprehensive set of indicators for marine cargo risk evaluation throughout the shipping process. The evaluation aims to fully reflect the various factors and their significance. Shipping is a system, where shipping companies, ship, cargo, crew, port and waterway transport system are crucial to maintain the normal operation of shipping (Frankel, 1999). Any problems in an element or any errors arising from the interaction among the elements may lead to accidents. External factors such as weather conditions should also be included in the risk evaluation (Toffoli et al., 2005). The risk evaluation indicators representing the sources of risks will be elaborated below.

4.1 Human factor (R_1)

Human factor mainly refers to seafarers as they are the personnel directly controlling the shipping process. Several researches (UK P&I 1999; Portela, 2005) reflected that human error caused 60% to 80% of all the maritime accidents. The human factor can be divided into two categories as below.

1) Knowledge and Skill (R_{11})

Seafarers have to go through specialized training and the level of technical quality is fundamental. With more advanced marine technology, the requirement on crew's knowledge and skills has become more complicated (Celik and Cebi, 2009). Safety training programmes can help to reduce vessel accidents (Lu and Tsai, 2008). Such training should cover both accident preventive measures and handling techniques should any incidents occur. Crew should be equipped with knowledge and skills adequate for manning the specific ship type and cargo operations.

2) Safety Consciousness (R_{12})

Fatigue, stress, teamwork, communication and safety culture are important human factors influencing maritime safety (Hetherington et al., 2006). Safety consciousness is an appropriate indicator to reflect these issues since the crew's awareness in risk-prone acts and circumstances is directly related to shipping safety level (Griffin and Neal, 2000).

4.2 Vessel (R_2)

Sub-standard or aging vessel is one of the risk sources. The ship's status is closely related to maintenance and duration of usage. In general, the overall situation of the ship can be reflected from its technical condition.

1) Age of the Ship (R_{21})

With hull structural strength declining due to corrosion and physical damage sustained during cargo operations, the ability to resist wave, the operational reliability of ship equipment and the intact rate drop (Lloyd's, 1991; Wang et al., 2002). According to the accident statistics taken by DNV (DNV, 2001), vessels aged 15 years or above account for 86% of total loss in ship accidents, meaning that ship's age has great impact on the stability and strength of vessels.

2) *Hull and Machinery* (R_{22})

The condition of the vessel's hull and machinery also directly determines shipping operations. Cargo vessels should satisfy the requirements of hold configuration, fireproofing and waterproofing condition, electronic facilities, communication facilities, lightning conductors and cargo gear (FAA, 2000); otherwise problems will appear and may lead to vessel capsized.

4.3 *Cargo* (R_3)

The cargo itself is responsible for marine cargo and shipping risks.

1) *Cargo Attributes* (R_{31})

Cargo attribute evaluation should focus on whether the goods are dangerous. Dangerous goods should be specially taken care of to avoid explosion and other serious consequences. As such, shipping operations should obey the International Maritime Dangerous Goods Code (IMDG) published by IMO (Gold, 1986; IMO, 2011).

2) *Cargo Stacking* (R_{32})

In recent years, a large number of marine accidents investigation showed that a considerable proportion of the incidents is directly or indirectly due to the movement of goods carried. According to MAIB statistics in 2010 (MAIB, 2010), out of 12 cases occurred in merchant ships, six happened due to stacking issue which directly reflects the problem of staking system. Hence, cargo staking should obey the SOLAS Convention and have cargo securing certification approved by the authorities.

4.4 *Port* (R_4)

Ports interface with ships and are responsible for cargo handling hence play a key role in shipping and cargo safety.

1) *Ship Berthing and Unberthing Procedure* (R_{41})

Water depth, shoreline length, number of berths, cranes, throughput, management capacity, service type and quality are important indicators of port capacity (Lam and Dai, 2011; Mansouri, 2010). These derive the standards for port management and operations. The major evaluation focus here is the safety level of ship berthing and unberthing procedure (Hu et al, 2007).

2) *Cargo Loading and Unloading Procedure* (R_{42})

The availability of appropriate cargo handling equipment, port's competency in cargo operations and port's responsiveness in any emergency form a necessary index to be included in the port operation performance assessment process (Mansouri, 2010).

4.5 *Environmental factor* (R_5)

Shipping operation is also determined by environmental factors which are the external risks affecting meteorological condition and seaworthiness to navigation. Such risks can be broadly classified into natural hazards and weather extremes.

1) *Natural Hazards* (R_{51})

This indicator includes earthquake, tsunami, volcano eruption and natural disasters alike concerning "low-frequency high-impact disruption scenarios" in the context of maritime risks. However, there is an increase in natural disasters over the past 30 years (EM-DAT, 2012) which means there could be higher marine cargo exposure especially in seismically vulnerable regions.

2) *Weather Extremes* (R_{52})

The weather conditions influencing ship navigation include wind, fog, rain, snow, clouds and so on. As to sailing ship, the greatest impact on her navigation is wind which will in turn create waves (Toffoli et al., 2005). Ships at different routes or in different season would suffer from various impacts of waves (Bruce, 2008).

4.6 Geopolitical factor (R_6)

Those risks involving the relationships among politics and geography, demography and economics are considered under the geopolitical factor.

1) Piracy (R_{61})

Piracy has been a threat to merchant shipping for long. Notably, the piracy crisis in the Gulf of Aden, off the coast of Somalia, and in the wider Indian Ocean, has worsened since 2008 (MSC, 2012). Analysis of piracy hijacking incidents suggests that state weakness encourages more sophisticated attacks (Hastings, 2009).

2) Political conflicts (R_{62})

Political risks such as war and terrorist attacks are also possible sources of shipping risks. Major terrorist hubs are located in the coastal regions, namely LTTE in Jaffna, Sri Lanka; Al Qaeda in Yemen, Somalia and Pakistan; the Abu Sayyaf Group in the Philippines, the Free Aceh Movement in Indonesia (MSC, 2012). The sea serves as a safe highway for those terrorist groups and acts as a catalyst for promoting terrorists' activities if there are insufficient countermeasures.

5. Modelling by Rough Set Approach

This section presents a numerical analysis in evaluating marine cargo risk to demonstrate the computational process as described in above sections of the proposed approach. The analysis is based on an international shipping company located in Singapore. Thus it is an industry example demonstrating our model's practicality.

5.1 Set up information table

$U = \{1, 2, 3, 4, 5, 6\}$ represents the study objects, i.e. a set of marine cargo incidents, and each number stands for an incident that a shipping company had during shipping operation. R_{ij} represents the 12 risk evaluation indicators as explained in section 4. Based on historical data from the incidents' records kept by the company, a score of 1 to 5 is given to each indicator, with 5 being the highest risk exposure level. The scoring means that in one case, if certain situation is very tough, such as poor weather condition, then 5 is given to represent very high risk level. On the contrary, if an indicator is relatively reliable and safe, for instance competent cargo handling by the port, then 1 can be given to represent very low risk exposure in this aspect. In addition, the outcome on marine cargo is represented by $D = \{\text{cargo incident outcome}\}$. Y stands for cargo damage and/or loss, and N means no cargo damage/loss.

Uncertainty is inevitable no matter how experienced is the assessor and how much data is given to support the choice of a score. Moreover, the characteristic of the shipping industry is that the related conditions are changeable. For example, policies and economic environment are dynamic and we cannot use a certain standard to judge them (Jacobs and Hall, 2007; Panayides, 2003). Hence the record kept by shipping companies may be incomplete and have some flaws. This is especially true for shipping incidents since their occurrence is unanticipated and some data may be lost or unrecorded during the events. These features of the problem make the rough set approach an ideal methodology as it is capable in handling vague, inconsistent, uncertain and missing data by separating certain and doubtful knowledge extracted from exemplary cases (Pawlak, 1995; Grzymala-busse, 2003). Table 1 shows the initialized information in the numerical example for demonstration. The rough-set approach is flexible and can accommodate any number of objects and indicators as long as they are finite sets. Also, other values can be taken according to different cases. For instance, the incidents can be rated in a seven-point scale instead.

Table 1: Initialized information S'

U	R_{11}	R_{12}	R_{21}	R_{22}	R_{31}	R_{32}	R_{41}	R_{42}	R_{51}	R_{52}	R_{61}	R_{62}	D
1	4	*	1	2	5	2	2	*	1	4	3	4	Y

2	4	3	1	3	5	2	2	3	3	1	2	1	Y
3	5	5	4	4	4	4	4	5	5	3	3	2	Y
4	3	4	1	4	4	2	2	*	1	2	4	4	N
5	4	*	2	2	2	*	*	2	2	2	2	3	N
6	2	3	3	3	4	1	3	2	1	4	1	2	N

* denotes that data is unavailable and/or assessor is unable to give a score

5.2 Solution and analysis

5.2.1 Obtain similarity relation from information table

A denotes a subset of the attribute, i.e. risk evaluation indicators, a refers to a particular indicator within A . $SIM(A)$ denotes binary *similarity relation* between objects that are indiscernible with regards to indicator's value. The *similarity relation* can be defined as:

$$SIM(A) = \{(x, y) \in U \times U | \forall a \in A, a(x) = a(y), \text{ or } a(x) = * \text{ or } a(y) = *\} \quad (1)$$

Where (x, y) stands for pair of study objects. This means, two study objects (x, y) has binary similarity relation if the value of each attribute for object x , i.e. $a(x)$, is the same as the value of the corresponding attribute for object y , i.e. $a(y)$. For any value of attribute which is missing, i.e. $a(x) = *$ or $a(y) = *$, $a(x)$ and $a(y)$ are considered the same since $*$ can represent any number.

$S_A(x)$ represents the maximal set of objects which are possibly indiscernible by A with x .

$$S_A(x) = \{y \in U | (x, y) \in SIM(A)\} \quad (2)$$

Referring to table 1, we compare the objects' attributes. No object has the same attribute values as the other object. Hence, no objects are similar in this case. Then the similarity relation is given below.

$$S_A(1) = \{1\}$$

$$S_A(2) = \{2\}$$

$$S_A(3) = \{3\}$$

$$S_A(4) = \{4\}$$

$$S_A(5) = \{5\}$$

$$S_A(6) = \{6\}$$

5.2.2 Determine all reducts

A reduct is a minimal set of indicators from A that preserves the original classification defined by A . This can be determined by establishing Boolean Discernibility Matrix (Pawlak and Skowron, 2007) with $\alpha_A(x, y)$ for any pair (x, y) of the objects. Place $x \in U$ and $y \in \{z \in U | d(z) \notin \delta_A(X)\}$ in table 2, where z is a particular object, $d(z)$ is cargo incident outcome of object z showing in the last column of table 1, $\delta_A(X)$ is the cargo incident outcome of object x . Let $\alpha_A(x, y)$ be a set of indicators, which $a \in A$ and $(x, y) \notin SIM(\{a\})$. This means, table 2 lists out those objects which are dissimilar in terms of cargo incident outcome. Let $\sum \alpha_A(x, y)$ be a Boolean expression which is equal to 1, if $\alpha_A(x, y) = \emptyset$. Otherwise, let $\sum \alpha_A(x, y)$ be a disjunction of variables corresponding to attributes contained in $\alpha_A(x, y)$.

Δ is a *discernibility function* for information table.

$$\Delta = \prod_{(x,y) \in U \times \{z \in U | d(z) \notin \delta_A(X)\}} \sum \alpha_A(x, y) \quad (3)$$

$\Delta(x)$ is a *discernibility function* for *Object x* in information table.

$$\Delta(x) = \prod_{y \in \{z \in U | d(z) \notin \delta_A(X)\}} \sum \alpha_A(x, y) \quad (4)$$

Table 2: Discernibility Matrix

$x \backslash y$	1	2	3	4	5	6
1				R11R22R31R52R61	R21R31R51R52R61R62	R11R21R22R31R32R41R61R62
2				R11R12R22R31R51R52R61R62	R21R22R31R42R51R52R62	R11R21R31R32R41R42R51R52R61R62
3				R11R12R21R32R41R51R52R61R62	R11R21R22R31R42R51R52R61R62	R11R12R21R22R32R41R42R51R52R61
4						
5						
6						

5.2.3 Calculate the importance degree of each risk indicator

Then the importance degree of each indicator can be calculated by using the following equation:

$$f(a) = \sum_{i=1}^n \sum_{j=1}^n \frac{\lambda_{ij}}{Card(E_{ij})} \quad (5)$$

In equation (5), $\lambda_{ij} = 1$ when $a \in C_{ij}$, $\lambda_{ij} = 0$ when $a \notin C_{ij}$.

C_{ij} represents a risk evaluation indicator appeared in table 2.

$Card(E_{ij})$ means the total number of indicators in one entry of table 2.

E_{ij} represents the element of Boolean Discernibility Matrix in table 2.

Here is the calculation of R_{11} 's importance degree as an example:

$$f(R_{11}) = \frac{1}{5} + \frac{1}{8} + \frac{1}{8} + \frac{1}{10} + \frac{1}{9} + \frac{1}{9} + \frac{1}{10} = 0.87$$

Thereafter, the importance degree can be normalized for easier comparison, which can be calculated by the following equation: $\omega_{ij} = \sigma_{cd}(C_{ij}) / \sum_{i=1}^n \sigma_{cd}(C_{ij})$, where $\sum \omega_{ij} = 1$. Table 3 shows the results. In this shipping company, the most significant risk evaluation indicators are R_{52} weather extremes, closely followed by R_{61} piracy and then R_{31} cargo attributes.

Table 3: Importance Degree of the 12 Risk Indicators

	R ₁₁	R ₁₂	R ₂₁	R ₂₂	R ₃₁	R ₃₂	R ₄₁	R ₄₂	R ₅₁	R ₅₂	R ₆₁	R ₆₂
<i>f</i>	0.872	0.336	0.857	0.804	0.971	0.436	0.436	0.454	0.857	1.057	1.039	0.882
ω	0.097	0.037	0.095	0.089	0.108	0.048	0.048	0.050	0.095	0.117	0.115	0.098

5.2.4 Risk analysis

As illustrated above, the relative significance of risk factors can be revealed and quantified. Further insights can be obtained by knowing the relative risk exposure of each aspect. The equation “ $Q_{ij} = \omega_{ij} \times V_{ij}$ ” can be used to calculate and evaluate the risk exposure of a shipping service. Like those values given in table 1, V_{ij} is given by assessor(s) from the shipping company. In other applications, the values can be obtained from a third party such as surveyor or from a combination of various creditable sources. Higher Q_{ij} implies higher risk. Table 4 illustrates an example from which it can be seen that R_{21} ship’s age having the highest Q value of 0.476 represents the greatest risk, followed by R_{61} piracy. Although R_{52} weather extremes is the most significant risk evaluation indicator as shown in table 3, the risk score of 2 indicates that the shipping route’s weather is rather stable. Hence this Q value is relatively low and would not be a high risk factor in this example.

Table 4: Risk Analysis Example

	R ₁₁	R ₁₂	R ₂₁	R ₂₂	R ₃₁	R ₃₂	R ₄₁	R ₄₂	R ₅₁	R ₅₂	R ₆₁	R ₆₂
ω	0.097	0.037	0.095	0.089	0.108	0.048	0.048	0.050	0.095	0.117	0.115	0.098
<i>v</i>	3	4	5	4	3	4	2	1	2	2	4	3
<i>Q</i>	0.291	0.149	0.476	0.357	0.324	0.194	0.097	0.050	0.190	0.235	0.462	0.294

This example can also be used for validating our rough set model. First, $\sum Q_{ij}$ indicating the overall risk level is calculated from samples with complete data, i.e. samples 2, 3 and 6 in table 1. The scores are 2.473, 3.643 and 2.455 respectively. Based on the cargo incident outcomes Y, Y and N, the results reveal that 2.46 would be the score representing the risk threshold above which cargo incident is more likely to happen. Next, based on the example from table 4, $\sum Q_{ij}$ is 3.119 which means that cargo incident is likely to happen. According to the shipping company’s data, there was indeed cargo damage during this shipping service. We would like to highlight that it is not the purpose for the model to be a definitive guide to predict whether there will be a cargo incident or not, although higher $\sum Q_{ij}$ would generally reflect greater likelihood of cargo incident. Instead, the merit of the approach is to find out the influential risk factors in order to improve awareness and risk mitigation, which fulfills the major objective of this study.

6. Research and Practical Implications

The study has contributed to research and practice in various ways. First, the study has provided a novel method for analyzing marine cargo risks. In a broader sense, it is an original attempt to use the rough set approach for transportation risk problems. The novelty of this study is to address the concern of objective and precise weight of the factors in the framework of RST. This concern has not been tackled by the maritime safety and risk studies reviewed previously, and virtually majority of the studies applying RST. This is very crucial for any risk analysis since the reliability of research outcomes significantly depend on the attributes’ weight (Belton and Stewart, 2002). As illustrated by the example of a shipping company, we are able to calculate the significance of each risk factor based on the original data without assigning the weight subjectively. In fact, the main theme of RST is to measure the “ambiguity” inherent in the data and to reveal

hidden patterns.

Second, the method is capable of handling missing data. Unlike statistical analysis, it is not necessary to discard samples with incomplete data. More samples can be retained when the rough set method is used which reduces the limitation of data problems. Quality solutions can still be obtained without the hassle to collect extra samples, if at all possible. The method's advantage makes a valuable advancement to the risk management field.

Furthermore, the quantitative importance degree of the risk evaluation indicators reveals the major root causes of marine cargo incidents. Managerial implications can be drawn and appropriate actions can be taken accordingly. While all factors play a part contributing to safe shipping operations, due to cost constraints in practice, shipping companies can pay particular attention to the most decisive factors and resources can be reallocated if necessary. For instance, R_{52} weather extremes and R_{61} piracy are found to be the most significant risk evaluation indicators in the company. These risks are generated from external sources so a possible way to reduce such risks is to transfer them by insurance policy. Another recommendation is to review the shipping routes and try to avoid high risk areas in terms of adverse weather and pirate active zones such as Somalia. The shipping company should also strengthen staff training in handling navigation and cargo operations during bad weather conditions and pirate attacks. Moreover, referring to a specific company and shipping service's situation, risk exposure of each aspect can be quantified. High risk areas should be tackled first by utilizing appropriate risk mitigation measures. The study can strengthen the identification and monitoring of shipping risks. In addition to application by shipping companies in terms of operations safety, the rough set method offers insurance companies an alternative to assess safety status of the underwriting ships and cargoes and provides valid support for underwriting policy and decision making.

7. Conclusions and Future Research Directions

Maritime safety and risk management is an important topic affecting shipping companies, seafarers, cargo owners, insurance companies and regulatory authorities among others. It is necessary for stakeholders, particularly shipping companies and classification societies, to design, establish and apply effective risk assessment system. The merits of RST to handle incomplete and uncertain information, and its capability of minimizing subjective analysis have been exploited in this study. The paper established a systematic marine cargo risk exposure assessment, and also offered a guide for risk identification process in maritime-related business. By this, risk mitigation strategies can be formulated. In sum, a major contribution of this paper is demonstrating how to establish risk analysis with vague, dynamic, complex and incomplete data in maritime business.

Same as other studies, the paper contains research limitation. A rather low number of incidents are used for illustration. Future research can be devoted to examine more samples. However, we should note that the number of marine cargo incidents in a particular shipping company may not be very high in practice. Also, a low number of samples does not pose any problems in rough set algorithm. As a whole, the numerical example has clearly demonstrated the analysis and research outcomes, and has fulfilled the objectives of the research. Regarding more future research, the research process and model developed provide a lot of potential that study can be undertaken on other types of cargos, such as dangerous goods and refrigerated cargo, as well as other risk management topics.

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Damage and Compensation for Marine Pollution in China

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Abstract

In the past two decades, imports of crude oil have been increasing dramatically as a result of China's economic development. In the mean time, the risk of oil pollution from ships has also been increasing along with the growing need for crude oil. To deter oil pollution from ships, China has enacted laws and regulations for prevention of and compensation for vessel-source oil pollution. In particular, several laws and regulations have come into effect during past three years and they brought significant changes to the compensation system of vessel-source oil pollution in China. This paper aims to illustrate how China is establishing its compensation system and improving its compensation standards for vessel-source oil pollution. The current situation with regard to oil spills from ships in Chinese sea area and legal framework of compensation for vessel-source oil pollution are explored. It is found that China has made great efforts to improve the compensation capacity for oil pollution damage from ships. The framework of a two-tier compensation system for oil pollution damage from ships, afforded by both the shipping industry and the oil industry, is hoped to be established once a national compensation fund is successfully established. However, if major oil pollution incidents occur in Chinese sea area, the compensation from the national compensation fund would not be adequate. Acceding to the Fund Convention could give stronger protection to both victims and marine environment.

Keywords: vessel-source, pollution, compensation system, China

1. Introduction

China is a coastal country with long coastline. It has a coastline of more than 18,000 kilometers and an island coastline of over 14,000 kilometres. The mainland of China is flanked to the east and south by the Bohai Sea, the Yellow Sea, the East China Sea and the South China Sea. Since early 1980s, marine environmental deterioration has occurred in China with rapid economic development and population growth (Wang et al., 2006). A whole array of measures to strengthen marine environmental protection has been adopted by Chinese government in the past 20 years¹. China Ocean Agenda 21 was published in 1996, setting forth basis, objectives, principles and counter-measures for ensuring sustainable ocean development. Besides, the legal system of marine environmental protection has been gradually established by participation of a number of international conventions and promulgation of a series of domestic legislations. Despite all the efforts and progress made so far, the environmental situation in coastal marine zone is still serious in China (Wang, 2006).

¹ Report on the China Environmental Protection (1996-2005) published by State Council conduct a systematic review of the environmental protection in China. Available at: <http://eng.chinalawinfo.com/Wbk/display.asp?id=52&keyword=>

As defined in United Nations Convention on the Law of the Sea (hereinafter referred to as UNCLOS), pollution of the marine environment means ‘the introduction by man, directly or indirectly, of substances or energy into the marine environment, including estuaries, which results or is likely to result in such deleterious effects as harm to living resources and marine life, hazards to human health, hindrance to marine activities, including fishing and other legitimate uses of the sea, impairment of quality for use of sea water and reduction of amenities’.² Based on the pollutant source, pollution of marine environment is usually classified into following 6 types³: (1) pollution from land-based source; (2) pollution from coast construction projects; (3) pollution from marine construction projects; (4) pollution by dumping of waste; (5) pollution from vessels; and (6) pollution from or through atmosphere. This paper is concerned with the vessel-source marine pollution in China.

As the world’s second largest importer of crude oil, China imported 234.6 million tonnes of crude oil in 2010. Meanwhile, about 90% of imported oil is transported by tankers (Liu, 2009). Along with development of marine petroleum industry and marine transportation, vessel-source oil pollution has become a grave threat to marine environment in China (Zou, 1999). Compensation for vessel-source oil pollution plays an essential role in protecting the interests of victims and in prevention of oil pollution. The purpose of this paper is to investigate how China is establishing its legal system of compensation for vessel-source oil pollution and improving its compensation standards.

2. Current Situation of Oil Spill from Vessels in Chinese Sea Area

According to statistics from the Ministry of Communications of the PRC, during the period from 1973 to 2009 approximately 37,514 tonnes of oil were discharged or escaped into Chinese sea area from ships, this involving 84 oil spill incidents of over 50 tons each.⁴ On average, 2 incidents involving more than 50 tonnes take place each year, and the average annual spillage volume is 1,014 tonnes. As indicated in Figure 1, amount of oil spilled in the 1970s (i.e. 1973 to 1979), being nearly twice that recorded for the 1980s (1980 to 1989), is the highest on record among the last four decades. However, contrary to the internationally downward trend, there is an upward trend in oil spillage showing in terms of both the spillage volume and the number of incidents since 1990. The total oil spillage volume for the 2000s (2000-2009) comes to 11,121 tonnes. This increase can be attributed to the continued rise in oil imports since 1993, when China turned from being an oil exporter into an oil importer (Zhang and Zhou, 2002). As stated in above section, about 90% of imported oil is transported by tankers. It is very likely that such large scale oil transportation by sea has significantly increased the risk of an oil spill incident. Moreover, it has to be noted that oil spill incidents of over 50 tonnes have taken place frequently during past 10 years. The total number of oil spill incidents during the 2000s was the largest throughout the last four decades. Consequently, from an analysis of oil spillage statistics over recent decades, it can be seen that, although there has not been a catastrophic oil spill incident in Chinese sea waters, the risk of oil pollution from ships keeps rising.

Figure 1: Number and Volume of Oil Spillage in China Over 50 Tonnes by Decade

Decade	Number of Spills	Percentage of Total Number	Volume of Spillage (Tonnes)	Percentage of Total Volume
1970s	11	13.1%	12,613	33.6%
1980s	8	9.5%	6,499	17.3%
1990s	30	35.7%	7,281	19.4%
2000s	35	41.7%	11,121	29.6%

Source: Author(s) of the original source

Under those circumstances, the compensation for vessel-source oil pollution is becoming a key issue in protection of the interest of victims and in prevention of oil pollution. In following sections, compensation system for vessel-source pollution in China will be analysed.

²UNCLOS, Article 1(4)

³UNCLOS, Article 207-212 and Marine Environment Protection Law, 1999 (MEPL 1999), Article 29, 42, 27,55,62

⁴ All oil spills mentioned in this article refer to oil spills of over 50 tonnes from ships into Chinese sea water.

3. Legal System of Compensation for Vessel-Source Oil Pollution in China

There is no specific oil pollution law in China; stipulations of the civil liability and compensation for oil pollution damage from ships can be traced in several national legislations and international conventions to which China has acceded (Figure 2).

Figure 2: Laws concerning Compensation for Oil Pollution Damage from Ships in China

	Name of Law/Regulation/International Convention	Year of Promulgation/ Accession
National Legislations	1. General Principle of Civil Law	1986
	2. China Maritime Code	1992
	3. Marine Environmental Protection Law	1999
	4. Regulations on the Prevention and Control of Marine Pollution from Ships	2009
	5. The Tort Law	2009
	6. The Measures for Implementation of Insurance of Civil Liability of Oil Pollution from Ships	2010
	7. The Provisions of the Supreme People's Court on Several Issues Concerning the Trial of Cases of Disputes over Compensation for Vessel-induced Oil Pollution	2011
International Conventions	1. The 1992 Civil Liability Convention ⁵	1999
	2. Bunker Convention 2001 ⁶	2008

Source: Compiled by Authors

3.1. Recent Development

During past three years, several laws and regulations regarding compensation for vessel-source oil pollution have come into effect. They brought significant changes in this area. On 1 March 2010 the amended Regulations of the PRC on the Prevention and Control of Marine Pollution from Ships (hereinafter referred to as “the Amended Regulations”) took effect. Meanwhile, the Measures for Implementation of Insurance for Civil Liability of Oil Pollution from Ships (hereinafter referred to as “the Oil Pollution Insurance Regulation”) took effect as of 1 October 2010. In addition, the Provisions of the Supreme People's Court on Several Issues Concerning the Trial of Cases of Disputes over Compensation for Vessel-induced Oil Pollution (hereinafter referred to as “the Judicial Interpretation”)⁷ came into effect on 1 July 2011. A number of uncertain issues with regard to liability and compensation for oil pollution damage from ships have been clarified.

3.2. Applicable Law

The oil pollution from ships can usually be classified into two different kinds: (1) oil pollution caused by Chinese flagged vessels engaged in coastal services between Chinese coastal ports (hereinafter referred to as “purely domestic oil pollution”) and (2) oil pollution from ships in which foreign elements are involved (hereinafter referred to as “foreign-related oil pollution”). It is unanimously recognized in China that the 1992 CLC and Bunker Convention are applicable to foreign-related oil pollution. However, various conflicting views exist as to whether these two conventions should also apply to purely domestic oil pollution. The predominant opinion holds that these two conventions should only apply to foreign-related oil pollution and thereby purely domestic oil pollution should only be regulated by national legislations. Furthermore, it should also be noted that, due to the limited scope of its application, such as oil type and vessel type, the 1992 CLC cannot apply to all of the oil pollution that has foreign elements involved. The 1992 CLC applies exclusively

⁵ The Protocol of 1992 to Amend the International Convention on Civil Liability for Oil Pollution Damage, 1969 (referred to as “the 1992 CLC” in this paper)

⁶ The International Convention on Civil Liability for Bunker Oil Pollution Damage, 2001 (referred to as “Bunker Convention” in this paper)

⁷ According to Articles 5 and 6 of Provisions of the Supreme People's Court on the Judicial Interpretation Work, a judicial interpretation has legal force.

to persistent hydrocarbon mineral oil.⁸ Therefore, non-persistent oil pollution and other oil pollution outside of the scope of 1992 CLC (excluding oil pollution to which Bunker Convention applies) shall be subject to domestic legislation, even when foreign elements are involved⁹. To summarize, the foreign-related oil pollution within the scope of 1992 CLC/Bunker Convention shall be regulated by both national regulation and international conventions which will take priority in application¹⁰ if there are conflicts between them, while purely domestic oil pollution and foreign-related oil pollution outside the scope of the 1992 CLC /Bunker Convention shall be only governed by national legislation.

3.3. *Strict Liability and Liable Parties*

3.3.1 *Foreign-Related Oil Pollution*

Shipowner is strictly liable for any oil pollution,¹¹ and at the same time limited exemptions offered.¹² If oil is discharged or escapes from two or more vessels, owners of all the ships concerned shall be jointly and severally liable for all such damage that is not reasonably separable.¹³ As to the oil pollution from tankers, the 1992 CLC channels the liability to the shipowner¹⁴ that refers to the registered owner or the person or persons owning the ship when registered owner is in absence.¹⁵ At the same time, Bunker Convention provides a wider definition of shipowner for bunker oil pollution from non-tanker. The definition of shipowner under Bunker Convention, which includes registered owner, bareboat charterer, manager and operator of the vessel, may increase the chance of recovering compensation for pollution victims (Zhu, 2009).

3.3.2 *Purely Domestic Oil Pollution*¹⁶

Marine Environment Protection Law 1999 (hereinafter referred to as “MEPL 1999”),¹⁷ the Tort Law,¹⁸ the Amended Regulations¹⁹ and the Judicial Interpretation²⁰ shall apply in deciding on strict liability for or exonerations from liability for purely domestic oil pollution. Any parties who cause pollution damage to marine environment shall remove the pollution and compensate for any losses.²¹ It is by nature a strict liability, which is in line with the 1992 CLC and Bunker Convention. Liability can be exempted if, when the pollution damage is caused by any of the following circumstances, the pollution damage to marine environment cannot be avoided despite prompt and reasonable measures taken: (a) War; (b) irresistible natural calamities; or (c) negligence or other reckless acts of the departments responsible for the maintenance of lights or other aids to navigation in the exercise of that function.²² If oil is discharged or escapes from two or more vessels, owners of all the ships concerned shall be jointly and severally liable for all such damage that is not reasonably separable.²³ Where oil is discharged or escapes after a both-to-blame collision between two or more vessels, victims are entitled to claim for oil pollution damage against the owner of the spilling vessels.²⁴

3.4. *Limitation of Liability*

⁸ The 1992 CLC, Article 1 (5)

⁹ It should be noted that the Bunker Convention has the same application rule as the 1992 CLC with regard to purely domestic oil pollution in China

¹⁰ The CMC, Article 168 and The Civil Law, Article 142

¹¹ The 1992 CLC, Article III (1) and Bunker Convention, Article 3(1)

¹² The 1992 CLC, Article III (2) and Bunker Convention, Article 3(3)

¹³ The 1992 CLC, Article IV and Bunker Convention, Article 3(2)

¹⁴ The 1992 CLC, Article III (4)

¹⁵ Ibid, Article I (1)

¹⁶ In following sections in this paper, ‘purely domestic oil pollution’ refers to oil pollution caused by Chinese flagged vessels engaged in coastal services between Chinese coastal ports and the foreign-related oil pollution outside the scope of the 1992 CLC and Bunker Convention.

¹⁷ MEPL 1999, Article 90, 92.

¹⁸ The Tort Law, Article 65, 68

¹⁹ The Amended Regulations, Article 50, 51

²⁰ Judicial Interpretation, Article 3, 4

²¹ MEPL 1999, Article 90, and the Amended Regulation, Article 50

²² MEPL 1999, Article 92, and the Amended Regulation, Article 51

²³ Judicial Interpretation, Article 3

²⁴ Ibid, Article 4

3.4.1. *Foreign-Related Oil Pollution*

Owners of tanker vessels causing oil pollution where foreign elements are involved shall be entitled to limit his liability in respect of any one incident to an aggregate amount calculated as follows:²⁵ (a) 4.5 million units of account for a ship not exceeding 5000 units of tonnage; (b) 630 units of account for each additional unit of tonnage for a ship with a tonnage in excess of 5000 units of tonnage, provided that the aggregate amount shall not in any event exceed 89.77 million units of account. However, the right of limitation under the 1992 CLC shall be lost if it is proved that the pollution damage resulted from the tanker owner's personal act or omission, committed either with the intent to cause such damage, or recklessly and with knowledge that such damage would probably result.²⁶

Owners of non-tanker vessels causing bunker oil pollution are, under Bunker Convention, also entitled to limit their liability. However, according to Article 6, the convention is not intended to establish a separate limitation regime, or make a limitation fund available, to be exclusively devoted to bunker oil pollution claims (Zhu, 2007). Accordingly, the limitation rule shall be subject to applicable national law in China.

3.4.2. *Purely Domestic Oil Pollution*

The Amended Regulations²⁷ and the Judicial Interpretation²⁸ shall apply in determining the limitation of liability for oil pollution damage from ships. According to Article 52 of the Amended Regulations, with regard to limitation of liability for pollution damage caused by vessels, the provisions of the China Maritime Code (hereinafter referred to as "CMC") in respect of limitation of liability for maritime claims shall apply. However, with regard to the limitation of liability for pollution damage caused by vessels carrying persistent oil in bulk to sea areas under the jurisdiction of China, the provisions of the international treaties concluded or acceded to by China shall apply. In addition, according to Article 19 of the Judicial Interpretation, limitations provided in the CMC shall apply to oil pollution damage resulting from the spillage of non-persistent bunker oil from tankers and the spillage of bunker oil from non-tankers.

Therefore, the limitations stipulated in the 1992 CLC²⁹ shall apply to oil pollution damage caused by vessels carrying persistent oils in bulk (except for oil pollution damage that results from the spillage of non-persistent bunker oil from tankers carrying persistent oil), whereas limitations that are provided in the CMC³⁰ shall apply to oil pollution damage caused by vessels carrying non-persistent oils in bulk, and non-tanker vessels, as well as oil pollution damage caused by the spillage of non-persistent bunker oil from tankers carrying persistent oil. The right of limitation shall be lost if it is proved that the pollution damage resulted from the tanker owner's personal act or omission, committed either with the intent to cause such damage, or recklessly and with knowledge that such damage would probably result.³¹

3.5. *Compulsory Insurance*

3.5.1. *Foreign-Related Oil Pollution*

Owners of tanker vessels carrying more than 2,000 tons of persistent oil as cargo are required to maintain insurance or other financial guarantees under the 1992 CLC³², while owners of non-tanker vessels having a gross tonnage greater than 1,000 are required to maintain insurance or other financial guarantees under Bunker Convention³³. However, the scope of applicable tankers required to purchase compulsory insurance in China is wider than that under the 1992 CLC due to the stipulation in the Amended Regulations. According to

²⁵ 1992 CLC, Article V (1) and its 2002 Amendment

²⁶ 1992 CLC, Article V (2)

²⁷ Amended Regulations, Article 52

²⁸ Judicial Interpretation, Article 5, 6, 19

²⁹ 1992 CLC, Article V (1) and its 2002 Amendment

³⁰ CMC, Article 210 (2):.

³¹ Judicial Interpretation, Article 6

³² The 1992 CLC, Article VII (1)

³³ Bunker Convention, Article 7(1)

Article 53 of the Amended Regulations, owners of all vessels navigating the sea areas under the jurisdiction of China, except for vessels of less than 1000 gross tonnage carrying cargos other than oil, shall be required to maintain insurance or other financial security.

Claimants are entitled to directly claim the oil pollution damage from the insurer or financial guarantor even if the owner is bankrupt or winding up³⁴. The insurer may avail himself of the limits of liability, even though the owner is not entitled to limit his right. Furthermore, it is the right of the insurer to avail himself of any defenses which the owner himself would have been entitled to invoke. The insurer can be discharged of his liability if the pollution damage resulted from any wilful misconduct of the owner himself. However, in no case can the insurer reject a claim for the defense which he might have been entitled to invoke in a proceeding brought by the owner against him.

3.5.2. Purely Domestic Oil Pollution

According to Article 2 of the Oil Pollution Insurance Regulation, vessels carrying persistent oil in bulk as cargo and vessels carrying non-persistent oil cargoes and non-oil cargoes are all regulated. Vessels engaged in either international service or coastal service that need to maintain compulsory insurance or other financial security include the following: (a) Vessels, however small, carrying persistent oil in bulk; (b) vessels, however small, carrying non-persistent oil in bulk; and (c) vessels over 1000 tons carrying non-oil cargoes. Claimants are entitled to directly claim for oil pollution damage against the insurer or financial guarantor.³⁵ The insurer can be discharged of his liability if the pollution damage resulted from any wilful misconduct of the owner himself.³⁶ However, in no case can the insurer reject a claim for the defense which he might have been entitled to invoke in a proceeding brought against him by the owner.³⁷

4. Further Thinking on the Compensation System for Vessel-Source Oil Pollution in China

4.1. Will the compensation be adequate?

4.1.1. Increase of Compensation Available under Compensation System in China

Before effectiveness of the new legislations mentioned in above Section 3.1, compensation for vessel-source oil pollution, especially for the purely domestic oil pollution, was set at a low level in China. In reality, most of the serious oil pollution incidents which cannot receive compensation or receive adequate compensation were caused by tankers engaged in domestic service (Han, 2007). Except for the low compensation capacity of the shipowner of these tankers, this could be attributable to two main legislative reasons as follows. (1) Limitation amount for tankers engaged in domestic service was low. Prior to the promulgation of the Amended Regulations, limitation amount of purely domestic oil pollution from tankers was subject to Article 210 of CMC, which is much lower than the 1992 CLC limit applicable to foreign-related oil pollution from tankers. (2) There was no requirement of compulsory insurance for tankers engaged in domestic service before the Amended Regulations and Oil Pollution Insurance Regulation took effect. Victims cannot be compensated in the event of insolvency of shipowner.

After the Amended Regulations came into effect, the limitation amount for oil pollution damage from tankers, especially to tankers engaged in domestic service, was greatly impacted. The 1992 CLC limitation shall be applicable to oil pollution caused by vessels carrying persistent oil in bulk, regardless of whether or not they are engaged in international service.³⁸ In terms of tankers carrying persistent oil and engaged in coastal services, especially the small tankers, this is a significant increase. In addition to the increase of limitation amount, owners of all vessels navigating in Chinese sea areas are required to purchase compulsory insurance or other financial security, except for owners of vessels of less than 1000 gross tonnage carrying cargos other

³⁴ Bunker Convention, Article 7 (10) and The 1992 CLC, Article VII (8)

³⁵ Judicial Interpretation, Article 8

³⁶ Ibid, Art 7

³⁷ Ibid, Art 8

³⁸ The Amended Regulations, Article 52

than oils³⁹, in order to ensure adequate and prompt compensation for victims. Despite all the efforts and progress made so far, the compensation amount available under Chinese compensation system is still much lower than that under international compensation system, which will be analysed in following sections.

4.1.2. *International Compensation System for Vessel-Source Oil Pollution*

International compensation system of vessel-source oil pollution has been established since 1960s by several international conventions and their amendments.⁴⁰ Under the international system, two separate sub-systems exist simultaneously. They are three-tier compensation system of oil pollution damage from tankers and single-tier compensation system of bunker oil pollution damage from non-tanker vessels.

As to the compensation system of oil pollution damage from tankers, the framework has been established on the basis of the 1992 CLC and the Fund Convention. Under the 1992 CLC, the owner of tanker and his compulsory insurer shall be strictly liable for oil pollution damage. Meanwhile, the 1992 CLC are supplemented by the International Oil Pollution Compensation Fund (hereinafter referred to as “IOPC Fund”), which has been established in accordance with the Fund Convention. IOPC Fund is an intergovernmental organization established to administer the fund (De La Rue and Anderson, 1998) that is financed by contributions levied on oil receivers in contracting states.⁴¹ It aims to provide compensation for pollution damage resulting from spills of persistent oil from tankers where the protection afforded by the 1992 CLC is inadequate.⁴² Part of the financial burden of compensation for oil pollution damage is shifted from the shipping industry to the oil industry, which is regarded as the main beneficiary of the carriage of oil by sea (Wu, 1996). This framework is designed to assure not only prompt and adequate compensation for oil pollution victims, but also fair apportionment of financial burden of compensation between shipowners and oil receivers. The maximum compensation amount available for any one incident under the 1992 CLC is 87.99 million SDR⁴³, while the maximum compensation amount available under the Fund Convention is up to 203 million SDR⁴⁴ which includes the amount payable under the 1992 CLC.

Following the *Erika*⁴⁵ and *Prestige*⁴⁶ incidents, under the two-tier system established by the 1992 CLC and the Fund Convention, the limits of liability were inadequate (Tsimplis, 2008). A third tier compensation was created by the 2003 Supplementary Fund. The 2003 Supplementary Fund provides additional compensation beyond that available under the Fund Convention for oil pollution damage in Contracting States of the Fund Convention, which are also Parties to the 2003 Supplementary Fund. The maximum compensation available under the 2003 Supplementary Fund for any one incident is 750 million SDR.

As to the bunker oil pollution damage from non-tankers, Bunker Convention was created to ensure the adequate and prompt compensation to victims of oil pollution damage when the oil is carried as fuel in ships bunker (Zhu, 2007). Convention does not set new liability limits. Instead, the limits shall be subject to applicable national laws of the Contracting States. Additionally, there is no supplementary compensating source for bunker oil pollution under the international system.

4.1.3. *Reasons for China Not Acceding to the Fund Convention and Proposal to Establish a National Compensation Fund*

³⁹ Ibid, Article 53 and Oil Pollution Liability Insurance Regulation, Article 2

⁴⁰ (1) International Convention on Civil Liability for Oil Pollution Damage, 1969 and its 1976 /1992 protocols /2000 Amendments, (2) International Convention on the Establishment of an International Fund for Compensation for Oil Pollution Damage, 1971 and its 1976/1992 protocol /2000 Amendments, (3) the Protocol of 2003 to the International Convention on the Establishment of an International Fund for Compensation for Oil Pollution Damage, 1992 (hereinafter referred to as “the 2003 Supplementary Fund”) and (4) Bunker Convention.

⁴¹ The Fund Convention, Article 10 (1)

⁴² Ibid, Article 2(1).

⁴³ The 1992 CLC, Article V(1)

⁴⁴ The Fund Convention, Article 4(4)

⁴⁵ Erika incidents took place in France in 1999.

⁴⁶ Prestige incidents took place in Spain in 2002.

China has not acceded to the Fund Convention, which is currently only applicable to Hong Kong SAR, and 2003 Supplementary Fund. This is mainly on the grounds of economic considerations. China imported 234.6 million tonnes crude oil in 2010, and ranks as the second largest oil importing country in the world. It is therefore very likely that China will become the largest contributing country to the IOPC Fund if it chooses to join the Fund Convention. So far, there has not been any major oil pollution incident in or near Chinese sea waters. In addition, the clean-up cost is much lower than that in other countries. The Chinese government considers that it is not the right time to accede to the Fund Convention, because any contributions to the IOPC Fund are probably much greater than the benefits gained after a pollution incident. However, the Chinese government has realized that the current compensation availability for oil pollution damage from ships in China is not sufficient, but instead of acceding to the Fund Convention, the government has decided to provide a supplementary compensation source for oil pollution victims in China by establishing a Chinese national compensation fund. The Administrative Measures for Use and Collection of the Compensation Fund for Oil Pollution Damage from Ships (hereinafter referred to as “the Compensation Fund Regulation”) has been under discussion since 2003, and the final draft has been prepared and is now awaiting approval by the State Council (Shan and Zhang, 2009).

The national compensation fund will be contributed to by receiver (or his agent) of persistent oil goods and materials (including crude oil, fuel oil, heavy diesel oil, lubricating oil and other persistent hydrocarbon mineral oils) transported by sea. A tax will be levied at the rate of RMB 0.3 per tonnage (Sun, 2009). The fund shall cover oil pollution damage in Chinese sea area where (a) oil pollution damage exceeds the owner’s liability limitation; (b) the shipowner liable for the pollution is exempted from liability; (c) the shipowner liable for the pollution is financially incapable of meeting his obligations in full; and where (d) oil pollution damage is caused by an unidentifiable ship. The national compensation fund will in no case pay more than RMB 30 million for any one incident. The amount paid by the shipowner liable for the pollution is not included in this amount paid by the national compensation fund.

The establishment of national compensation fund will provide a supplementary compensation source for victims. Once the Compensation Fund Regulation becomes effective, the framework of a two-tier system of compensation for vessel-source oil pollution will be in place. However, the maximum compensation amount under this two-tier system will be still much lower than that under international system.⁴⁷ With the continuing increase in oil imports and the rapid development of oil carriage industry, the potential risk of incurring a major oil pollution incident is much greater than before. Once it happens, the national compensation fund will be far from being sufficient. Acceding to the Fund Convention could give even stronger protection to both victims and the marine environment.

4.2. Will the balance be achieved between shipowner and cargo receiver?

As stated in above section 4.1.3, based on the principle that those who benefits from an activity should bear the risk produced by such an activity, both shipowner and cargo receiver should undertake the liability or obligation of compensation. Moreover, the financial burden of compensation for oil pollution damage should be apportioned fairly and reasonably between the shipowner and the cargo receiver (Wu, 1996).

On the international level, although the 2003 Supplementary Fund highly increases the compensation amount available for oil pollution victims, it breaks the balance which has been reached by the 1992 CLC and the Fund Convention since the financial burden of compensation carried by oil receivers becomes disproportionate. The imbalance has been adjusted by two voluntary agreements, including (1) the Tanker Oil Pollution Indemnification Agreement, 2006 (hereinafter referred to as “TOPIA 2006”) and (2) the Small Tanker Oil Pollution Indemnification Agreement, 2006 (hereinafter referred to as “STOPIA 2006”). STOPIA 2006 and TOPIA 2006 are established by legal binding agreements between shipowners which are insured against oil pollution risks by P&I Clubs in the International Group. Under the scheme of STOPIA 2006,

⁴⁷ Taking the compensation for oil pollution damage from tankers as example, the maximum compensation amount available under the international three-tier compensation system is up to approximately 1.16 billion USD⁴⁷. However, under the two-tier compensation system in China, the maximum compensation amount available, which comprises the limitation of liability under the 1992 CLC and additional RMB 30 million from the national compensation fund, is approximately 143.55 million USD.

relevant owners of tankers of 29,548 gross tonnage or less agree to indemnify the Fund Convention for difference between the vessel's limit of liability under CLC 1992 and 20 million SDR⁴⁸. In other words, the minimum limit of liability for small tankers, which is 4.5 million SDR under the 1992 CLC, is increased to 20 million SDR. STOPIA applies to oil pollution incidents in countries which are members of the Fund Convention. At the same time, TOPIA 2006 covers oil pollution damage in countries which are members of the 2003 Supplementary Fund. Under TOPIA 2006, relevant tanker owners undertake to indemnify the 2003 Supplementary Fund in respect of 50% of the amount of any claim falling on the 2003 Supplementary Fund. Both STOPIA 2006 and TOPIA 2006 strive to ensure that the overall costs of claims falling within international system are shared approximately equally between shipowners and oil receivers. The adjustment mechanisms offered by STOPIA 2006 and TOPIA 2006 provide a mean for progressively correcting any significant imbalance, especially where the very large oil spill incidents take place.⁴⁹

Under the two-tier compensation system in China, the national compensation fund also aims to provide supplementary compensation to victims and establish a compensation mechanism, under which the financial burden is shared by shipowner and cargo receiver. The maximum compensation amount of RMB 30 million is determined mainly based on the average compensation amount of the vessel-source oil pollution occurring in Chinese sea area during past 10 years. Since the maximum compensation amount under the 1992 CLC are much higher than the maximum compensation amount paid by the national compensation fund, the financial burden of compensation carried by the shipowner will be disproportionate where major oil spill incidents take place; if such oil spill incidents occur frequently, balance between shipowner and cargo receiver will hardly be achieved (Zhang, 2011).

5. Conclusion

Although there has not been any catastrophic oil spill incidents in the Chinese sea area, oil pollution incidents from ships over 50 tonnes have taken place more frequently over the last 10 years. Prevention and compensation are of equal importance to protect the marine environment and the interests of victims. China has made great effort to improve the compensation capacity of vessel-source oil pollution by promulgation of a number of new legislations. Whether these new legislations⁵⁰ will also have a positive impact on discouraging the oil pollution in Chinese sea areas is still uncertain now. It is expected to be tested by observing whether there will be a decrease in the number of oil pollution incidents in next few years. Moreover, a two-tier compensation system, under which the financial burden is shared by both the shipping industry and the oil industry, is being established. However, the compensation standards will be still much lower than the international standards even after successful establishment of the national compensation fund. If major oil pollution incidents occur in Chinese sea area, the compensation from the national compensation fund would not be adequate. Acceding to the Fund Convention could give stronger protection to both victims and the marine environment.

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⁴⁸ STOPIA 2006, Article IV

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Restructuring of Environmental Management in Baltic Ports: Case of Poland

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Abstract

The growth of trade in Poland in recent years has resulted in corresponding rapid growth in the amount of goods shipped by sea. This phenomenon directly correlates with ports' cargo turnovers and the level of pollutants emission. Polish ports' activities have a significant impact on the marine environment of the Baltic Sea, as well as on port cities. The environmental performance of ports is all the more important because of the Baltic Sea's vulnerability. This unique basin, due to its special geographical, climatological, and oceanographic characteristics, is highly sensitive to the environmental impacts of human activities in its catchment area.

The main objective of this paper is to evaluate the environmental performance (policy and management) of Polish ports and terminals. The paper identifies current top environmental priorities of Polish ports and highlights a progress in the field of environmental management after joining the EU in 2004. As all ports are obliged to meet the legal requirements, a particular attention is driven to the policy's aim to improve environmental standards beyond those required under legislation.

This paper mainly focuses on experiences with the implementation of the environmental management systems (EMS) like ISO 14001 or similar. It highlights different attitudes towards EMS process of certification.

Moreover, as Polish ports are considered to be significant sources of pollution and greenhouse gases emission in their cities, ports' initiatives aimed at reducing this negative impact are taken into consideration, including cooperation between port and city authorities.

The analysis is carried out in comparison with other major ports of the Baltic Sea Region.

Keywords: Baltic Sea, environmental management, Polish ports

1. Introduction

Sea ports are gateways for the movements of thousands passengers and a wide range of goods. The growth of global trade, which has been experienced in recent years, has resulted in corresponding rapid growth in the amount of goods shipped by sea. This phenomenon directly correlates with ports' cargo turnovers and the level of port pollutants emissions. For many years port operators have been concerned more with the effect of the environment on them, than with the effects of their operation on the environment (Wooldridge, Tselentis and Whitehead, 1998).

Marine and port pollution has received much attention in recent years. A research carried out confirmed that the marine transport sector contributes significantly to air pollution, particularly in coastal areas, causing adverse health effects on the exposed population (Colbert et al., 2007). Ports, due to their nodal position, focus all transport modes and therefore the concentration of transport related pollution is significantly high within their territories. In many cases ports are among the most substantial sources of pollution and greenhouse gases emission in their cities (Klopott, 2009). A broad review of the environmental issues in ports was examined by Trozzi and Vacaro (2000) and Gouliemos (2000). The most significant sources of pollution encompass ships calling on the port, loading/unloading operations, storing and warehousing, the industry settled within the port area and port workers.

Nevertheless, ports taking advantage from their nodal positions, can actively contribute to the achievement of sustainability, being the centre of environment friendly transport systems. A number of initiatives and programs to counteract the pollution problem are in progress now at numerous ports, in response to the environmental imperative. It is also observed that sustainable development has been established as a significant component of ports' mission statements.

This is of great importance to water basins surrounded by many countries such as the Baltic Sea, which is additionally highly sensitive to the environmental impacts of human activities in its catchment area, due to its special geographical, climatological, and oceanographic characteristics.

2. The Baltic Sea Uniqueness and Vulnerability

The Baltic Sea is a unique and vulnerable water basin. A number of features make it so sensitive. First of all, it is an almost closed sea, connected to the world's oceans by the narrow and shallow waters of the Sound and the Belt Straits, what limits the water exchange and lowers water salinity, making the Baltic one of the world's largest bodies of brackish water (Helsinki Commission, 2003).

The Baltic Sea is one of the most heavily trafficked seas in the world, accounting for up to 15% of the world's cargo transportation. Both the number and the size of ships have increased in recent years, especially in case of oil tankers, and this trend is expected to continue. (Helcom, 2009). According to the HELCOM Automatic Identification System (AIS) for monitoring maritime traffic, established in mid-2005, there are about 2,000 ships in the Baltic marine area at any given moment, and each month around 3,500–5,000 ships ply the waters of the Baltic (Helcom, 2009).

The main environmental effects of shipping and other activities at sea include: air pollution, illegal deliberate and accidental discharges of oil, hazardous substances and other wastes, and the unintentional introduction of invasive alien organisms via ships' ballast water or hulls. Shipping adds up to the problem of eutrophication of the Baltic Sea with its nutrient inputs from sewage discharges and nitrogen oxides (NO_x) emissions (Helsinki Commission, 2003).

The Baltic Sea catchment area extends over some 1.7 million km² and is home to about 85 million people, from among 44.8% live in Poland.

3. Overview of the Polish Port Industry

Gdańsk, Gdynia, Szczecin and Świnoujście – these four cities host major Polish ports, being among the largest ports groups in the Baltic Sea Region.

The ports of Gdansk and of Gdynia are situated at Gdańsk Bay in the central part of the southern Baltic coast, in direct vicinity of a conurbation called Tricity, with a population of over one million inhabitants. These ports do not cooperate, but are competitive with each other. Within the area of port of Gdańsk operates the Gdańsk Naftoport Liquid Fuels Loading Company (Naftoport), which has been set apart for the purpose of this paper.

The ports of Szczecin and Świnoujście, which are located in the south-western Baltic, comprise one port complex managed by the same authority. They are situated on the shortest path connecting Scandinavia with central and southern Europe. The port in Świnoujście is located directly at the sea, whereas the port in Szczecin is 65 km inland.

All Polish sea ports operate in the neighborhood of or within the conservation areas selected for the Natura 2000 project, which is an ecological network of protected areas in the territory of the European Union. The basis for the creation of Natura 2000 protected areas are two EU directives: the Habitat Directive and the Birds Directive. Moreover, ports are located near water intakes and beaches, which are very popular among Tricity inhabitants.

Considering their specific location, ports are expected to treat all environmental issues with care and responsibility; the concern for the environment is an important aspect of every port's activities.

Polish port industry changes dynamically. Growing turnovers, modernization and new investments (e.g. new Deep-water Container Terminal in Gdańsk servicing the Maersk's AE10) contribute to regional and urban development. The importance of port industry in Poland is demonstrated by the statistics gathered in Table 1.

Table 1: Ports' Generic Overview

Port	Generic characteristic	Generic statistics		
Gdańsk	universal seaports; modern deep-water container terminal; offers comprehensive operation of bulk and general cargo, ro-ro and ferry terminals	containers	2010	511.876 TEU
			2011	685.643 TEU
		other	2010	12,78 million tonnes
			2011	14,91 million tonnes
Gdańsk Naftoport	transshipment of petroleum and liquid fuels; located within the area of the port of Gdansk;	2010	14,40 million tonnes	
		2011	10,39 million tonnes	
Gdynia	universal port; two container terminals; offers comprehensive operation of bulk, general cargo and liquid fuels; ro-ro and ferry operation, cruise ships	containers	2010	485.255 TEU
			2011	616.441 TEU
		other	2010	14,73 million tonnes
			2011	15,91 million tonnes
Szczecin-Świnoujście	universal seaports' complex; offers handling of bulk and general cargo, as well as passengers and other modes of transport.	other	2010	20,84 million tonnes
			2011	21,35 million tonnes
		containers	2010	56.503 TEU
			2011	55.098 TEU

Source: Author's own elaboration based on ports' statistics

4. Environmental Performance of Polish Ports

The environmental operation of Baltic ports is determined by evolving legislation (domestic and international) aimed at protecting the environment.

Under the Helsinki Convention¹ and guidelines from the Helsinki Commission and the MARPOL International Convention² the authorities of seaports are engaged in implementation of the environmental policy in the field of protecting the Baltic Sea Region against pollution from ships and land sources. Moreover, the operation of the ports' authorities is conducted according to and on the basis of regulations on environment protection of the domestic and EU laws, as well as on the basis of permissions concerning environment protection.

European Sea Port Organization (ESPO) survey revealed environmental priorities of European and Baltic ports, which are summarized in Table 2. There is a visible change in the ranking of priorities in comparison with the previous study from 1996 (Wooldridge, Tselentis and Whitehead, 1998) and 2004 (ESPO, 2004), also conducted by ESPO. Some environmental issues are of the same importance. However, for example, in 1996 ports did not mention air quality, noise, energy consumption and relationship with local community as issues of primary concern. In 2009 these priorities appeared among the most important ones, with the noise emission on the top, followed by air quality. It has a remarkable significance: ports attempt to reduce negative externalities generated by its operation and improve its image among city inhabitants. As one of the main

¹ Convention on the Protection of the Marine Environment of the Baltic Sea Area, 1992 (entered into force on 17 January 2000).

² Marpol 73/78 is the International Convention for the Prevention of Pollution from Ships, 1973 as modified by the Protocol of 1978.

triggering factors for the high priority of noise could be considered the European Environmental Noise Directive³.

Table 2: Top Ten Environmental Priorities of European, Baltic* in 2009 and Three Polish Ports in 2012

No.	European ports	Baltic ports	Polish ports	
			Gdynia/Gdańsk	Szczecin
1	Noise	Noise	Ship waste (sewage)	Dredging: disposal
2	Air Quality	Dredging: disposal	Noise	Ship waste (sewage)
3	Garbage/port waste	Air Quality	Dust	Dredging: operations
4	Dredging: operations	Relationship with local community	Dredging: disposal	Conservation areas
5	Dredging: disposal	Dust	Port development (land)	Ship exhaust emission
6	Relationship with local community	Dredging: operations	Conservation areas	Noise
7	Energy consumption	Energy consumption	Ballast water	Energy consumption
8	Dust	Ship exhaust emission	Ship exhaust emission	Ballast water
9	Port development (water)	Climate change	Energy consumption	Port development (land)
10	Port development (land)	Port development (land)	Relationship with local community	Relationship with local community

**this research did not embrace Polish ports*

Source: Author's own research (Polish ports) and EcoPorts Port Environmental Review 2009 (ESPO, 2010)

The list of top ten environmental priorities of Polish ports embraces almost the same issues as Baltic ports with some exceptions. Ballast water treatment is the priority not mentioned by other ports, as well as ship waste disposal (sewage from ferries and passenger ships) and conservation areas (mentioned above Natura 2000 areas). Dredging operation and disposal are the most important priorities for Szczecin, because of the port geography.

Polish ports have achieved significant progress in the field of environmental management. Generally, a number of improvements result from legal requirements; however, some initiatives beyond those required under legislation have also been observed. A lot of improvements came into fruition due to EU financial supports.

Interviews with the staff of ports' environmental protection departments constitute the basis for the overview of environmental performance of Polish ports.

Ports systematically monitor the emission of chemical substances and compounds. Particular attention is directed towards: water, air, noise, dredging and ballast water. The main areas of ports' environmental interests are briefly described in the sections below.

4.1. Water

Port water quality is regularly checked and now complies with all accepted standards. It should be pointed out that water quality has shown a marked improvement in recent years, particularly due to modernization of the sanitary sewage system and the storm/rain drain system, as well as rebuilding of car wash stations, which were finally connected with the municipal sewage system (previously all sewage was dropped directly to the ports'

³ Directive 2002/49/EC of the European Parliament and of the Council of 25 June 2002 relating to the assessment and management of environmental noise

basins). A special security of the environment has a remarkable significance while handling liquid fuels. Thus, Naftoport has increased the security by implementation of the tanker maneuvering systems within the port area, as well as the newest technical measures of effective collection of even the smallest spills. All rainwater undergoes full separation and filtration. The transshipment installations are assembled on tight tubs and equipped with automatic anti-spill systems. The anti-spill protection, elimination of the emissions to the atmosphere and water resulted in creating favorable conditions for maintaining the natural habitats surrounding Naftoport in their unchanged state.

4.2. *Air*

Within the areas of polish ports there is a variety of installations and sources of outdoor air pollution. Ports continuously monitor the emission of hydrocarbon and PM to the atmosphere.

They founded and sponsor (together with other main polluters) the ARMAAG Foundation, which provides information on air condition in the whole agglomeration (information data are processed in real time from the automatic measurement network).

The Port of Gdynia has been battling against higher concentration of suspended particulates matter for a long time. This most vital problem concerns loading and discharging operations of bulk cargo.

Due to the proximity of Gdynia city, every activity towards reducing dust is desirable. Therefore, the Port of Gdynia applied the best available technologies to minimize the dust emission to the atmosphere. Bunkers for dry goods have been built and pneumatic bulk material handling system (Vigan) to aluminium oxide was installed. The Port also introduced strict procedures for handling bulk cargo using grab system, where every crane is obliged to meet strict rules of grab operating under threat of sanction. All these activities enable them to drastically reduce dust and concentration of SPM.

Among the air pollutants there are thermal power plants within the port areas. In recent years every port closed all of the coal-fired thermal power plants and built the modern ones, substituting previously used solid fuel by light oil or natural gas, which resulted in impressive reduction of CO₂ emission to the atmosphere.

Improvement of air quality has also been achieved by installing the Petrol Vapour Recovery System (EU project) at Naftoport, but also at the Station of Liquid Fuels Handling in Gdynia port, which allows to recover (in the liquid form) hydrocarbons evaporating from liquid petroleum products during storage and handling.

4.3. *Noise*

As it has been stated above, noise pollution is a major issue of concern. Noise measurements are carried out during normal loading, unloading and transport operations.

The majority of operations in Polish ports related to environmental noise emission are conducted in the areas of individual quays at a considerable distance from the areas that are subject to protection against noise. The noise measurements in Gdańsk and in port complex Szczecin-Świnoujście have confirmed that noise emission does not exceed permissible values. Nevertheless, a scrap yard and container terminals in the port of Gdynia are the exceptions here, as being located in the vicinity of residential areas. The results of measurements and calculations indicate that the permissible values are exceeded at the borders of the protected areas. An important factor influencing the acoustic climate in these areas is also the traffic noise from the Kwiatkowski Flyover being the main road connecting the container terminal.

A few initiatives have been undertaken by the port of Gdynia to reduce noise emission. For example, the port has invested in modernization of terminal equipment and new, noise-absorbing tracks for gantry cranes, but the problem still exists.

4.4. Dredging

Dredging is essential to maintain navigation in ports and harbours as well as for the development of port facilities. Dredging operation and disposal of dredging material have been always pointed as the main environmental priorities and are a big challenge for many ports (HELCOM, 2007).

For example, in Gdynia, the recently completed reconstruction of the port channel, including the dredging of port basins, the passage fairway and three turn-basins, has resulted in the idea of reusing the dredged material. The port is striving now for EU funds, which can help to discover and implement a method of reusing dredged material and utilizing it to restructure the port's infrastructure, port's berths in the first place

4.5. Ballast Water

The port of Gdynia is an initiator and performer of a project of risk assessment for ballast water, which constitutes a part of recently finalized The Baltic Master II EU project⁴. It should be borne in mind that ballast water can be a "mode of transport" for invasive alien species, which are a threat to biodiversity that has not yet received the attention it deserves. By out-competing native species, invaders from outside the ecosystem can cause significant damage, as, for example, the round goby (*Neogobius malanostomus*) in the South Baltic. The recognition of this phenomenon, its scale and real danger, was the main objective of this project. To fulfil this aim, port keeps a water ballast record, as every ship calling on the port is obliged to fill in a special ballast water form.

4.6. Other Issues of Port Environmental Performance

The examples of proactive environmental initiatives originating from different ports in the world revealed that ports can influence other partners in the logistic chain and that their activity goes beyond legal requirements. (Klopott, 2009) The role of port hinterland strategy is being recognized (Notteboom, 2008) and a number of ports (for example the port of Göteborg) have attempted to modify the hinterland connections, investing in inland terminals (dry ports), minimizing unnecessary and environmentally hostile transports to and from the port (Roso, 2007). Other initiatives being worthy of note embrace programs launched by the ports of Long Beach and Los Angeles i.e. Clean Trucks Programme, Vessel Main Engine Fuel Incentive Program or reducing the speed of vessels entering/leaving the port (GreenPort, 2008; websites of the ports of Long Beach and Los Angeles).

Nevertheless, Polish ports' environmental activities are limited solely to the port territory and, to all intents and purposes, do not go beyond. There are still problems connected with cooperation with transport operators. There is a lack of good experiences and relationships among transport operators, especially rail, mainly due to the hangover from the old political system. Moreover, ports' competitive position is vulnerable and none of the ports is willing to lose its clients in favour of other port, only because of stricter environmental rules. Only the port of Gdynia has taken some active steps in the field of traffic management, encouraging drivers to avoid using city roads at rush hours, but with small success. The other problem is that ports have a limited range of possibilities for influencing the development and/or modernization of road and rail infrastructure; ports are only able to lobby the government or strive for financial support from the EU. The port of Gdynia has recently made decisive steps towards offering high voltage shore-side electricity, as examples from other ports prove to dramatically reduce the pollution from ships at berth (Andreoni, Miola, Perujo, 2008).

5. Environmental Management Systems in Polish Ports

There are a number of tools that ports, which intend to improve their goals on environmental performance, are able to use. The Environmental Management System (EMS), as a set of procedures and techniques enabling an organization to reduce the environmental impacts, is considered to be the most comprehensive tool (Paipai, Brigden, Wooldridge, 2000). Some Baltic ports have decided to implement formal EMS, verified by

⁴ The overall aim of Baltic Master II is to improve the on-land response capacity to oil spills in the Baltic Sea as well as to enhance the prevention of pollution from maritime transport.

independent audit institution, other have set their own informal (not necessarily less effective) EMS programme.

The most common in Europe voluntary EMS standards encompass European EMAS and worldwide ISO 14000 family. EMAS (*Eco-Management and Audit Scheme*) is an environmental management instrument, which was developed in 1993 by the EU to stimulate and synchronize European environmental policies. The ISO 14000 family addresses various aspects of environmental management. The very first two standards, ISO 14001 and ISO 14004 deal with the EMS. ISO 14001 provides the requirements for the EMS and ISO 14004 gives general EMS guidelines. Requirements for ISO 14001 are an integral part of EMAS. Organizations listed in the EMAS-Register automatically comply with the requirements that the international standard demands as well. However, EMAS registered organizations fulfil requirements that go beyond the scope of ISO 14001 (Wenk, 2005).

Standards mentioned above do not consider the specificity of the port sector, as they are generic in their nature. To facilitate ports' introduction of formal EMS, ESPO/EcoPorts has developed the Port Environmental Review System (PERS), which considers the highly specialized nature of port environmental challenges and is the only port-sector specific environmental management standard. PERS stems from work carried out by the ports themselves and is specifically designed to assist port authorities with the functional organisation necessary to deliver the goals of sustainable development.

PERS is adapted to deliver effective port environmental management and its implementation can be independently certified by Lloyd's Register. (www.ecoport.com)

There are other standards than PERS useful to ports; however they are broader in scope, as they also include other port activities. Among these standards are the International Port Safety and Environment Protection Management Code (IPSEM) developed by Bureau Veritas, as well as PSHEMS (Port Safety, Health and Environmental Management System), offered to Asian ports by PEMSEA.

Some Baltic ports have decided to acquire accreditation and currently sixteen Baltic ports have ISO 14001 accreditation, one has completed PERS certification and two are in the process of applying for PERS certification.

There are two Polish ports, which have introduced the formal EMS and boast about ISO 14001 certificate. It is the Naftoport and newly-certified port complex Szczecin-Świnoujście.

The aim of fulfilling strong ISO certification requirements was to demonstrate port's commitment to environmental protection, improve relationship with city government and give a strong evidence for the urban community that port meets all environmental requirements. These motives, as the most important in the implementation of ISO standards, appear in Swedish studies as well (Poksinska, Dahlgaard, Eklund, 2003).

However, in the opinion of Naftoport's staff of the environmental department, the cost of certification is really high and does not translate into notable and measurable benefits. Moreover, they pointed out a lot of difficulties connected with adjustment of ISO generic procedures to the specificity of port operation.

On the other hand, the staff of the environmental department in port complex Szczecin-Świnoujście did not consider the ISO certification cost to be excessive, as well as they did not perceive the ISO implementation as too onerous. However it should be emphasized that Szczecin-Świnoujście had had an informal EMS before and, besides some subjectivism of the staff's opinion, it is the reason for different perception of the same situation.

Both ports admit that accreditation has no practical effects on overall environmental performance and it is worth mentioning that this opinion coincides with the results of some research studies (Freimann and Walther, 2001). Significant improvement of communication between those responsible for environmental performance is considered to be the main benefit of achieving ISO standard.

The remaining ports are not going to apply for ISO certification and do not ponder over PERS. These ports' authorities, as the managers of the ports' areas, are more focused on compliance with the environmental regulations than on creation of formal EMS. They do not believe that formal EMS can lead to environmental improvement. Moreover, the cost of ISO certification process is perceived as disproportionately high compared to its benefits.

It is pertinent to note that there is no evidence that successful EMS must go simultaneously with certification to either of standards (Paipai, Brigden, Wooldridge, 2000) and that informal EMS is less effective than the formal ones.

The Port of Gdynia, for example, has created an informal EMS within its area of management, which is operating effectively. The environmental management is systematically updated in accordance with newly published, legal acts on the environment protection and waste management. The port continually aims at improvement of its environmental performance and sets its own environmental targets as additional to the parameters set by legislation (numerical standards). Port's environmental initiatives confirm its commitment to continual improvement.

As far as the port of Gdańsk is concerned, it mainly focuses on compliance with environmental legislation and its environmental management does not display any features of a systematic approach.

Table 3 below demonstrates a summary of several indicators of Polish ports' environmental management.

Table 3: Some indicators of Polish ports' environmental management

Does the port...	Naftoport	Gdańsk	Gdynia	Szczecin-Świnoujście
have environmental policy?	yes	no	yes	yes
have an environmental department?	yes	yes	yes	yes
publish environmental reports?	to some extent	to some extent	to some extent	to some extent
take the environmental initiatives (carbon footprint)?	yes	yes	yes	yes
take the environmental initiatives (port waste)?	yes	no	yes	no
take the environmental initiatives (renewable energy)?	no	no	no	no
care about nature preservation?	yes	yes	yes	yes
care about port-city relationship (consultation with local community, cooperation)?	yes	insufficiently	insufficiently	yes
carry out an environmental monitoring?	yes	yes	yes	yes
have formal environmental management (which one?)	yes (ISO)	no	no	yes (ISO)
have informal environmental management system?	n/a	no	yes	n/a

Source: Author's own elaboration based on interviews; questions inspired by ESPO survey (ESPO, 2010)

Interestingly, all ports pointed out the same problem influencing their environmental performance: an ambiguous legislation. They complained about Polish legislators, who, by introducing some executory provisions of international law, render Polish law stricter than originally intended. The ports also have to tackle problems with implementation of some legal acts, due to confusion between different directives. There is a further complication within the Polish law, which imposes obligations on the ports' authorities, but does not provide legal tools allowing enforcement of their rights. There is also no possibility for the ports to impose any kind of environmental fees on companies operating within ports' areas.

6. Conclusions

Polish port industry develops dynamically. However, its development does not impair ports' environmental performance. Similarly to other ports operating around the Baltic Sea, they comply with all existing and evolving legislation, which aim at the protection of this unique water basin.

Polish ports transform slowly but decisively into the newest port generation – green ports. They have achieved significant progress in the field of environmental management in recent years, especially thanks to EU legislation and EU financial support. Nowadays, ports water quality complies with all accepted standards, the emission of pollutants is systematically monitored and ports invest in technologies, which enable them to reduce their negative impact on the environment.

Moreover, some ports have demonstrated their commitment to the environment protection through ISO 14001 accreditation. Although it does not influence ports' overall environmental performance, certification has improved internal communication and relationship with port city inhabitants.

Polish ports significantly contribute to the protection of the Baltic Sea as well as to a better and cleaner environment in port cities. Unfortunately, they all are rather focused on compliance with the international, EU and domestic environmental regulations than on proactive initiatives going beyond legislation. They should cooperate more closely with other partners in the supply chain as well as the port city in order to become a centre of environmental friendly transport systems.

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Container Transshipment and Port Competition

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Abstract

The purpose of this paper is to study container port competition for transshipment cargo in duopoly market. We develop the linear container handling demand function which incorporates transshipment traffic and applies a non-cooperative two-stage game to a vertical-structure seaport market with ports as upstream players and shipping lines as downstream players. We explain the drivers behind port competition through the existence of a unique Nash equilibrium which incorporates the shipping lines' port call decision and the ports' pricing decision. We also analyze a port collusion model and a social optimum model, and compare it with the non-cooperative model for further insights. Numerical simulations are conducted to demonstrate the result.

Keywords: Container transshipment, Port competition, Two-stage game, Nash equilibrium

1. Introduction

In 2000, Maersk Sealand relocated its major transshipment operations from the Port of Singapore (PSA) to the Port of Tanjung Pelepas (PTP) in Malaysia. The impact of this relocation on the regional transshipment market structure was significant. Maersk Sealand was then the largest shipping operator in Singapore. Its shift to PTP resulted in a decline of approximately 11% in PSA's overall business. In 2001, PSA's total container throughput fell from 17 million TEUs to 15.52 million TEUs, marking a year-on-year drop of 8.9% [1]. In the same period, PTP's container throughput had increased nearly 5 folds, from 0.42 million to 2.05 million TEUs.¹

The shipping industry in Singapore and the region grew concerned about Maersk Sealand's relocation and the potential ripple effect on other shipping lines' decisions and related business activities [2].² As shipping lines form strategic alliances to achieve economies of scale, the interdependency among alliance members and small- and medium-size shipping lines heightens. Consequently, Maersk Sealand's decision on changing its transshipment port-of-call could well induce similar decisions among affiliating carriers. In 2002, Evergreen and its subsidiary Uniglor followed in Maersk Sealand's footsteps and shifted most of their container operations, amounting to 1-1.2 million TEUs of annual throughput, from PSA to PTP. Since then, other shipping lines have also started to provide direct services to PTP. APL, for example, had chosen PTP for its West Asia Express service between Asia and the Middle East [3].

This study aims to investigate a regional hub port competition for transshipment containers within a duopolistic framework. In the case of competition between PTP and PSA, the acquisition of transshipment cargo is critical. Both ports are subjected to stringent growth limitations as gateway ports but possess excellent locations along the Strait of Malacca. Transshipment presents a good opportunity for these ports to expand beyond the demands of their respective catchment economies and more importantly, tap into the international cargo flows to enjoy superior profits. Beyond the potential spike in the number of cargo handling jobs and value-added activities, a transshipment port would also gain access to profitable feeder line networks which

¹ The container throughput data is taken from the official website of Port of Tanjung Pelepas, <http://www.ptp.com.my/history-2000.html> and <http://www.ptp.com.my/history-2001.html>.

² The issue was, for example, discussed in the article written by Allison of *Asia Times Online* on 2 September 2000.

serve to transport containers to/from tributary ports. These networks give the transshipment port good connectivity, which in turn strengthens itself through the ripple effect. As the importance of achieving dominance in the market becomes apparent, it is foreseeable for regional ports to compete for transshipment container traffic.

Of the many possible attributions to the above mentioned relocations, price stands out as one of the most probable causes. As global customers exert increasing pressure on shipping lines to lower their prices, the competition to reduce costs among shipping lines inevitably intensifies. Shipping lines are forced to explore options which give the most cost-saving. With these drivers in mind, the attractiveness of PTP's port price, which is some 30% lower than that of PSA's, becomes apparent. In fact, Evergreen has estimated that their shift to PTP would save them between US\$ 5.7 million and US\$ 30 million per annum [3]. As such, port pricing will, among others, become one of our major factors for analysis.

In particular, we construct a linear demand function for a container port's transshipment traffic. A review of the existing studies of port selection and competition [4-9] have led us to identify port capacity, price, transshipment level and port congestion as the primary factors of relevance to our study. The port price and transshipment level³ primarily determine the demand levels of a port. The resulting level of demand, coupled with the port capacity, will determine the port's congestion level. This congestion level will in turn influence the demands of the port and its rival port. This study attempts to investigate these relationships to achieve greater clarity. Especially, we examine how different levels of port capacities, prices and transshipment level affect the ports' congestion levels and, more importantly, how a port can capture a greater transshipment demand with appropriate port pricing and capacity building. Moreover, we focus on interior solutions, so that the distribution of shipping lines' port call over the ports is endogenously determined within the model.

We find that in the non-cooperative model, (i) the price difference between two ports is further accentuated when both port has high spare capacities, as in this case, congestion becomes less of an inhibiting factor. (ii) Shipping lines are inclined to make more port calls at the port that provides a higher transshipment coefficient when the port capacity is sufficient to offset the accompanying congestion. (iii) A bigger port can set a lower port price to attract more demand as it is more likely to have spare capacity and hence less congestion. (iv) The port that possesses a higher transshipment level can set a higher port price in order to ease the congestion. Similarly, a rival port with a lower transshipment level can set a lower port price in order to attract the demand. However, in the event where the market demand approaches port capacity and there is congestion in the predominate port, the probability of demand switching from predominant port to rival port is higher and this means that the rival port can set a higher price as well. (v) The port collusion model yields a higher port price than that of non-cooperative model, and the profit margin of the social optimum model is higher than that of the non-cooperative model.

A number of studies have looked at port competition: Lam and Yap [10-11] examined port competitiveness and the impact of competition in Southeast Asia while Yap and Lam [12] considered the case of East Asia and Anderson, et al. [13] considered the case of Northeast Asia. Saeed and Larsen [14] considered intra-port competition and examined the possible combinations of coalitions among container terminals at the Karachi Port of Pakistan. Port competition is further investigated as part of rivalry between two alternative intermodal transportation chains; hence, recent studies have taken into account hinterland access and road congestion in order to observe their impact on ports and port competition [15-18]. Unlike our consideration of "transshipment container demand," these papers have focused on "gateway container demand" – these are two different types of container demand at a transshipment port. The gateway demand represents the import and export container demands, whilst the transshipment demand is generated through the additional container handling jobs necessary for further seaborne transfers after unloading, including consolidation, deconsolidation and value-added activities of containers.⁴ Our transshipment focus can help advance the

³ "Transshipment level" measures port connectivity and efficiency (the transshipment-coefficient definition is given below in section 3), which will affect the decision of shipping lines' choice of port, thereby affecting port demand.

⁴ The import container demand is further defined as containers destined for hinterland transportation out of the port after unloading from the vessels, and the export container demand as containers meant for seaborne transfer out of the port.

analysis on a port's transshipment capabilities and enable the port to uncover and balance its demand and capacity levels so as to strategize for the long term. It can also provide better visibility on the shipping lines' criteria when choosing a transshipment port.

Our study is closely related to the applications of game theory to port competition problem. Zan [20] was one of the earliest authors who had attempted to use the game theory to investigate the behaviour of port users (carriers and shippers) in transshipment port management policy. He used a bi-level Stackelberg game to capture the flow of foreign trade containers. In more recent studies, Saeed and Larsen [14] used the two-stage game to analyze possible coalitions: in the first stage, three container terminals at Karachi Port decide whether to act individually or to join a coalition; and in the second stage, the resulting coalition plays a non-cooperative game against non-members. In another study relevant to our work, De Borger, et al. [21] used a two-stage game to analyze the interaction between the pricing behaviour of competing ports and the optimal investment policies in the ports and hinterland capacity. Beyond maritime-related research, studies have been performed on the duopolistic interactions between congestible facilities using a two-stage game [22-26].⁵ For example, Basso and Zhang [26] developed a model for congestible facility rivalry in vertical structures which explains the relationship among the congestible facility and its intermediate user (airline) and final users (passengers). We will leverage on this approach to explain the drivers behind the container transshipment port competition through the existence of a unique Nash equilibrium for the shipping lines' port call decision and the port pricing strategies. We will also analyze a port collusion model and a social optimum model, and compare it with the non-cooperative model for further insights, where the port collusion model can behave like a monopoly, whereas the social optimum model reflects a maximization of the combined profits of all the players in the game.

The paper is organized as follows: Section 2 shows our model formulation with linear container handling demand functions. We then proceed to apply the non-cooperative two-stage game to our problem in section 3. In section 4, a port collusion model and a social optimum model which may reflect the current business models of shipping lines, are analyzed. Results from our numerical simulations are then shown in section 5 to further explain the findings of this study. Some of special cases are presented in section 6. Finally, section 7 contains the concluding remarks.

2. The Model

Consider two container transshipment ports, $r = 1, 2$, which provide homogenous container handling services to their customers within a stipulated period of time. The customers are identical shipping lines, $i = 1, \dots, N$.

The notations used for developing our model are defined as follows;

f	loaded and unloaded gateway container demand
g_r	coefficient of loaded and unloaded transshipment container demand
N	number of shipping lines
q_{ir}	a fraction of transshipment port calls made by shipping line i at port r
p_i	price per container charged by shipping line i
c_i	shipping line i 's constant per-container cost
F_{ir}	total loaded and unloaded containers of shipping line i at port r
π_i	profit for shipping line i

The distinction between gateway and transshipment demands has been discussed in air transport research by Zhang[19], where "gateway" traffic refers to "local and gateway" traffic, whereas "transshipment" traffic to "hub" (air to air) traffic.

⁵ As defined by De Borger and Van Dender [23], congestible facilities are facilities which are prone to congestion when the volume of simultaneous users increases amid constant capacity. Examples of such facilities include seaports, airports, Internet access providers and roads.

μ_r	port price per container at port r
K_r	85% capacity utilization of port r
Π_r	profit for port r
$Q_r = \sum_{i=1}^N q_{ir}$	total port calls at port r
$F_r = \sum_{i=1}^N F_{ir}$	total container volume at port r
$D_r(F_r, K_r)$	cost of congestion delays per container at port r

Our container handling demand function, F_{ir} , is the total number of containers which shipping line i loads and unloads at port r .

$$F_{ir} = f + g_r \cdot Q_r \quad \text{for } r=1,2 \quad (1)$$

where $Q_r = \sum_{i=1}^N q_{ir}$, $0 < q_{ir} < 1$, $q_{is} = 1 - q_{ir}$ for $r \neq s$ and g_r is nonnegative coefficient. q_{ir} is a decision variable which indicates a fraction of transshipment port calls that shipping line i makes at port r , and is determined by the capacity of port r , its price and transshipment coefficient during the stipulated period of time.

F_{ir} is made up of two components: The gateway container, i.e. import and export container demand, and the transshipment container that is generated through transshipment performance at port r . f is the gateway container demand that the shipping line handles at port r , which is inclusive of both the unloading of import containers and loading of export containers. Since this study focuses on the impact of transshipment container demand, we assume that the gateway container demand is constant. This assumption helps simplify analytical work. The coefficient g_r , on the other hand, refers to the transshipment container demand volume. At a conceptual level, g_r can be used to represent a port's "connectivity," which can be defined as or the port's network connection to other transport modes that extend to other destinations (e.g. feeder services, hinterland connection). In logistics, a transshipment port is akin to a transit facility. As such, shipping lines which adopt the hub-and-spoke transportation system are likely to prefer a transshipment port that has an extensive and strong network connection. To a certain extent, g_r can also be used to represent port efficiency. An efficient port is one which can effectively and quickly perform the handling jobs arising from transshipment traffic, be it through an advanced IT system or an optimized scheduling algorithm. In general, transshipment containers require consolidation, deconsolidation and value-added activities such as assembly, calibration and customization [27]. The ability to handle these tasks efficiently therefore adds to the port's overall attractiveness as a transshipment port. To take our argument further, a more efficient port would be able to get more capacity out of its fixed infrastructure, hence increasing the 'real' capacity of the port. It will also provide a faster turnover for vessels, hence improving the port's service quality. With these characteristics in mind, it becomes clear that a 'stronger' port would possess a higher g_r and hence would be more attractive to shipping lines for their transshipment calls.

Meanwhile, it is noted that our container handling demand function generates an equal amount of transshipment volume for all shipping lines calling at the same port, regardless of the number of port calls that each shipping line has made. This may not be practical; however to focus on an examination of major factors, we assume that the transshipment container demand depends only on ports' handling capability and aggregate contribution of shipping lines' port calls in the stipulated period of time. This may be regarded as two-service providers – one service user problem since N -identical service users will show exactly the same pattern of characteristics of one service user.

From container handling demand function (1), each port's demand function (2) can be derived:

$$F_1 = \sum_{i=1}^N F_{i1} = N(f + g_1 Q_1); \quad F_2 = \sum_{i=1}^N F_{i2} = N(f + g_2 Q_2) \quad (2)$$

where $Q_2 = \sum_{i=1}^N q_{i2} = \sum_{i=1}^N (1 - q_{i1}) = N - Q_1$. Then we can derive the following properties by differentiating with respect to q_{i1} :

$$\frac{\partial F_{i1}}{\partial q_{i1}} = g_1, \quad \frac{\partial F_{i2}}{\partial q_{i1}} = -g_2 \quad (3)$$

$$\frac{\partial F_1}{\partial q_{i1}} = Ng_1, \quad \frac{\partial F_2}{\partial q_{i1}} = -Ng_2 \quad (4)$$

Properties (3) and (4) illustrate that an increase in the expected number of port calls made at port 1 would lead to a decrease in the expected number of port calls made at port 2. This is expected since we assume $q_{i2} = 1 - q_{i1}$. Furthermore, the magnitude of changes in the expected number of port calls depends on each port's transshipment coefficient g_r .

For a major part of the paper, we shall consider that the congestion delay cost function, as shown in (5) below, possesses a quadratic form.⁶ Since this study only considers port capacity and port demand as a measurement of port congestion, this quadratic congestion function simply and efficiently captures the trend of congestion at the port. To guarantee an interior solution, we further assume that $F_r / K_r \leq 1$, with K_r being 85% utilization of port r 's maximum capacity K_r^{\max} .

$$D_r(F_r, K_r) = a_r \left(\frac{F_r}{K_r} \right)^2 \quad \text{for } r = 1, 2 \quad (5)$$

where a_r is a positive parameter and $K_r = 0.85 K_r^{\max}$. Thus, the congestion function D_r is increasing with the number of port calls made to port r while decreasing with the port's capacity K_r . The following properties are derived:

$$\frac{\partial D_r}{\partial F_r} = 2a_r \frac{F_r}{K_r^2} \geq 0, \quad \frac{\partial^2 D_r}{\partial F_r^2} = 2a_r \frac{1}{K_r^2} \geq 0 \quad (6)$$

$$\frac{\partial D_r}{\partial K_r} = -2a_r \frac{F_r^2}{K_r^3} \leq 0, \quad \frac{\partial^2 D_r}{\partial K_r^2} = 6a_r \frac{F_r^2}{K_r^4} \geq 0, \quad \frac{\partial^2 D_r}{\partial F_r \partial K_r} = -4a_r \frac{F_r}{K_r^3} \leq 0 \quad (7)$$

Property (6) depicts that the congestion externality is convex in the port's traffic volume. It is also intuitive that the congestion externality would decrease with an increase in the port handling capacity as shown in (7). The delay cost parameters a_r are further assumed to be the same across the two ports, and will be denoted a in further derivations.

3. A Non-Cooperative Two-Stage Game

We now study a non-cooperative two-stage game with duopolistic transshipment ports and a continuum of identical shipping lines. We first develop profit functions for shipping lines and ports. The shipping lines' profit function and constraints are given by:

⁶ De Borger and Van Dender [23] mentioned that strictly convex congestion functions prevent full capacity usage, so that interior solutions automatically result. The quadratic function has the property that the congestion costs approach infinity when demand approaches capacity.

$$\begin{aligned}
\max \pi_i &= \sum_{r=1}^2 (p_i - c_i - \mu_r - D_r) F_{ir} \\
\text{subject to} \quad & 0 < q_{ir} < 1 \quad ; i = 1, \dots, N \quad r = 1, 2 \\
& \sum_{r=1}^2 q_{ir} = 1 \quad ; i = 1, \dots, N \\
& F_r \leq K_r
\end{aligned} \tag{8}$$

where p_i is the shipping line's container price, c_i is the unit operating cost and μ_r is the port charge. Among the shipping lines, both pricing and cost incurrence are assumed to be identical, hence denoting them with p and c respectively. In the shipping line's profit function, the congestion function D_r is captured as a cost component. This is to model the shipping line's preference for a less congested port, considering that port congestion often leads to delays, which in turn translate to additional costs to the shipping lines. The first constraint in (8) shows that q_{ir} is normalized between 0 and 1. The second constraint indicates that the total number of port calls for all shipping lines is fixed to 1 so as to facilitate our analysis of the shipping lines' allocation decision in response to the ports' capacities, prices and transshipment coefficients. The third constraint is, as indicated above, a capacity constraint.

The ports' objective is also to maximize profits. A port's profit function Π_r is given by

$$\max \Pi_r = (\mu_r - O_r) F_r - m_r K_r \quad \text{for } r = 1, 2 \tag{9}$$

where O_r is the ports' operation cost per unit and m_r is the (unit) capacity cost. As can be seen, the ports' operation and capacity costs are, for simplicity, assumed to be separable and constant.

Based on these profit functions, we now specify our two-stage game: in the first stage, each port maximizes its profit by choosing its port charge. In the second stage, each shipping line makes its port call decision to maximize profit, observing the ports' capacities, prices and transshipment coefficients.

3.1 Stage two: Shipping lines' port call decision

To examine the sub-game perfect Nash equilibrium, the game is to be solved using backward induction, starting with the second-stage game. Given port capacities $K \equiv (K_1, K_2)$, port prices $\mu \equiv (\mu_1, \mu_2)$, and transshipment coefficients $g \equiv (g_1, g_2)$, the shipping lines simultaneously assign their port calls at the two ports. We assume Cournot behaviour in shipping line competition,⁷ leading to the following first-order conditions of (8):

$$\frac{\partial \pi_i}{\partial q_{i1}} = (p - c - \mu_1 - D_1) \frac{\partial F_{i1}}{\partial q_{i1}} - \frac{\partial D_1}{\partial F_1} \frac{\partial F_1}{\partial q_{i1}} F_{i1} + (p - c - \mu_2 - D_2) \frac{\partial F_{i2}}{\partial q_{i1}} - \frac{\partial D_2}{\partial F_2} \frac{\partial F_2}{\partial q_{i1}} F_{i2} = 0 \tag{10}$$

The assumption of symmetry among the shipping lines' price $p_i = p$ and cost $c_i = c$ for all i , and partial derivatives from (3) and (4) imply that the best response function of shipping line i is identical for all i , i.e. $q_{ir} = \dots = q_{Nr}$. Applying our earlier analysis on the shipping lines' profit function, we obtain

⁷ Cournot behavior by congestible facility users, such as airlines and shipping lines, has been assumed in, e.g., Zhang and Zhang [24] and Lam and Yap [10].

Lemma 1. Shipping line i 's profit π_i is concave in q_{ir} .

Proof. See the Appendix.

Lemma 1 shows that π_i has a maximum in q_{ir} . Hence, there exists a unique Nash equilibrium in shipping lines' port call decision.

We solve (10) to obtain the best response function of port call decision made by shipping line i at port 1:

$$q_{i1}^G = \frac{\{f(g_2^2 K_1^2 + g_1^2 K_2^2) + g_2^3 N K_1^2\}}{N(g_2^3 K_1^2 - g_1^3 K_2^2)} - \frac{K_1 K_2 \{f(g_1 + g_2) + g_1 g_2 N\}}{N(g_2^3 K_1^2 - g_1^3 K_2^2)} \sqrt{\frac{g_1 g_2 - \frac{(g_2^3 K_1^2 - g_1^3 K_2^2)\{g_1(p - c - \mu_1) - g_2(p - c - \mu_2)\}}{3aN^2\{f(g_1 + g_2) + g_1 g_2 N\}^2}}{g_1 g_2 - \frac{(g_2^3 K_1^2 - g_1^3 K_2^2)\{g_1(p - c - \mu_1) - g_2(p - c - \mu_2)\}}{3aN^2\{f(g_1 + g_2) + g_1 g_2 N\}^2}}}} \quad (11)$$

where superscript G stands for the generalized case. A similar expression holds for port 2. We focus on the solution range of larger than 0 but less than 1. If the solution falls outside this range, our solution will be at the boundary of the constraints. Similarly, in the scenario where the root function in (11) fails to return a real value, the solution will again be forced to either close to 0 or 1.

We now conduct comparative statics analysis to see the changes in shipping lines' equilibrium with respect to the changes in parameters such as port capacity, price, transshipment coefficient and shipping lines' marginal price and cost. Since the best-response functions of shipping lines' port call decision are identical across the shipping lines and depend only on the aggregate port calls at each port, we investigate the comparative statics of the shipping lines' aggregate output at port r with respect to parameter set $X = \{\mu_1, \mu_2, K_1, K_2, g_1, g_2\}$.

The results are shown below (and the details of derivations are given in the Appendix):

$$\frac{\partial Q_r}{\partial \mu_r} < 0, \quad \frac{\partial Q_r}{\partial \mu_s} > 0, \quad \frac{\partial Q_r}{\partial K_r} > 0, \quad \frac{\partial Q_r}{\partial K_s} < 0 \quad (12)$$

As shown in (12),⁸ the shipping lines' aggregate output at port r decreases with the own port's price and increases with the own port's capacity. We further obtain the responses of aggregate shipping lines' output to transshipment coefficient:

$$\frac{\partial Q_r}{\partial g_r} = \frac{(p - c - \mu_r - D_r) - 2D_r}{\left(N \left(\frac{\partial^2 D_r}{\partial F_r^2} g_r^2 F_r + \frac{\partial^2 D_s}{\partial F_s^2} g_s^2 F_s \right) + 2 \left(\frac{\partial D_r}{\partial F_r} g_r^2 + \frac{\partial D_s}{\partial F_s} g_s^2 \right) \right)} \quad (13)$$

$$\frac{\partial Q_r}{\partial g_s} = \frac{-(p - c - \mu_s - D_s) + 2D_s}{\left(N \left(\frac{\partial^2 D_r}{\partial F_r^2} g_r^2 F_r + \frac{\partial^2 D_s}{\partial F_s^2} g_s^2 F_s \right) + 2 \left(\frac{\partial D_r}{\partial F_r} g_r^2 + \frac{\partial D_s}{\partial F_s} g_s^2 \right) \right)} \quad (14)$$

Expression (13) shows that if the shipping lines' profit margin at port r is higher than twice port r 's total delay cost, the aggregate shipping lines' output increases in the transshipment coefficient, implying that higher transshipment coefficient leads to more port calls from shipping lines. Otherwise, total delay cost would

⁸ This result is consistent with the comparative statics in Zhang and Zhang [24] and Basso and Zhang [26].

overtake profit margin. On the other hand, as given in (14), if the competing port offers a higher profit margin than overall congestion delay cost, shipping lines may assign more port calls at that port.

$$\frac{\partial Q_r}{\partial p} = \frac{g_r - g_s}{\left(N \left(\frac{\partial^2 D_r}{\partial F_r^2} g_r^2 F_r + \frac{\partial^2 D_s}{\partial F_s^2} g_s^2 F_s \right) + 2 \left(\frac{\partial D_r}{\partial F_r} g_r^2 + \frac{\partial D_s}{\partial F_s} g_s^2 \right) \right)} \quad (15)$$

$$\frac{\partial Q_r}{\partial c} = \frac{-(g_r - g_s)}{\left(N \left(\frac{\partial^2 D_r}{\partial F_r^2} g_r^2 F_r + \frac{\partial^2 D_s}{\partial F_s^2} g_s^2 F_s \right) + 2 \left(\frac{\partial D_r}{\partial F_r} g_r^2 + \frac{\partial D_s}{\partial F_s} g_s^2 \right) \right)} \quad (16)$$

Next, the effects of shipping lines' marginal price and cost on port container are shown in (15) and (16). If port r 's transshipment coefficient, g_r , is greater than that of competitor port, g_s , then port r 's output increases in shipping lines' marginal price, but decreases in their marginal cost. On the other hand, if g_r is less than g_s , port r 's output decreases in shipping line's marginal price, but increases in their marginal cost.

3.2 Stage one: Port pricing strategies

The port pricing strategy is analyzed in the first stage, when the ports maximize their profits (9) by choosing port price μ_r . The first-order condition is shown in (17),

$$\frac{\partial \Pi_r}{\partial \mu_r} = F_r + (\mu_r - O_r) \frac{\partial F_r}{\partial \mu_r} = 0 \quad (17)$$

Based on shipping lines' decision behavior obtained from stage two and analyzing the ports' profit functions, we have

Proposition 1. Port r 's profit function Π_r is strictly concave in μ_r when $g_s^3 K_r^2 - g_r^3 K_s^2 < 0$.

Proof. See the Appendix

Based on Proposition 1 and the condition of $g_s^3 K_r^2 - g_r^3 K_s^2 < 0$, we have the following

Proposition 2. Port competition has a unique equilibrium in port price, $\mu^* = (\mu_1^*, \mu_2^*)$.

Proof. See the Appendix.

Based on Proposition 1 and 2, solving (17) yields a unique interior Nash equilibrium in port prices, for given capacities and transshipment coefficients. However, if the condition of $g_s^3 K_r^2 - g_r^3 K_s^2 < 0$ does not hold, then a unique Nash equilibrium may not be guaranteed.

The best-response functions may not yield a closed form in this model. In this case we will, in the following sections, explore the results of the port pricing stage using numerical experiments. We will also look at a special case with linear congestion delay costs.

4. Ports Collusion and Social Optimum

Thus far in this study, we had focused mainly on the non-cooperative game where every port and shipping line makes independent decisions to maximize own profit. We now consider the case of two ports cooperating on prices and capacities, and of all market players, two ports and N-shipping line, cooperating to maximize the market profit to compare with the non-cooperative model.

4.1 Ports collusion model

Considering the case in which the two ports decide their prices and capacities concurrently. The profit function of ports collusion model is shown in (18).

$$\max_{\mu_r} \Pi_1 + \Pi_2 = (\mu_1 - O_1)F_1 - m_1K_1 + (\mu_2 - O_2)F_2 - m_2K_2 \quad (18)$$

The first-order condition for each port price from (18) is:

$$\begin{aligned} \frac{\partial(\Pi_1 + \Pi_2)}{\partial\mu_1} &= F_1 + (\mu_1 - O_1)\frac{\partial F_1}{\partial\mu_1} + (\mu_2 - O_2)\frac{\partial F_2}{\partial\mu_1} = 0 \\ \frac{\partial(\Pi_1 + \Pi_2)}{\partial\mu_2} &= F_2 + (\mu_1 - O_1)\frac{\partial F_1}{\partial\mu_2} + (\mu_2 - O_2)\frac{\partial F_2}{\partial\mu_2} = 0 \end{aligned} \quad (19)$$

where $\partial F_1/\partial\mu_1 = -\partial F_2/\partial\mu_1$. Therefore, $\partial(\Pi_1 + \Pi_2)/\partial\mu_1 > 0$ and $\partial(\Pi_1 + \Pi_2)/\partial\mu_2 > 0$ which means that the port price would approach infinity if no boundary for maximum port price was set. This is due to our assumption, first constraint in (8), that shipping lines must call at both ports. We can easily observe that the port collusion model yields higher port price than that of the non-cooperative model. The result stems from the monopolistic power that the ports now possess, rendering them a free hand in escalating their prices to maximize their profits. Moving forward, this analysis would help better explain the competitive landscape and strategies among regionally bounded terminal operators.

4.2 Social optimum model

We now consider a social optimum model that reflects cooperation among all players in the game to maximize their combined profits. This is captured in the social-welfare function (SW) given below:

$$SW = \max_{\mu_r, q_{ir}} \sum_{r=1}^2 \Pi_r + \sum_{i=1}^N \pi_i = \sum_{r=1}^2 \{(\mu_r - O_r) \cdot F_r - m_r K_r\} + \sum_{i=1}^N \sum_{r=1}^2 (p - c - \mu_r - D_r) F_{ir} \quad (20)$$

A reduced form of (20) is presented by

$$SW = (p - c)(F_1 + F_2) - (O_1 + D_1) \cdot F_1 - m_1 K_1 - (O_2 + D_2) \cdot F_2 - m_2 K_2 \quad (21)$$

It is important to note that the port price disappears from (20) to give (21). In this case, the port price is internalized due to the equality between total port revenue and the sum of shipping lines' port cost. Therefore, there is no pricing stage in this model, but the port call decision game among shipping lines is considered. The shipping lines' port call decision in social optimum model is characterized by the first order condition below.

$$\begin{aligned} \frac{\partial SW}{\partial q_{i1}} &= -(O_1 + D_1) \frac{\partial F_1}{\partial q_{i1}} - \left(\frac{\partial D_1}{\partial F_1} \frac{\partial F_1}{\partial q_{i1}} \right) F_1 - (O_2 + D_2) \frac{\partial F_2}{\partial q_{i1}} \\ &\quad - \left(\frac{\partial D_2}{\partial F_2} \frac{\partial F_2}{\partial q_{i1}} \right) F_2 + (p - c) \left(\frac{\partial F_1}{\partial q_{i1}} + \frac{\partial F_2}{\partial q_{i1}} \right) = 0 \end{aligned} \quad (22)$$

We solve (22) to achieve the best response of shipping lines' port call decision below.

$$q_{il}^{SW} = \frac{\left\{ f \left(g_2^2 K_1^2 + g_1^2 K_2^2 \right) + g_2^3 N K_1^2 \right\}}{N \left(g_2^3 K_1^2 - g_1^3 K_2^2 \right)} - \frac{K_1 K_2 \left\{ f \left(g_1 + g_2 \right) + g_1 g_2 N \right\}}{N \left(g_2^3 K_1^2 - g_1^3 K_2^2 \right)} \sqrt{g_1 g_2 - \frac{\left(g_2^3 K_1^2 - g_1^3 K_2^2 \right) \left\{ g_1 \left(p - c - O_1 \right) - g_2 \left(p - c - O_2 \right) \right\}}{3 a N^2 \left\{ f \left(g_1 + g_2 \right) + g_1 g_2 N \right\}^2}} \quad (23)$$

It depicts that in social optimum model, the shipping lines' port call decision takes into account port operation cost in order to maximize overall profits.

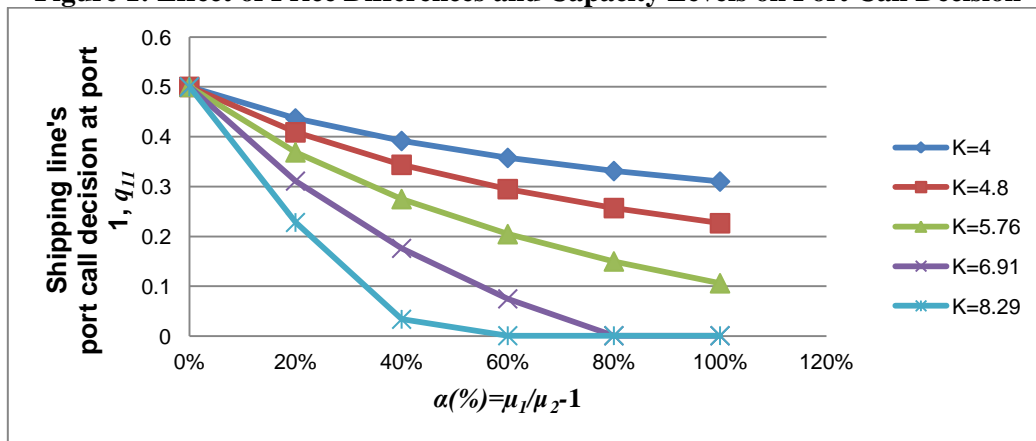
To better appreciate the model, we can perceive the stipulated conditions as a vertical expansion of shipping lines, where they extend their core businesses from liner shipping to terminal operation. In this case, social optimum model explains the structure of these shipping lines' profit, where ports' prices are internalized and ports' demands are affected by port operation cost, capacity and transshipment volume.

5. Numerical Results

In addition to the derived functions for the shipping lines' port call decision and the port pricing model, we further explore the comparative statics through numerical experiments. First, we explain the effect on shipping lines' port call decision, driven by differing port prices between two ports while applying various levels of port capacities. Second, we show the effect of transshipment coefficient on shipping lines' port call decision while applying various levels of port capacities. Third, we explore the changes in equilibrium port price in accordance with changes in the parameters such as capacities and transshipment levels. Finally, we compare the results of the social optimum model and non-cooperative model in terms of shipping lines' port call decision and market profits.

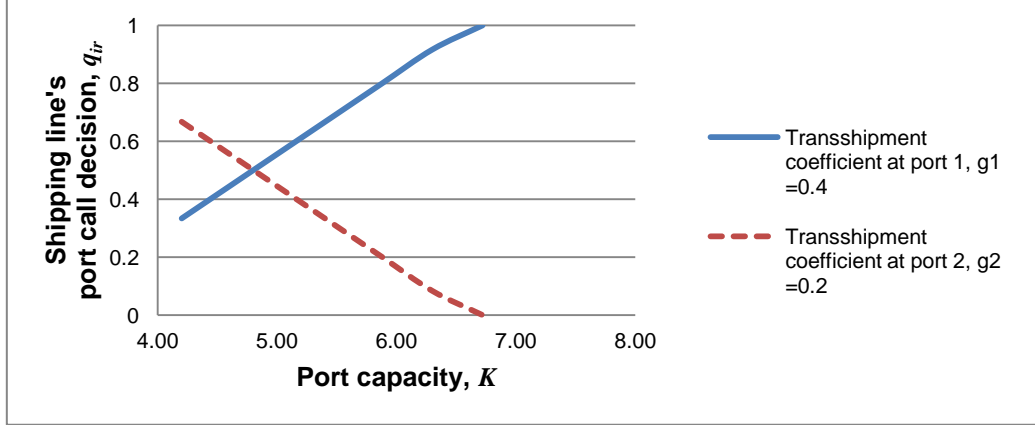
Figure 1 shows the shipping lines' port call decision subjected to differing prices between two equally-sized ports. As expected, similar port prices will yield an equal portion of port calls to both ports. The portion of port calls to port 1 decreases as port 1's price increases. This implies that shipping lines are easily attracted by a cheaper port price. Another important finding from Figure 1 is the combined effect of capacity and price level. Different slope gradients were obtained when different port capacities were subjected to similar price differentials (see $K=4$ and $K=8.29$). While capacity $K=4$ carried a gentle slope, the capacity $K=8.29$ resulted in the steep slope. These results showed that when the both ports' capacities are large, a marginal difference between two port prices is sufficient to drive significant demand to the cheaper port. In contrast, when both ports' capacities are small, the shift of demand becomes inelastic to the difference in port prices. Therefore, it is reasonable to assume that the congestion effect associated with a small port capacity offsets the price difference between ports, and that a large port capacity offsets the congestion effect and hence amplifies the effect of price difference.

Figure 1: Effect of Price Differences and Capacity Levels on Port Call Decision



Since g_r is a factor that determines the transshipment demand of shipping lines, shipping lines are inclined to make more port calls at the port that provides a higher g_r . However, this only holds true when the port capacity is sufficient to handle the additional transshipment demand and offset the congestion effect, which is shown at the intersection point between the curves in Figure 2. In other words, when the port capacity is small, the congestion effect takes precedence over the transshipment effect, and hence result in the lower portion of port calls despite a higher g_r .

Figure 2: Effect of Transshipment Coefficient and Capacity Levels on Port Call Decision



We examine the equilibrium port prices of port 1 and port 2 in the context of varying difference between the two ports' capacities. This perspective translates into port expansion in practice. As shown in Figure 3, capacity expansion in either port will decrease the equilibrium prices. This finding can be interpreted as such: a larger port can aggressively lower its price to attract more demand as they are more likely to have spare capacity and hence less congestion. In response, the rival port has to lower its price as a countermeasure since its capacity level cannot retain its market share.

Figure 3: Equilibrium Port Price over Capacity

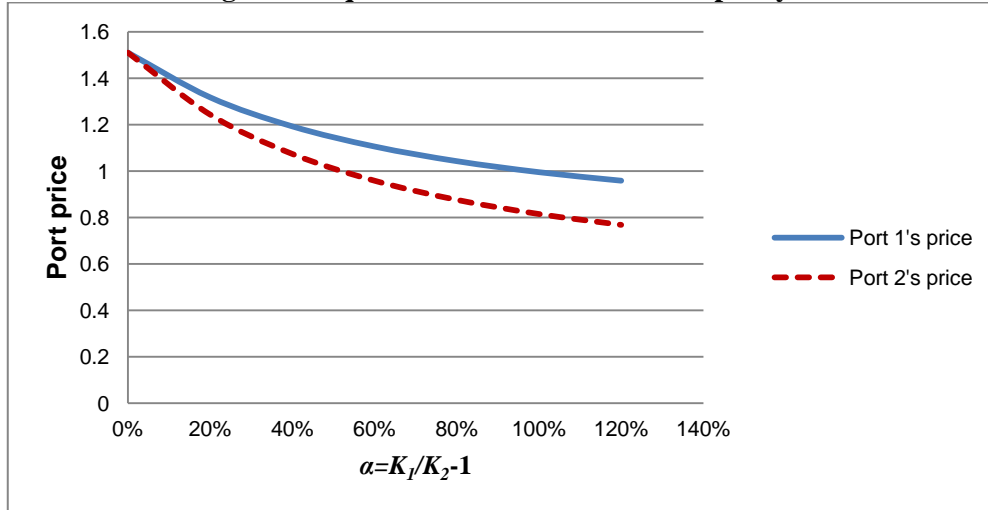
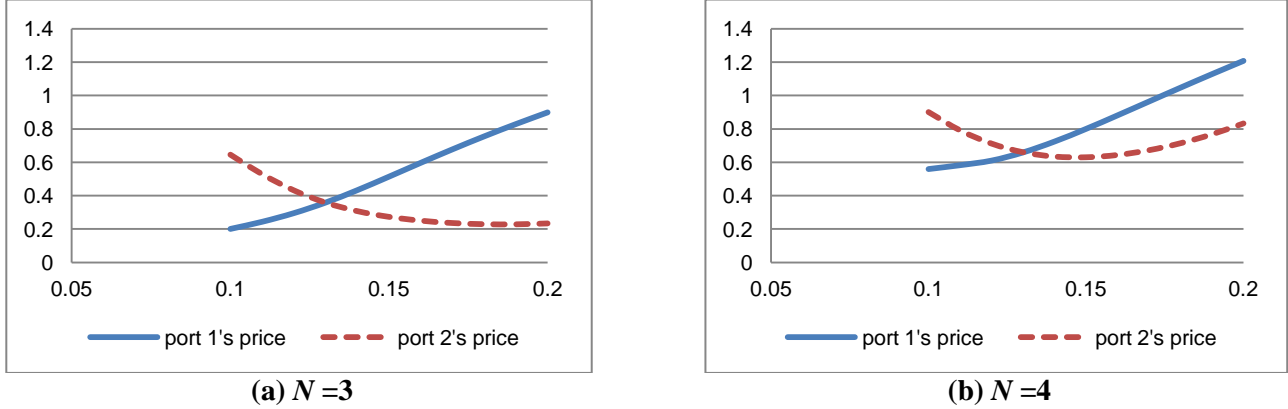


Figure 4 shows the equilibrium port price under different market demand conditions subjected to differing transshipment coefficient between two equally-sized ports. In particular, both ports capacities are fixed at $K=10$, and the port 1's transshipment coefficient is varied in $[0.1, 0.2]$ while port 2's transshipment coefficient is held constant at 0.13. The x-axis in the figure represents the level of transshipment coefficient at port 1 and the y-axis represents the port price. Figure 4(a) and 4(b) consider $N=3$ and $N=4$ shipping lines in the market, respectively. Figure 4(a) shows that port 1's price increases as own transshipment level increases, and that port 2's price decreases as port 1's transshipment level increases. However, in Figure 4(b), port 2's price increases with port 1's transshipment level. These findings suggest that when the port fails to achieve the predominant position, they will compete by lowering their price as long as the spare capacity level is high.

However, when the overall market demand increases, there is a heightened probability of demand switching from the popular port to the other one. This is due to the increased congestion in the popular port (port 1), and such consideration prompts the other port (port 2) to increase its price as well. This implies that the neighboring rival port would benefit from the congested popular port.

Figure 4: Equilibrium Port Price over Transshipment Coefficient



In previous analysis on the social optimum model, we found that the shipping lines' port call decision depends on port capacity, transshipment coefficient and port operation cost when the port price is internalized in the objective function. We now take our analysis further by comparing the non-cooperative model and the social optimum model. In the following analysis, we give both models identical parameters and compare the resulting shipping lines' port call decisions and market profits. We also fix the port operation cost of port 1 to be lower than that of port 2, while subjecting both models to varying differences between the two port capacities. The transshipment coefficient is set to be identical for the two ports so as to reduce complexities. Therefore, the given conditions for this experiment are summarized as: $O_1 < O_2$, $K_1 > K_2$ and $g_1 = g_2$.

As shown in Figure 5, under the social optimum conditions, shipping lines have a higher propensity to call at port 1 regardless of the capacity of port 2 due to port 1's lower operation cost. In fact, when the capacity of port 2 is less than 40% of the capacity of port 1, maximum port call is diverted to port 1. In the non-cooperative model, the propensity to make a port call at port 1 is comparatively lower than the social optimum model because of port prices. However, when the capacity of port 2 is less than 40% than that of port 1, the percentage of port call diverted to port 1 increases rapidly. This is because in this case, the capacity difference between two ports is large enough to disregard the effect of port prices.

Figure 5: Port Call Decision of Non-Cooperative and Social Optimum Model

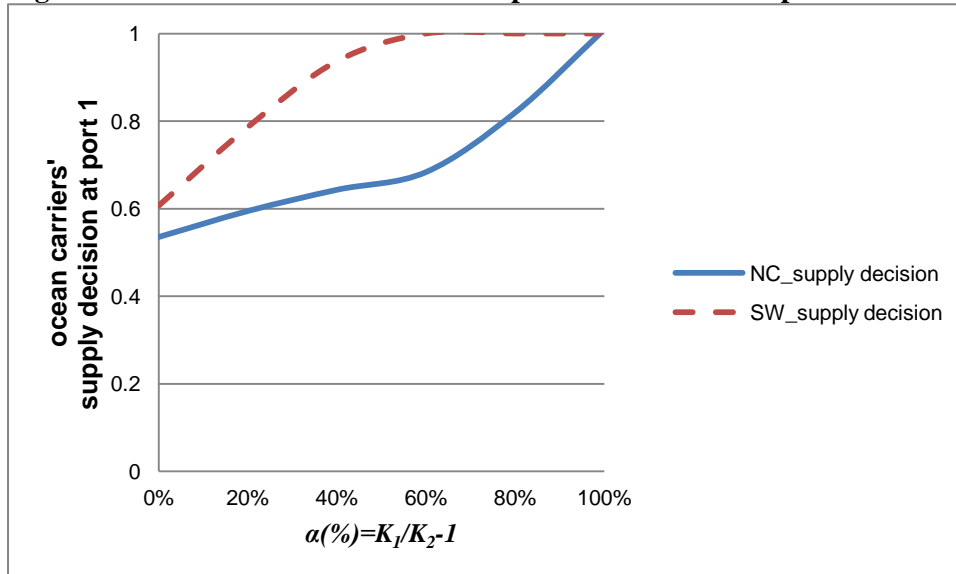
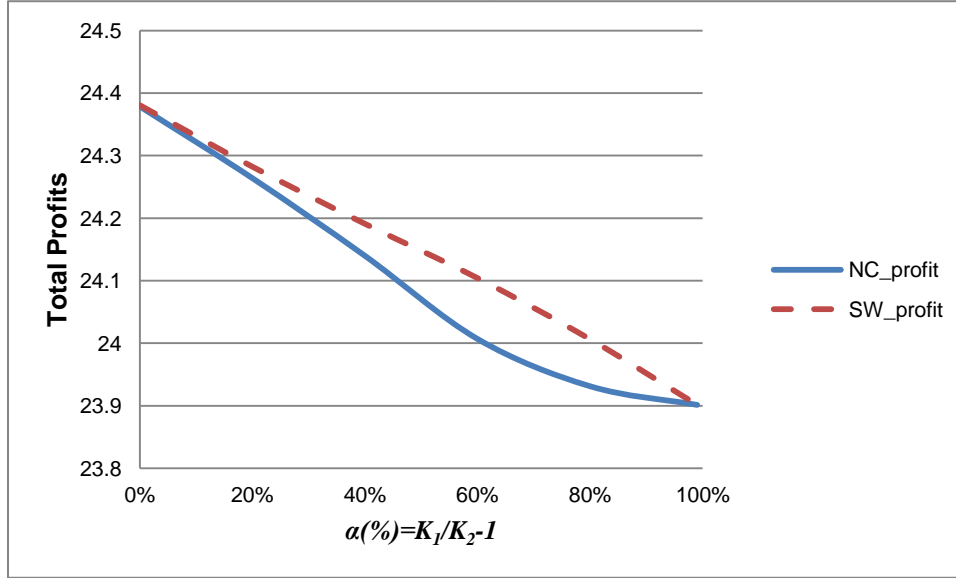


Figure 6 shows that the market profit of the social optimum model is higher than that of the non-cooperative model. This finding is explained in Figure 5, where the port call diverted to port 1 in social optimum model is shown to be comparatively higher. In addition, the decline tendency of profits of both models according to a varying difference between the two port capacities is due to the setting of port 1's capacity to be constant and of port 2's capacity to be decreasing every 20% of port 1's. Therefore, the congestion delay cost increases with the difference between the two port capacities.

Figure 6: Total Profits of Non-Cooperative and Social Welfare Model



6. Special Cases

As our model is limited to numerical results for port pricing stage, in this section, we consider two cases that enable analytical work to achieve the best response function of port pricing stage. We found that the results obtained in special cases are consistent with our numerical results.

6.1. Symmetric ports

Thus far in this study, we have focused on the generalized case where the ports have different prices, capacities and transshipment levels. This case is complicated by the existence of possible combined effects among the key factors. For our special case, we reduce the complexities by considering symmetric conditions, where both ports have the same port capacities and transshipment levels, i.e. $K := K_1 = K_2$ and $g := g_1 = g_2$. The ports will only differentiate on prices. The best response function of port call decision made by shipping line i at port 1 is:

$$q_{i1}^S = \frac{1}{2} + \frac{K^2 (\mu_2 - \mu_1)}{6agN^3 (2f + gN)} \quad (24)$$

where superscript S represents symmetric ports case. Expression (24) shows that allocating port call decision by shipping lines initially begins at the point 0.5, or half of maximum port call, as we have set 1 as the upper bound of port call. Thereafter, depending on the difference between port prices, the port call decision moves downward or upward. Based on shipping lines' decision behavior given (24) and the first order condition of port profit function (17), we have the followings:

$$\frac{\partial^2 \Pi_r}{\partial \mu_r^2} = 2 \frac{\partial F_r}{\partial \mu_r} + (\mu_r - O_r) \frac{\partial^2 F_r}{\partial \mu_r^2} < 0 \quad (25)$$

$$\sum_{r \neq s} \left| \frac{\partial^2 \Pi_r}{\partial \mu_r \partial \mu_s} \right| = \left| \frac{\partial F_r}{\partial \mu_s} + (\mu_r - O_r) \frac{\partial^2 F_r}{\partial \mu_r \partial \mu_s} \right| \quad (26)$$

Expression (25) shows the existence of Nash equilibrium. Comparing (25) and (26), we found that this satisfies the contraction condition, $\partial^2 \Pi_r / \partial \mu_r^2 + \sum_{r \neq s} |\partial^2 \Pi_r / \partial \mu_r \partial \mu_s| < 0$. This implies that the (25) and the contraction condition guarantee a unique Nash equilibrium in port prices.

6.2. Linear congestion delay cost

De Borger and Van Dender [23] applied the linear volume-capacity ratio congestion costs function in their study. As they also focused on interior solutions, their linear congestion function allows them to keep the analysis tractable while guaranteeing firms produce positive output in the duopoly case, and avoid the use of exogenous rationing rules.

In similar fashion, we consider the linear congestion delay cost in this section as a special case. The linear congestion delay cost function is given below.

$$D_r = a \frac{F_r}{K_r} \quad (27)$$

We apply (27) for the two-stage game instead of our quadratic congestion function (5). Solving (10) yields the best response functions of shipping lines' port call decision at port 1:

$$q_{i1}^L = \frac{2a \{ f(g_2 K_1 - g_1 K_2) + g_2^2 N K_1 \} N - K_1 K_2 \{ g_2(p - c - \mu_2) - g_1(p - c - \mu_1) \}}{2a(g_2^2 K_1 + g_1^2 K_2) N^2} \quad (28)$$

where superscript L stands for linear congestion delay cost. In similar fashion to symmetric port case, based on shipping lines' decision behavior (28) and the first order condition of port profit function (17), we found that this case satisfies (25) and contraction condition. Hence, this case also guarantees that there exists the unique Nash equilibrium in port price.

The best response function of port 1 can be obtained by substituting (28) into port 1's first order condition (17), and solving for its price μ_1 :

$$\mu_1^L = \frac{2aN(g_1^2 K_2 + 2g_2^2 K_1)(f(g_1 + g_2) + g_1 g_2 N)}{3g_1^2 g_2 K_1 K_2} + \frac{g_1(p - c + 2O_1) - g_2(p - c - O_2)}{3g_1} \quad (29)$$

We now apply comparative static analysis on (29) with respect to the transshipment coefficient of each port.

$$\frac{\partial \mu_1^L}{\partial g_1} = \frac{2a(g_1^3(f + g_2 N)K_2 - 2g_2^2(f(g_1 + 2g_2) + g_1 g_2 N)K_1)N}{3g_1^3 g_2 K_1 K_2} + \frac{g_2(p - c - O_2)}{3g_1^2} \quad (30)$$

Based on input parameters for interior solutions, the marginal profit of shipping lines, $(p - c - \mu_r - D_r)$, has to be positive, and port operation cost has to be less than port price, $\mu_r > O_r$. This implies that $(p - c - O_2)$ is always positive. The value of first term is less than second term since it is divided by multiple of capacities, $K_1 K_2$. Thus, the value of (30) is positive.

$$\frac{\partial \mu_1^L}{\partial g_2} = \frac{2a(2g_2^2(f(g_1 + 2g_2) + 2g_1g_2N)K_1 - fg_1^3K_2)N}{3g_1^2g_2^2K_1K_2} - \frac{(p - c - O_2)}{3g_1} \quad (31)$$

Similarly, based on input parameters for interior solutions, the value of (31) is negative. Thus we have:

$$\frac{\partial \mu_1^L}{\partial g_1} > 0, \frac{\partial \mu_1^L}{\partial g_2} < 0 \quad (32)$$

It indicates that the port price increases with its own transshipment level, but decreases with the rival port's transshipment level when the ports capacities are viable for market demand. The higher transshipment level gives higher demand at port, thus the congestion level of port increases. As a result, in this situation, the port price increases in order to ease the congestion. On the other hand, when the competitor port has a higher transshipment level, the port may face the switching of shipping lines to the competitor port. Therefore, the port will choose to compete by lowering price.

Next, we apply comparative static analysis with respect to the port capacities. The effects of port capacities are shown in (33) and (34).

$$\frac{\partial \mu_1^L}{\partial K_1} = -\frac{2aN(f(g_1 + g_2) + g_1g_2N)}{3g_2K_1^2} < 0 \quad (33)$$

$$\frac{\partial \mu_1^L}{\partial K_2} = -\frac{4ag_2N(f(g_1 + g_2) + g_1g_2N)}{3g_1^2K_2^2} < 0 \quad (34)$$

It is observed from (33) and (34) that the equilibrium port price decreases with the port capacities of own and competitor. Explaining from the long term strategic perspective, port expansion in either port will decrease the equilibrium port prices.

7. Concluding Remarks

This paper developed a two-stage duopoly model of container port competition for transshipment cargo. We developed a linear container handling demand function which incorporates transshipment demand. These container handling demand functions were then combined to form the port demand function. Other important functions such as the congestion delay cost function and the profit functions for both shipping lines and ports were subsequently derived to set us up for the game analysis. We first conducted a non-cooperative two-stage game with duopolistic transshipment ports and a continuum of identical shipping lines, and solved it via backward induction.

The shipping lines' port call decision was first investigated with respect to the respective port's capacity, price and transshipment level in the second stage of the game. We had shown that the shipping lines' port call decision follows behaviour of assigning more port calls to the port that provides a lower price and a larger capacity. We then advanced to the first stage to derive, in relation to the shipping lines' port call behaviour, a competitive port price. We considered a port collusion and social optimum model that reflects cooperation between two ports and cooperation among all players in the game to maximize their combined profits. In the port collusion model, we found a monopolistic port market which resulted in infinite port price. In the social optimum model, we derived a shipping lines' port call best response function which reflected that the shipping lines' decision in number of port calls is contingent on the ports' operation costs and congestion delay costs.

To further our observation of the Nash equilibrium point, numerical experiments are conducted. We first found that the price difference between two ports is further accentuated when both port capacities are large, as in this case, congestion becomes less of an inhibiting factor. Next, shipping lines are inclined to make more

port calls at the port that provides a higher g_r when the port capacity is sufficient to offset the accompanying congestion delay cost. In other words, when the port capacity is small, the congestion delay cost takes precedence over the transshipment volume, and this results in a lower number of port calls despite a higher g_r . This result also suggests that ports do take into consideration their capacity when setting prices. A bigger port can set a lower port price to increase demand as they are more likely to have spare capacity and hence less congestion. Furthermore, the port that possesses a higher transshipment level can set a higher port price in order to ease the congestion. Similarly, a rival port with a lower transshipment level can set a lower port price in order to attract the demand. However, in the event where the market demand approaches port capacity and there is congestion in the predominate port, the probability of demand switching from predominant port to rival port is higher and this means that the rival port can set a higher price as well. Finally, the result of comparing non-cooperative model with social optimum model showed that the internalized port price enables the social optimum model to achieve the higher market profit than that of non-cooperative model. The non-cooperative model, in comparison, is restricted to acquire higher demand via port prices, and this results in a lower profit margin.

Finally, we considered some special cases so as to clearly observe the best response functions and the existence of the unique Nash equilibrium in port prices. The special cases are reduced the complexities in generalized case by considering symmetric conditions or linear congestion delay cost function. Both cases guaranteed that there exists a unique Nash equilibrium in port prices. We applied comparative static analysis on port price of linear congestion delay cost case. This showed that the port price is lowered when either of the port expands the capacity, and that port price increases with its transshipment level but decreases with its rival's transshipment level.

In the main, this study provided further insights to the shipping lines' behaviour and the characteristics of transshipment demand. Such insights can serve as useful information to the port operators when formulating their port pricing strategies. Moving forward, this study can be explored with a nonlinear demand function. The tradeoffs of the congestion delay cost and transshipment benefits can be shown clearly in nonlinear demand case. The conditions of asymmetric shipping lines can also be taken into account in future studies. In this case, the shift of port call decision can be affected by shipping lines' different operating cost, c_i , and price, p_i , since these affect the marginal profit of shipping lines.

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Appendix

1. Proof of Lemma 1

From (3),(4),(6),(7), we obtain

$$\begin{aligned}
\frac{\partial^2 \pi_i}{\partial q_{i1}^2} &= -2 \frac{\partial D_1}{\partial F_1} \frac{\partial F_1}{\partial q_{i1}} \frac{\partial F_{i1}}{\partial q_{i1}} - \frac{\partial^2 D_1}{\partial F_1^2} \left(\frac{\partial F_1}{\partial q_{i1}} \right)^2 F_{i1} - 2 \frac{\partial D_2}{\partial F_2} \frac{\partial F_2}{\partial q_{i1}} \frac{\partial F_{i2}}{\partial q_{i1}} - \frac{\partial^2 D_2}{\partial F_2^2} \left(\frac{\partial F_2}{\partial q_{i1}} \right)^2 F_{i2} \\
&= -2 \frac{\partial D_1}{\partial F_1} N g_1^2 - \frac{\partial^2 D_1}{\partial F_1^2} (N g_1)^2 F_{i1} - 2 \frac{\partial D_2}{\partial F_2} N g_2^2 - \frac{\partial^2 D_2}{\partial F_2^2} (N g_2)^2 F_{i2} \\
&= -g_1^2 \left(2 \frac{\partial D_1}{\partial F_1} N + \frac{\partial^2 D_1}{\partial F_1^2} N^2 F_{i1} \right) - g_2^2 \left(2 \frac{\partial D_2}{\partial F_2} N + \frac{\partial^2 D_2}{\partial F_2^2} N^2 F_{i2} \right) < 0
\end{aligned} \tag{A.1}$$

Therefore, π_i is concave in q_{ir} .

2. Derivations of comparative statics for the equilibrium shipping lines' port call decision

Let $X = (\mu_r, \mu_s, K_r, K_s, g_r, g_s)$,

$$q_{ir} = q_{ir}^*(X)$$

Using (10), we can express $\frac{\partial \pi_i}{\partial q_{ir}}(q_{ir}^*; X) \equiv 0$

Applying the total differential implicit function and chain rule, differentiate (10) with respect to X . Then, we obtain

$$\frac{\partial^2 \pi_i}{\partial q_{ir}^2} \frac{\partial q_{ir}}{\partial X} + \sum_{i \neq j} \left(\frac{\partial^2 \pi_i}{\partial q_{ir} \partial q_{jr}} \frac{\partial q_{jr}}{\partial X} \right) + \frac{\partial^2 \pi_i}{\partial q_{ir} \partial X} = 0 \tag{A.2}$$

$$\begin{aligned}
\frac{\partial^2 \pi_i}{\partial q_{ir} \partial q_{jr}} &= - \frac{\partial^2 D_r}{\partial F_r^2} \frac{\partial F_r}{\partial q_{jr}} \frac{\partial F_r}{\partial q_{ir}} F_{ir} - \frac{\partial D_r}{\partial F_r} \frac{\partial F_r}{\partial q_{jr}} \frac{\partial F_{ir}}{\partial q_{ir}} - \frac{\partial D_r}{\partial F_r} \frac{\partial F_r}{\partial q_{ir}} \frac{\partial F_{ir}}{\partial q_{jr}} \\
&\quad - \frac{\partial^2 D_s}{\partial F_s^2} \frac{\partial F_s}{\partial q_{jr}} \frac{\partial F_s}{\partial q_{ir}} F_{is} - \frac{\partial D_s}{\partial F_s} \frac{\partial F_s}{\partial q_{jr}} \frac{\partial F_{is}}{\partial q_{ir}} - \frac{\partial D_s}{\partial F_s} \frac{\partial F_s}{\partial q_{ir}} \frac{\partial F_{is}}{\partial q_{js}} < 0
\end{aligned} \tag{A.3}$$

Substituting (A.1) and (A.3) into (A.2),

$$\begin{aligned}
&\left\{ - \frac{\partial^2 D_r}{\partial F_r^2} \left(\frac{\partial F_r}{\partial q_{ir}} \right)^2 F_{ir} - 2 \frac{\partial D_r}{\partial F_r} \frac{\partial F_r}{\partial q_{ir}} \frac{\partial F_{ir}}{\partial q_{ir}} - \frac{\partial^2 D_s}{\partial F_s^2} \left(\frac{\partial F_s}{\partial q_{ir}} \right)^2 F_{is} - 2 \frac{\partial D_s}{\partial F_s} \frac{\partial F_s}{\partial q_{ir}} \frac{\partial F_{is}}{\partial q_{ir}} \right\} \frac{\partial q_{ir}}{\partial X} \\
&+ \sum_{i \neq j} \left\{ \left(- \frac{\partial^2 D_r}{\partial F_r^2} \frac{\partial F_r}{\partial q_{jr}} \frac{\partial F_r}{\partial q_{ir}} F_{ir} - \frac{\partial D_r}{\partial F_r} \frac{\partial F_r}{\partial q_{jr}} \frac{\partial F_{ir}}{\partial q_{ir}} - \frac{\partial D_r}{\partial F_r} \frac{\partial F_r}{\partial q_{ir}} \frac{\partial F_{ir}}{\partial q_{jr}} \right) \frac{\partial q_{jr}}{\partial X} \right\} + \frac{\partial^2 \pi_i}{\partial q_{ir} \partial X} = 0
\end{aligned} \tag{A.4}$$

From the properties of demand and congestion delay cost function in (3) and (4), the (A.4) can be expressed as:

$$\begin{aligned}
& \left(-\frac{\partial^2 D_r}{\partial F_r^2} (Ng_r)^2 F_{ir} - 2 \frac{\partial D_r}{\partial F_r} (Ng_r^2) \right. \\
& \quad \left. -\frac{\partial^2 D_s}{\partial F_s^2} (-Ng_s)^2 F_{is} - 2 \frac{\partial D_s}{\partial F_s} (-Ng_s)(-g_s) \right) \frac{\partial q_{ir}}{\partial X} \\
& + \sum_{i \neq j} \left(-\frac{\partial^2 D_r}{\partial F_r^2} (N^2 g_r^2) F_{ir} - 2 \frac{\partial D_r}{\partial F_r} (Ng_r)(g_r) \right. \\
& \quad \left. -\frac{\partial^2 D_s}{\partial F_s^2} (N^2 g_s^2) F_{is} - 2 \frac{\partial D_s}{\partial F_s} (-Ng_s)(-g_s) \right) \frac{\partial q_{jr}}{\partial X} + \frac{\partial^2 \pi_i}{\partial q_{ir} \partial X} = 0 \\
& \left(-\frac{\partial^2 D_r}{\partial F_r^2} (N^2 g_r^2) F_{ir} - 2 \frac{\partial D_r}{\partial F_r} (Ng_r^2) \right. \\
& \quad \left. -\frac{\partial^2 D_s}{\partial F_s^2} (N^2 g_s^2) F_{is} - 2 \frac{\partial D_s}{\partial F_s} (-Ng_s)(-g_s) \right) \frac{\partial q_{ir}}{\partial X} \\
& + \sum_{i=1}^N \left(-\frac{\partial^2 D_r}{\partial F_r^2} (N^2 g_r^2) F_{ir} - \frac{\partial D_r}{\partial F_r} (Ng_r)(g_r) - \frac{\partial D_r}{\partial F_r} (Ng_r)(g_r) \right. \\
& \quad \left. -\frac{\partial^2 D_s}{\partial F_s^2} (N^2 g_s^2) F_{is} - \frac{\partial D_s}{\partial F_s} (-Ng_s)(-g_s) - \frac{\partial D_s}{\partial F_s} (-Ng_s)(-g_s) \right) \frac{\partial q_{ir}}{\partial X} \\
& - \left(-\frac{\partial^2 D_r}{\partial F_r^2} (N^2 g_r^2) F_{ir} - 2 \frac{\partial D_r}{\partial F_r} (Ng_r)(g_r) \right. \\
& \quad \left. -\frac{\partial^2 D_s}{\partial F_s^2} (N^2 g_s^2) F_{is} - 2 \frac{\partial D_s}{\partial F_s} (-Ng_s)(-g_s) \right) \frac{\partial q_{ir}}{\partial X} + \frac{\partial^2 \pi_i}{\partial q_{ir} \partial X} = 0
\end{aligned}$$

Finally,

$$\begin{aligned}
& - \left(\frac{\partial^2 D_r}{\partial F_r^2} (N^2 g_r^2) F_{ir} + 2 \frac{\partial D_r}{\partial F_r} (Ng_r)(g_r) \right. \\
& \quad \left. + \frac{\partial^2 D_s}{\partial F_s^2} (N^2 g_s^2) F_{is} + 2 \frac{\partial D_s}{\partial F_s} (-Ng_s)(-g_s) \right) \frac{\partial Q_r}{\partial X} + \frac{\partial^2 \pi_i}{\partial q_{ir} \partial X} = 0
\end{aligned} \tag{A.5}$$

Summing up i in (A.5), then we obtain

$$\frac{\partial Q_r}{\partial X} = \frac{\frac{1}{N} \sum_{i=1}^N \frac{\partial^2 \pi_i}{\partial q_{ir} \partial X}}{\left(N \left(\frac{\partial^2 D_r}{\partial F_r^2} g_r^2 F_r + \frac{\partial^2 D_s}{\partial F_s^2} g_s^2 F_s \right) + 2 \left(\frac{\partial D_r}{\partial F_r} g_r^2 + \frac{\partial D_s}{\partial F_s} g_s^2 \right) \right)} \tag{A.6}$$

Using (10) to calculate $\partial^2 \pi_i / \partial q_{ir} \partial X$, we obtain:

$$\frac{\partial Q_r}{\partial \mu_r} = \frac{-g_r}{\left(N \left(\frac{\partial^2 D_r}{\partial F_r^2} g_r^2 F_r + \frac{\partial^2 D_s}{\partial F_s^2} g_s^2 F_s \right) + 2 \left(\frac{\partial D_r}{\partial F_r} g_r^2 + \frac{\partial D_s}{\partial F_s} g_s^2 \right) \right)} < 0 \tag{A.7}$$

$$\frac{\partial Q_r}{\partial \mu_s} = \frac{g_s}{\left(N \left(\frac{\partial^2 D_r}{\partial F_r^2} g_r^2 F_r + \frac{\partial^2 D_s}{\partial F_s^2} g_s^2 F_s \right) + 2 \left(\frac{\partial D_r}{\partial F_r} g_r^2 + \frac{\partial D_s}{\partial F_s} g_s^2 \right) \right)} > 0 \quad (\text{A.8})$$

$$\frac{\partial Q_r}{\partial K_r} = \frac{6g_r \frac{D_r}{K_r}}{\left(N \left(\frac{\partial^2 D_r}{\partial F_r^2} g_r^2 F_r + \frac{\partial^2 D_s}{\partial F_s^2} g_s^2 F_s \right) + 2 \left(\frac{\partial D_r}{\partial F_r} g_r^2 + \frac{\partial D_s}{\partial F_s} g_s^2 \right) \right)} > 0 \quad (\text{A.9})$$

$$\frac{\partial Q_r}{\partial K_s} = \frac{-6g_s \frac{D_r}{K_r}}{\left(N \left(\frac{\partial^2 D_r}{\partial F_r^2} g_r^2 F_r + \frac{\partial^2 D_s}{\partial F_s^2} g_s^2 F_s \right) + 2 \left(\frac{\partial D_r}{\partial F_r} g_r^2 + \frac{\partial D_s}{\partial F_s} g_s^2 \right) \right)} < 0 \quad (\text{A.10})$$

$$\frac{\partial Q_r}{\partial g_r} = \frac{(p - c - \mu_r - D_r) - 2D_r}{\left(N \left(\frac{\partial^2 D_r}{\partial F_r^2} g_r^2 F_r + \frac{\partial^2 D_s}{\partial F_s^2} g_s^2 F_s \right) + 2 \left(\frac{\partial D_r}{\partial F_r} g_r^2 + \frac{\partial D_s}{\partial F_s} g_s^2 \right) \right)} \quad (\text{A.11})$$

$$\frac{\partial Q_r}{\partial g_s} = \frac{-(p - c - \mu_s - D_s) + 2D_s}{\left(N \left(\frac{\partial^2 D_r}{\partial F_r^2} g_r^2 F_r + \frac{\partial^2 D_s}{\partial F_s^2} g_s^2 F_s \right) + 2 \left(\frac{\partial D_r}{\partial F_r} g_r^2 + \frac{\partial D_s}{\partial F_s} g_s^2 \right) \right)} \quad (\text{A.12})$$

3. Proof of Proposition 1

Expression (12) can be re-written

$$\frac{\partial \Pi_r}{\partial \mu_r} = F_r + (\mu_r - O_r) \frac{\partial F_r}{\partial Q_r} \frac{\partial Q_r}{\partial \mu_r} = 0 \quad (\text{A.13})$$

The second order condition derived from (A.13) is:

$$\frac{\partial^2 \Pi_r}{\partial \mu_r^2} = 2 \frac{\partial F_r}{\partial Q_r} \frac{\partial Q_r}{\partial \mu_r} + (\mu_r - O_r) \frac{\partial F_r}{\partial Q_r} \frac{\partial^2 Q_r}{\partial \mu_r^2} \quad (\text{A.14})$$

From (2) and (A.7), we have

$$\frac{\partial F_r}{\partial Q_r} > 0, \frac{\partial Q_r}{\partial \mu_r} < 0$$

The second order condition of (A.7) is then:

$$\frac{\partial^2 Q_r}{\partial \mu_r^2} = g_1^2 K_1 K_2 (g_2^3 K_1^2 - g_1^3 K_2^2) / 4N^2 \sqrt{\{C - 3a(g_2^3 K_1^2 - g_1^3 K_2^2)\} \{g_1(p - c - \mu_1) - g_2(p - c - \mu_2)\}}^3}$$

$$\text{where } C = 3^2 a^2 g_1 g_2 N^2 \{f(g_1 + g_2) + g_1 g_2 N\}^2$$

For an interior solution, $g_2^3 K_1^2 - g_1^3 K_2^2$ is negative for given capacities and transshipment coefficients. Hence,

$$\frac{\partial^2 Q_r}{\partial \mu_r^2} < 0$$

In this case Π_r is strictly concave since

$$\frac{\partial^2 \Pi_r}{\partial \mu_r^2} = 2 \frac{\partial F_r}{\partial Q_r} \frac{\partial Q_r}{\partial \mu_r} + (\mu_r - O_r) \frac{\partial F_r}{\partial Q_r} \frac{\partial^2 Q_r}{\partial \mu_r^2} < 0 \quad (\text{A.15})$$

4. Proof of Proposition 2

To prove uniqueness of port price, we show the contraction condition [28]. We have

$$\sum_{r \neq s} \left| \frac{\partial^2 \Pi_r}{\partial \mu_r \partial \mu_s} \right| = \left| \frac{\partial F_r}{\partial Q_r} \frac{\partial Q_r}{\partial \mu_s} + (\mu_r - O_r) \left(\frac{\partial^2 F_r}{\partial Q_r \partial \mu_s} \frac{\partial Q_r}{\partial \mu_r} + \frac{\partial F_r}{\partial Q_r} \frac{\partial^2 Q_r}{\partial \mu_r \partial \mu_s} \right) \right| \quad (\text{A.16})$$

Since $\frac{\partial^2 F_r}{\partial Q_r \partial \mu_s} = 0$, it becomes

$$\sum_{r \neq s} \left| \frac{\partial^2 \Pi_r}{\partial \mu_r \partial \mu_s} \right| = \left| \frac{\partial F_r}{\partial Q_r} \frac{\partial Q_r}{\partial \mu_s} + (\mu_r - O_r) \frac{\partial F_r}{\partial Q_r} \frac{\partial^2 Q_r}{\partial \mu_r \partial \mu_s} \right|, \text{ comparing this with (A.15), it satisfies}$$

$$\frac{\partial^2 \Pi_r}{\partial \mu_r^2} + \sum_{r \neq s} \left| \frac{\partial^2 \Pi_r}{\partial \mu_r \partial \mu_s} \right| < 0$$

This implies that the interior Nash equilibrium in port price is unique.

A Comparative Analysis of Container Security at Dry Ports in India and Europe

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Abstract

Dry ports play an increasingly critical role in relieving busy gateway seaports facing congestion problems. At present the dry ports/inland terminals in India handle majority of the international containers. The laws regulating the security of cargo during inland transportation by rail in India predate the era of containerization, resulting in lack of accountability amongst the service providers. This paper provides a comparative analysis of how security at dry ports in Europe and in India is organized. An analysis of the existing legislation and applicable rules in Europe and India is also undertaken. Additionally, specific issues such as the costs of security or risk-based container scanning are discussed. Finally, the paper provides an analysis of the reasons behind the poor security at dry ports in India. Our research reveals that the chief reason for poor container security at the Indian dry ports is the absence of appropriate legal regime that would saddle the dry ports with the necessary responsibility and commensurate liabilities with regards to exercise of *due diligence* in respect of the cargoes handled.

Keywords: Container Security, Dry port, Inspection systems, Europe and India.

1. Introduction

Since 9/11 the security of cargo within the existing maritime transport networks has been the subject of much discussion and scientific research. The carrier's liability during the sea leg of transportation is fairly unambiguous but the shipper's concerns during the land leg remain to be adequately addressed. In India, the land leg of container transportation between gateway seaports and dry ports is usually conducted by the dry port operators. The simultaneous application of different legal regimes to the different contractual relationships between the various parties involved in the inland transportation of goods in India leads to the creation of ambiguities as regards the responsibilities and liabilities of the different parties involved.

The ISPS Code (International Port Security Code) provides a legal basis for maintaining high security levels in international maritime transport. The code forms part of wider supply chain security concept which focuses on maintaining high security levels in the entire chain, including ports and terminals. The dry ports, however, fall under the provisions of the code only in selected number of cases [1]. The container cargo liability in dry ports is of special importance and may differ per type of the dry port and country. The situation in Europe differs significantly from the one in India. This paper provides a comparative analysis of how security at dry ports in Europe and in India is organized and who takes responsibility for container security in dry ports.

2. Multiple Legal Instruments

The inland transportation of containers in India is governed by different legal instruments, the provisions of which are not congruent; especially with regard to the liabilities and responsibilities of the dry port operator vis-à-vis the carrier who has issued the bill of lading for the entire door-to-door transportation service. For

example; a chemical shipment from a factory in New Delhi, India to a warehouse in Munich, Germany (both located away from the gateway sea ports) is covered by a *through bill of lading* issued by a carrier (shipping line). The carrier enters into a separate contract for the inland transportation leg with dry port operator, who issues a Inland Way Bill (IWB). The dry port operator further enters into another contractual agreement with a road/rail transport operator which is governed by the Carriage of Goods by Road Act.

In addition to the Indian Carriage of Goods by Sea Act (COGSA) of 1925, India has also enacted the Multimodal Transportation of Goods (MMTG) Act in 1993. However, the MMTG Act has not found wide use in practice, mainly because it does not cover the activities of the sub-contractors who are the actual performing parties. In addition, the Multi-modal Transport Document (MTD) issued under the MMTG Act is often not acceptable by foreign banks, resulting in inconvenience for shippers, carriers, Multi Modal Transport Operators (MTOs) and consignees.

According to COGSA 1925 (and subsequent amendments) the carrier is expected to exercise *due diligence* in protecting the cargo and also prompt dispatch until the final destination. But as per the Indian Railway Act, the dry port operator/or his contractors are responsible for the declaration regarding cargo given through the mandatory “Goods Forwarding Note”. Indian Railway, though required to exercise *due diligence* does not assume any liability for the contents, nor does it assume any liability for the delay in delivering the cargo [4].

3. The EU Customs Security

The Safety and Security amendment to the Community Customs Code (Regulation (EC) n° 648/2005 of 13 April 2005, Regulation 1875/2006) includes a number of measures and explains the basic concepts underlying the new security-management model for the EU's external borders. The implementing provisions include operational details in the customs processes. It aims at ensuring a relevant protection through customs controls for all goods brought into or exported out of the EU member country [10].

The Safety and Security amendment introduces a common harmonized and fully computerized risk assessment framework. This includes uniform Community risk-selection criteria for controls. The amendment imposes on the industry the requirement to provide information on goods entering and leaving the customs territory of the EU which was only an obligation since 1st January 2011 [1]. The amendment introduces the programme and term of the Authorised Economic Operator (AEO). Finally, it introduces the Community data base which enables all national registration numbers to be consulted (EORI). The provisions of the amendment are designed in order to enable a smooth flow of goods and the decrease the extent of delays of consignments pending the results of the risk analysis. It also aims at the concentration of all the information in a single customs office instead of several ones.

The Customs Security Programme (CSP) covers activities supporting the development and implementation of the security measures. It includes proper security controls aiming at ensuring the protection of the internal market as well as maintaining high security levels of international supply chains. The programme also provides assistance to traders who show compliant efforts to secure their part of the international supply chains.

3.1 Authorised Economic Operator

One of the main elements of the security amendment of the Community Customs Code is the introduction of the Authorized Economic Operator (AEO) concept. On the basis of Article 5a of the security amendment in 2006, Member States can grant the AEO status to any economic operator that meets common criteria (customs compliance, appropriate record-keeping, financial solvency and, where relevant, security and safety standards).

Economic operators can apply for an AEO status either to have easier access to customs simplifications or to be in a more favourable position to comply with the new security requirements. Under the security framework, which has been applicable since 1 July 2009, economic operators have to submit pre-arrival and pre-departure information on goods entering or leaving the EU. The security type of AEO certificate and the

combined one allow their holders to benefit from facilitations with regard to the new customs controls relating to security. The status of AEO granted by one Member State is recognised by the other Member States. This does not automatically allow them to benefit from simplifications provided for in the customs rules in the other Member States. Other Member States, however, should grant the use of simplifications to authorised economic operators if they meet specific requirements.

Directorate General for Taxation and Customs Union is a network including customs authorities and EC experts that were set up to support the introduction of the AEO rules throughout the Member States. The AEO Guidelines have been developed in order to harmonize the implementation of the AEO rules throughout the EU. The guidelines aim at equal treatment of economic operators and transparency of the rules. Agreements with third countries aiming at mutual recognition of the AEO status have already been signed with Switzerland, Norway and Japan while pilots are under tests with United States and China. If a dry port has an AEO status, it would have to meet safety and customs handling requirements. Government of India has also finalized the AEO programme for implementation to secure supply chain of imported and export goods, in Aug 2011.[7] This programme has also been developed pursuant to guidelines of WCO adopted in SAFE FoS (Framework of Standard) in 2005. In line with the European practice, getting an AEO status might be of special relevance to Dry Port operators in India too.

3.2 Cost Aspect of Containers Security

The costs involved in scanning can be divided in two elements: 1) the operation of the scanning equipment and 2) the transport to and from the scanning area. In the Port of Rotterdam, as in most other Western European ports, the scanning is free of charge to the cargo owner. The scanners are operated by Customs, who also bear the costs. Transport to and from the scanning area is carried out by the container terminal operator, for which a fee is charged to the cargo owner, often referred to as a scanning fee [2]. In Rotterdam, this transport fee amounts to 100 Euro per container on average (it is distance related). In some cases, governments or port authorities bear (part of) the costs involved in scanning order to protect their competitive position. In Rotterdam for instance, the Port Authority used to pay for a share in the transport costs to and from the scanner, but this practice was stopped [12].

Every company operating in the container transport chain can apply for the AEO status. The costs of obtaining an AEO certificate depend on many factors and the level of adjustments a company has to make. It has been estimated that the average cost of obtaining the AEO certificate ranges between € 8,000 and € 15,000 for small businesses while the annual costs related to maintaining the certificate are between € 3,000 and € 5,000 [18]. The costs of obtaining an ISO 28000-2007 certificate are € 2,500 and € 4,000 with annual costs to maintain the certificate at the level of € 1,000 - € 1500.

In India, customs have installed cargo X-ray machines for inspecting samples of import cargo. Occasionally, export cargo is also examined through X-ray. Entire cost of scanning is borne by customs, but the handling of consignments is at the cost of shipper. Since only a few packages are routed through the X-ray, cost of handling is not an issue. Customs has not yet installed any container scanning equipment in any dry port. In fact, there is only one container scanner in India that is at JNPT.

India has not yet upgraded its infrastructure for participating in CSI of USA. As and when pre-shipment of container scanning becomes mandatory, exports from India to US will have to be routed through another port which has the scanning facilities. The additional cost of compliance may add up to US\$100 per container!

3.3 Risk Assessment and Audit Testing

Within the EC funded Transumo project, audit tests of risks were done at selected participating container shipping companies [18]. The tests were done for the supply chain that begins with the receipt of cargo by the barge terminal and ends with delivering the cargo to the seaport or ship or vice versa. Within the project, generic risk assessment both for transport (the barge) and storage (inland terminal) test audits were prepared, performed and analysed [9]. After the above steps were completed and the security plans were adjusted, the

three participating terminals¹ (chains) worked under an assigned certification level. In the period of 3 months unannounced audits were performed. Both the terminals and vessels developed tools that can be useful for acquiring security certification. The main outcomes of the study performed include:

Each container must have a stamp before an export container is accepted at the terminal in the seaport (currently before a so-called bolt seal is used) – this means in practice that the shipper is obliged to use stevedore whether the container is actually sealed (an exception could be that the shipper has a procedure which prevents from sealing, also if there is no documentary proof that the container was sealed). Inland terminals have no procedures on seal verification provided that the containers are proven to be sealed by the shipper. The solution of the problem should be enhanced cooperation between the company, shipper and stevedore. The (mandatory) use of so-called smart seals (RFID) should solve this problem. There is, however, no global standard. It is crucial, therefore that the shipper takes the responsibility for sealing the container.

Currently, in cases where barges are used as a transport mode between the maritime vessel and dry port, a separate security certificate is needed for them. They should form an integral part of the logistics chain and a separate security certification process should be prevented.

With the increase of data exchange, more information is publicly available to various parties not directly involved in container handling. With the increase of information exchange, the security risks may increase. The container should, therefore, remain "anonymous" [16].

The inland terminals that are not covered by ISPS or are not under AEO rules, they often do not have a systematic approach towards risk assessment and have no specific instructions for dealing with security [18]. However, it should be noted that most inland terminals pass rather strict security requirements. This results of the market conditions and strict client's requirements rather than regulation. Additionally, these are compulsory for complying with the European insurance requirements for security.

4. Inland Transport Related Security Initiatives

ISO28000-2007 Certificate

The International Organization for Standardization (ISO) recently published specification for the ISO 28000-2007 certification aimed at implementing safety management in supply chains. It is a risk-based management system for transport operators. For organizations working in logistics this certification can be a valuable addition. It supports the management and reduction of security incidents as well as "just in time" delivery of goods. This standard is suitable not only for the transport chain but it is also helpful in meeting AEO requirements [21].

CSI: Container Security Initiative

International Trade Security and Facilitation Programs include also the Container Security Initiative (CSI). This initiative was undertaken by the US Department of Homeland Security - Customs and Border Protection (CBP) while the efforts focused on establishing working bilateral partnerships with foreign authorities aiming at identifying high-risk cargo containers before they are loaded on vessels with destination in the United States. The border security, therefore, is moved from the US territory to the territory of country of port of origin [3]. This leads to development of standards of port security worldwide. There are 23 operational CSI ports in Europe (out of 58 worldwide) [15]. There are none, however, in India. Additionally, 35 customs administrations have committed to join CSI. Approximately 86 percent of maritime containerized cargo that enters the US territory originate from or are transhipped in CSI ports. The selection of containers to be scanned is done in Europe based on risk assessment. Currently, 1-2% of containers are scanned. The USA would like to implement 100% container scanning rule. Due to enormous increase in costs of security, it is highly debatable whether it can be implemented. Implementation of this rule would require heavy investments

¹ Oosterhout Container Terminal, Barge Terminal Tilburg, Combined Cargo Terminals (Moerdijk)

in equipment and more importantly extensive physical reorganization of already congested seaports. A number of other initiatives on transport security are being developed.

5. National Regulatory Competencies in India

With regards to India an Inter-Ministerial Committee (IMC), acting under the overall control of the Ministry of Commerce, was set up in 1992 with the primary aim of facilitating exports by way of encouraging the establishment of dry ports. IMC is thus the competent authority for licensing the setting up of dry ports. However the IMC guidelines for setting up and specifying the functions of dry ports are silent when it comes to the law that should apply to dry port operations. The guidelines do, as a matter of fact, state that dry ports would broadly be under the overall control of the local Customs Commissioner, but they fail to give details on the powers and duties of the commissioner [17].

According to the Customs Act of 1962, the jurisdictional Commissioner of Customs is the competent authority for the approval of a physical place as *customs area* and for the approval/appointment of a *custodian* (in our case a dry port operator), under section 8 and 45 respectively. The General Clauses Act of 1897 (section 16) stipulates that powers vested with an authority, for any appointment, includes the power to suspend or dismiss the person so appointed. Hence, the Commissioner of Customs has also the authority to de-notify or take away a custodianship, in case of non-compliance to the principles of natural justice [6].

Thus the mechanism for the review of the conduct of the dry port operator (who is considered as a custodian of the cargo in his charge) and performance has been delegated to the jurisdictional Commissioner of Customs. As such the IMC, which had initially licensed the applicant for setting up a dry port, does not play any further role in the functioning of the dry port. Presently dry port operations, including container transportation, involve numerous key federal and regional actors such as customs, railways, police and similar enforcement and inspection agencies. Thus the onus of conducting the day-to-day operations of dry ports lies with the *custodian* [8][6]. The dry port operator as the *custodian* is responsible for safety and security of the goods stored in their dry port. The Commissioner of Customs has also been empowered to review the approval granted before the expiry of the initial period of approval and may order for review of the approval granted to any custodian before the completion of the period.

Security in the inland container transportation is a complex issue that involves numerous key actors including union government (through department of Customs and Railways), state governments (law and order is a state subject), other enforcement and inspection agencies; Dry Port custodian; private sector businesses; and organized labour and other port employees. The onus of providing security in the Dry Ports has been placed on the ‘custodian’ by the Customs Manual. The jurisdictional Commissioner of Customs appoints the operators of the ICDs/CFSSs as custodians under section 45 of the Customs Act, 1962, provided they satisfy the conditions relating to development of infrastructure & facilities and furnishes bonds and securities as laid down for such purpose in the CBEC Circular No.26/2009.

6. Liability of Dry Ports in Europe and India

There are many inland terminals in Europe but only selected terminals are called dry ports. For example out of all inland terminals in the Netherlands, there are 6 that have the ISPS code status. One of the areas that needs further development is the integration of freight information with security requirements and the matching of ISPS needs [13] [14]. From the ECT Inland terminal services and facilities, only Amsterdam has the AEO status. The terminals make attempts to get the AEO status as this enables them to get new more demanding clients. It can be stated, therefore, that while the obligatory measures are implemented in all terminals, more terminals are increasing their security measures due to the changing market conditions. Containers storage at different sites requires special safety and security provisions. When these are ensured, the safety and security become a contributing factor to goods being stored in port terminals. It is considered safer to store cargo in port terminals than at factory sites if they are CSI and ISPS compliant [16]. A dry port, therefore, should offer the same security level as a maritime port terminal.

This IWB is *prima facie* evidence of receipt of cargo by the Container Train Operator (CTO) (CONCOR for instance) from the consignor who is the carrier (shipping line/freight forwarder) in apparent good order and condition, except as otherwise noted with respect to damage sustained by the cargo before arriving at the dry port. The IWB is issued by the CTO for the containers to be carried by it, and the carrier must give it back at the destination at the time of taking delivery. The IWB is issued subject to the conditions and liabilities as specified in the India Railways Act, 1989 and, according to the terms stated in it, the carrier (who is the consignor in this case) must accept responsibility for all *particulars* furnished in respect of cargo tendered by him for carriage to the gateway port. Furthermore, the IWB goes on to state that the carrier (consignor) is **deemed to have indemnified** the dry port/CTO against any damage or loss suffered by it by reason of incorrect *particulars* provided by him in regard to the cargo. Thus it is obvious that the dry port operator/CTO absolves himself of all liability for ensuring the correctness of the particulars of goods declared. This becomes pertinent if the goods cause any kind of third party damage.

It can be surmised from the above that the Indian dry port operator treats the carrier (shipping lines NVOCC or Freight Forwarders) as a consignor and enters into a contractual relationship with him to handle and transport containerized cargo to and from the gateway port. The dry port operator does not recognize the shipper of the goods with whom the carrier has its own contractual relationship. Thus, the shipper cannot move against the dry port operator for loss or damage to his goods that occurs in the custody of the dry port operator. Accordingly, the dry port operator does not automatically indemnify the carrier with regard to any liabilities and responsibilities the latter may have accepted vis-à-vis the shipper.

It is noteworthy to highlight the fact that CONCOR's IWB mentions that "*This Inland Way Bill is issued subject to the conditions and liabilities as specified in the Railways Act 1989*". However, the Claims Procedure of CONCOR mentions that in no circumstance the liability would exceed Rs 50 per kg while goods are in custody of CONCOR.[5] This is a contradiction as under the Railways Act 1989, the liability of railway is not limited to Rs. 50/kg, but is limited to the value of goods. (Railways Act 1989, sec 103)

In practice, CONCOR has distanced itself from the railways' procedure. It has contended before a high court that Railway Claims Tribunal has no jurisdiction to adjudicate dispute between a customer who has filed for claim and CONCOR as CONCOR is not 'Railways'. This view has been upheld by Hon'ble Delhi High court [20].

7. Conclusion

The provisions and requirements of the AEO regulations are stricter than the ones of the ISPS regime. Having an AEO status means in principle that operators meet the ISPS requirements. Some dry ports in Europe have to comply with the ISPS regulations and have accordingly been recognized to have the ISPS status. The current market conditions, however require the dry ports that are not legally required to do so, to apply for the AEO status [11]. Thus, it would be in the interest of all the dry port operators to be within the preview of AEO provisions. Government of India is yet to prescribe the required minimum security standards for a dry port operator. Lack of visible and certified security system in India is resulting in poor patronage of dry ports. This might also result in higher risk premiums paid to insurance companies. This is especially so if a dry port is allowed to absolve itself of almost entire liability (including third party) for ensuring the correctness of the cargo particulars declared by the consignor. Such lacunae could be rectified as and when the Government of India ratifies the rules applied in Europe and saddles the dry port operator with the responsibilities and liabilities of a "performing party".

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Identifying Strategic Chokepoints in Contemporary Context: Assessing Security in India's Dry Ports

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Abstract

In the dynamic environment of international trade, the importance of maritime supply chains to a country's national security cannot be underestimated. Historically, maritime supply chain security has been conceptualized in geographic terms rather than logistical ones, using narrow geographic 'chokepoints' to the world's oceans as the central referent point. In the contemporary context, logistical referent points, rather than geographical ones, have greater utility in measuring the resilience of maritime supply chains. Specifically, the dry ports sector should be used as a referent point in assessment of supply chain security because of the important role that hinterland transport plays in overall trade development. In this paper an attempt has been made to understand the national security of a single developing economy, India, by analyzing its hinterland transport security. The analysis takes into consideration current logistical data from India's dry ports to support conclusions about overall supply chain 'resilience': the degree of economic impact arising from disruption in the hinterland sector of the maritime supply chain. Thus an attempt has been made to quantify dry port *resilience* in terms of container security by using a specially developed *CONSEC* model. The quantification of the dry port *resilience* takes into consideration both capacity and security. We assume a container security risk management approach to analyze existing security policies that should be re-considered.

This analysis of India's dry ports concludes that although implementation of container security measures is considered to be an additional cost, the strategic vulnerabilities of the supply chain cannot be ignored in measures of resilience. Because 'resilience' is directly proportional to the applicability of the geo-strategic concept of 'chokepoint', our paper concludes that low-resilience sectors of the maritime supply chain, including dry ports, should be understood by security planners as contemporary 'chokepoints' with respect to national economic security. In that context, the strategic value of investment in increased resilience of identified chokepoints in the maritime supply chain should be measured against the additional cost. This paper has two conclusions; first, Indian dry ports are resilient from the view of capacity yet fail to be so when security is taken into consideration; and second, Indian strategic planners need to develop appropriate legal regimes to decrease the vulnerability of key 'chokepoints' in the Indian economy as defined by resilience and not geography.

Keywords: Dry Ports, Container Security, chokepoints, resilience and India.

1. Introduction: Dry Ports as Chokepoints

Chokepoints, and mitigation of the risks they present to national well-being, have long been a central referent point for strategic thinkers of national development. Maritime history is full of accounts of major maritime powers battling to control strategic waterways for commercial advantage. In the United States, Alfred Thayer Mahan argued that consolidation of control of the Panama Canal was a prerequisite for American national development (Mahan, 1914).

While the utility of considering national development with respect to chokepoints remains, structural changes in global shipping and national economies suggest that the chokepoint should no longer be defined only in geographic terms. If chokepoints are defined by their effect on economic resilience, then logistical

chokepoints are a common feature of the modern seascape. This is due to the development of a global hub-and-spoke intermodal transport system in which the majority of the world's finished and semi-finished goods pass through a small number of nodal handling facilities. This revolution in the structure of maritime trade has simultaneously increased global economic activity and global economic vulnerability.

Dry ports are playing an increasingly important role in this system. Usually located near or alongside gateway seaports; industrial areas; and/or transportation axes, dry ports perform several important functions. (Nozick and Turnquist, 2000; Woxenius *et al.*, 2004). These include: (i) cargo aggregation and unitization; (ii) in-transit storage; (iii) customs clearance; (iv) issuance of bills of lading; (v) relieving congestion at gateway seaports; (vi) assistance in inventory management; and (vii) deference of import duties payments for goods stored in bonded warehouses (Paul, 2005). Globalization, economic reforms, trade liberalization, and the development of land infrastructure have abolished captive hinterlands, thus obliging dry ports to compete for custom. The consequent greater choice in the routing of cargo inland, and parallel advances in supply chain management techniques, have altered the nature of competition from one between seaports and dry ports to one between available supply chains. Intensifying supply chain competition is among the reasons that container security is a key comparative measure of supply chain performance (Benacchio *et al.*, 2000).

This dramatic world-wide shift from point-to-point bulk shipping to integrated global intermodal transport at sea and inland has made the transportation of goods over longer distances economically feasible. Economic distances have thus shrunk in real terms, expanding markets for raw materials and final products and facilitating the industrialization of many countries around the world. Often, international ocean transportation and information and communication technologies (ICT) have been referred to as the two basic ingredients of globalization (Haralambides, 2007; Stiglitz, 2006). The increased reliability and safety coupled with decreased transit time and cost, both on land *and* at sea, have almost uniformly enhanced standards of living, particularly in developing countries that have made the appropriate investments. Efficiencies harnessed through this model are estimated between 60 to 96% (Stopford, 2000; Levinson, 2006).

Radically re-structured cost calculations associated with intermodal maritime transport demand a similarly re-structured assessment of resilience associated with dependence on global trade. In the contemporary context, in which economic distances have shrunk considerably, reliability and safety of transport logistics becomes more heavily weighted in any calculation of cost, relative to the length of the vessel transit at sea. This is so because the cost of a few extra days' transit on a longer routing is minimal while the cost of additional warehouse space at port, or the cost of delay of component parts are very significant factors in overall manufacturing productivity and profitability (Stopford, 2000). This trend suggests that safety and reliability at major transport hubs/dry ports is a key indicator of overall national economic vulnerability. In this kind of trading system, it should be obvious that a failure of container security will result in lowered performance of national supply chains. If strategic chokepoints are defined by their relation to economic resilience, nodal points in national supply chains constitute strategic chokepoints and require substantial investment and attention from strategic planners to mitigate risk and maximize an economy's opportunity to harness gains.

Re-structured assessments of costs and reliability are particularly needed in developing countries, as changes in the global transport system have arguably altered their trading practices more than those of developed economies. From that starting assumption, this analysis takes India's burgeoning hinterland intermodal trading infrastructure as a case study in security and resilience. The Indian hinterland makes a particularly instructive case study of resilience in dry ports for several reasons. First, India's economy has become newly entrenched in the global trading system and its logistics in the past two decades. As a newly important player, its overall impact on the resilience of maritime supply chains is important to assess. Second, India's geography, with relatively limited seacoast and relatively extensive hinterland, has meant a high rate of proliferation of dry ports when compared to other countries. Last, India's risk profile, especially following the terrorist attacks in Mumbai in 2008, means that vulnerability to security-related disruption is more acute in India than in some other national contexts. An assessment of Indian vulnerability is thus important for both Indian strategic planners and for those national economies that are integrated with Indian supply chains.

This analysis is composed of five parts. First, a survey of relevant security instruments in supply chain security will be presented, to set the context for an analysis of India's strategic performance. Second, India's

strategic performance against these instruments will be presented in terms of compliance and application. Third, a discussion about India's dry ports as strategically vulnerable chokepoints will outline the need to reconceptualize security not as a drag on efficiency but as an investment in resilience of national supply chains. Fourth, research design and data collection of the analysis' empirical study will be outlined. Finally, the authors will offer the dual conclusion that first, Indian dry ports are resilient from the view of capacity yet fail to be so when security is taken into consideration; and second, Indian strategic planners need to develop appropriate legal regimes to decrease the vulnerability of key '*chokepoints*' in the Indian economy as defined by resilience and not geography.

2. Security Instruments: A Global and National Survey

The importance of addressing the vulnerability of the world's logistical chokepoints has generated several globally applied instruments since 2001. As a contextual foundation to assessing the resilience of Indian dry ports, these instruments and their application are discussed here.

2.1 International Ship and Port Security (ISPS) Code

The perceived strategic vulnerability of the global supply chain was the impetus for the drafting of the International Ship and Port Security (ISPS) Code. The ISPS Code was adopted by IMO in December 2002, and was fully effectuated in July 2004 (IMO, 2002b). It is presently the most obvious indication of an international recognition of the strategic vulnerability of the global supply chain following the terrorist attacks in the United States in 2001. The code is based on IMO's International Convention for the Safety of Life at Sea (SOLAS) 1974 and its subsequent additions regarding Special Measures in Enhancing Maritime Security (Chapter XI-2) to SOLAS (IMO, 2002a). In essence, the ISPS code takes a risk management approach to security, implying that, in order to determine appropriate security measures, an assessment of the risks needs first to be made, in each individual case separately. The Code also provides a standardized and concise framework for evaluating risks and possible responses.

The Code proposes to achieve its stated objectives by (i) detecting and identifying potential security risks; (ii) implementing security measures, e.g. protection terms, procedures, communications, etc; (iii) collating and promulgating information related to maritime security; (iv) providing a reliable method of assessing maritime security risks; (v) developing detailed security plan procedures in reacting to changing security levels; and (vi) establishing security related roles and responsibilities for contracting governments, port administrations and shipowning and operating companies at national and international levels, including the provision of professional training (Hariharan, 2007).

2.2 Inland Transport Related Security Initiatives

ISO: 28000-2007 Certificate

The International Organization for Standardization (ISO) recently published specification for the ISO 28000-2007 certification aimed at implementing safety management in supply chains. It is a risk-based management system for transport operators. For organizations working in logistics this certification can be a valuable addition. It supports the management and reduction of security incidents as well as "just in time" delivery of goods. This standard is suitable not only for the transport chain but it is also helpful in meeting AEO requirements (Schoonen Advies en Management, 2009).

CSI: Container Security Initiative

International Trade Security and Facilitation Programs also include the Container Security Initiative (CSI). This initiative was undertaken by the US Department of Homeland Security - Customs and Border Protection (CBP) while the efforts focused on establishing working bilateral partnerships with foreign authorities aiming at identifying high-risk cargo containers before they are loaded on vessels with destination in the United States. The border security, therefore, is moved from the US territory to the territory of country of port of origin (CBP, 2012). This leads to development of standards of port security worldwide. There are 23

operational CSI ports in Europe (out of 58 worldwide). Additionally, 35 customs administrations have committed to join CSI. India, however, is not included in CSI although discussions about Indian participation in the program have been reportedly conducted by U.S. and Indian government officials (personal communication with authors). At present, approximately 86% of maritime containerized cargo that enters US territory originate from or are transhipped in CSI ports.

The USA would like to implement 100% container scanning rule. It, is however, highly debatable due to enormous increase in costs of security. Implementation of this rule would require heavy investment in equipment and more importantly extensive physical reorganization of already congested harbours. A number of other initiatives on transport security are being developed.

2.3 *National Regulatory Competencies in India*

With regards to India, an Inter-Ministerial Committee (IMC), acting under the overall control of the Ministry of Commerce, was set up in 1992 with the primary aim of facilitating exports by way of encouraging the establishment of dry ports. IMC is thus the competent authority, licensing the setting up of dry ports. However the IMC guidelines for setting up and specifying the functions of dry ports are silent when it comes to the law that should apply to dry port operations. The guidelines do, as a matter of fact, state that dry ports would broadly be under the overall control of the local Customs Commissioner, but they fail to give details on the powers and duties of the commissioner (Customs India, 2012). Thus the mechanism for the review of the dry port (who is considered a custodian of the cargo in his charge), conduct and performance has been delegated to the local commissioner of customs. As such the IMC, which had initially licensed the applicant for setting up a dry port, does not play any further role in the functioning of the dry port.

According to the Customs Act of 1962, the jurisdictional Commissioner of Customs is the competent authority for the approval of a physical place as *customs area* and for the approval/appointment of a *custodian* (in our case a dry port operator), under section 8 and 45 respectively. The General Clauses Act of 1897 (section 16) stipulates that powers vested with an authority, for any appointment, include the power to suspend or dismiss the person so appointed. Hence, the Commissioner of Customs has also the authority to de-notify or take away a custodianship, in case of non-compliance to the principles of natural justice (Customs Circular F No. 450, 2008).

3. **Assessing India's Strategic Performance**

Starting with reference to global convention, this analysis finds that despite the adoption of the ISPS Code at the IMO and application in India, our research of Indian dry ports reveals that the government of India has not yet made security investments commensurate with the strategic risks that these chokepoints present to the national supply chain. The major problem faced by Indian dry ports in complying with ISPS Code requirements is inadequate co-operation and information exchange. There is a glaring lack of procedural uniformity between different stakeholders, and no government protocol is in place to overcome this lack. In addition, there is also a genuine lack of supranational coordination of dry port security related issues, with obvious effects on information flows and information sharing. According to anecdotal information, the sharing of security information between different authorities and ports is scarce, and is often untimely and unspecific.

Conflicts of interest between different authorities and stakeholders have resulted in lack of adequate co-operation and in diverse interpretations of international guidelines. Responses to security questions have often been subject to social, political and institutional constraints, and it has been clear that the concept of security is interpreted very differently in the context of Indian dry ports.

India's non-participation in other global initiatives, such as the U.S.-led Container Security Initiative (CSI) means that the gaps left by uneven and unclear application of the ISPS are not addressed by parallel programs or initiatives. Though non-participation in the voluntary and selective CSI program alone does not indicate low security or low resilience in Indian ports, when coupled with poor application of the ISPS Code, it does further underline the security vulnerability of Indian facilities.

With respect to the domestic regulatory framework, a strategic assessment of Indian performance also reveals important vulnerabilities to security disruption. Presently dry port operations, including container transportation, involve numerous key federal and regional actors such as customs, railways, police and similar enforcement and inspection agencies. Thus the onus of conducting the day-to-day operations of dry ports lies with the *custodian* (Customs Manual, 2006-2007). The dry port operator as the *custodian* is responsible for safety and security of the goods stored in their dry port. The Commissioner of Customs has also been empowered to review the approval granted before the expiry of the initial period of approval and may order for review of the approval granted to any custodian before the completion of the period.

Through personal interviews of the authors with a number of senior Indian dry port stakeholders, it has become apparent that there is a certain lack of clarity on liability and responsibility issues regarding container security. Among others, this often necessitates the actual examination of all containers, something naturally rather impractical and costly.

According to the manning guidelines of the Central Board of Excise & Customs, dry ports would normally operate with a staff of 10-12 officers. For dry ports having an annual throughput of 10,000 TEUs or more, it appears that such officers may be insufficiently equipped to undertake a thorough inspection of cargoes and containers, and are thus often obliged to outsource security related activities. This is one of the reasons why explosive materials and live ammunition have escaped the eye of dry port officials at the Tughlakabad and Ludhiana dry ports, near New Delhi. Ironically, none of the Indian dry ports or for that matter most of the seaports have explosives detection equipment or X-ray scanning facilities.

Indian dry ports are both in the public and private domain and permission for their construction is granted by the Ministry of Finance. In granting such permissions, the government implicitly expects individual dry ports to develop their own security plans. However, no explicit stipulations are in place, on liability and responsibility issues, in cases of security breaches.

The government allows only public dry ports to issue railway receipts (RR) on its behalf for the transport of containers to and from gateway seaports. By doing so, the government indirectly assumes responsibility for container security and, consequently, relieves the dry port of any liability for security lapses. On the other hand, private sector dry ports who are not equipped with rail heads issue lorry receipts (LR) for the containers they themselves transport. They are thus liable for container security. Among other complexities, these differentiated policies of the government towards public and private dry ports is also an interesting case of *moral hazard* with respect to public dry ports, indicated by measurably greater diligence by private sector dry ports with respect to their security arrangements.

Containerized cargo is cleared by customs at dry ports. However, inspections are random and largely based on documents such as shipping bills and forwarding notes prepared by the shippers themselves. Furthermore, only a small percentage of randomly selected packages are actually opened for physical inspection and verification of actual contents. Due to time, manpower and equipment constraints, the reliability of such examinations is not satisfactory. As yet, no attempt has been made to empirically investigate the impact of such security procedures on the operational resilience of dry ports and this is one of the objectives of the present paper.

Security in the inland container transportation in India is thus a complex issue that involves numerous key actors including union government (through the Department of Customs and Railways), state governments (law and order is a state subject), other enforcement and inspection agencies, the dry port custodian, private sector businesses, and organized labor and other port employees. The onus of providing security in the dry port has been placed on the '*custodian*' by the Annexure-II (Setting up of ICDs/CFSs) Customs Manual 2006-07. The jurisdictional Commissioner of Customs appoints the operators of the ICDs/CFSs as custodians under section 45 of the Customs Act, 1962, provided they satisfy the conditions relating to development of infrastructure & facilities and furnish bonds and securities as laid down for such purpose in the CBEC Circular No.26/2009.

Indian dry ports are currently significantly vulnerable to security-related disruption. Such disruption is of national strategic importance, rather than just of local or regional interest. As an integral element of both a national maritime supply chain and a global one, security disruption at Indian dry ports carries costs for multiple stakeholders. Security vulnerability carries strategic costs for several national stakeholders, including but not limited to India. A discussion about the significance of Indian dry ports as chokepoints in the global maritime supply chain illustrates this fact.

4. Contemporary Chokepoints: India's Dry Ports Today

Before the advent of containerization in India, dry port competition was negligible and limited to two locations only: New Delhi and Mumbai (JNPT). With the rapid development of intermodal transportation, however, that situation has changed dramatically. Dry port establishments are mushrooming throughout the country now, competing for custom through efficiency and quality of service. Moreover, in the past few years, especially after the Mumbai attacks of 2008, container security management has commanded increasing attention and, judging from current trends, this is going to be a most critical issue going forward.

The operational efficiency of the Indian logistics sector in general, and dry ports in particular, have been recently suffering from the consequences of massive overcapacity. This has resulted in unsustainable pressures on prices and profitability. In such an environment, the only possible way forward for logistics companies has been to cut costs and increase efficiency. This has had far reaching implications for container security and, in the opposite, security measures and related costs and benefits have had their own impact on dry port efficiency. This relationship is investigated here through DEA analysis, encompassing *container security* as an additional *output* in the measurement of dry port performance.

In the past decade, a number of scholars have carried out research on the various resilience measurement aspects of the port sector, from different perspectives. Tongzon (1995) specified and empirically tested the various factors influencing the efficiency and performance of container terminals, using data from 23 international ports. Tongzon (2001) and Hidekazu (2002) have also applied DEA models to identify the factors influencing the efficiency of container terminals. Farsi *et al.* (2006) have computed the impact of cost and scale efficiencies on container terminals operating within regional networks. Roy and Yvrande-Billon (2007) have investigated the impact of ownership structures and contractual choices on the performance and efficiency of French ports.

Most earlier research, however, adopts *port throughput* as the sole *output* of different simulation models. In simple words this means 'the more the better' and the higher the throughput, given resources, the more efficient the port. Such a perspective is nowadays untenable. More often than not, economic activity creates significant negative externalities, most notable among them are safety risks and security threats. Such a measurement of efficiency is biased against economic agents who, either by necessity or choice, internalize such externalities, as ISPS Code requires them to do (in an earlier paper (Haralambides and Gujar, 2012) we have dealt other externalities, such as the environmental impacts of dry port operations; here, the focus is only on 'security', while 'safety' is reserved for a future paper). The approach we take here, as well as in our earlier and forthcoming research, is that the output of a productive agent is a multiproduct one, including such intangibles as the benefits deriving from a secure environment. Industr priorities such as these, no matter how desirable they may be in modern societies, cost money and if not properly weighed within a dry port's comprehensive output they could lead to lower efficiency assessments for dry ports of higher societal awareness. Some examples of such costs, and disruptions, from India, could suffice to exemplify this point.

5. Research Design and Data Collection

The measurement and analysis of security standards needs to be the starting point of our analysis. While there have been multitudinous efforts in the study of container security, to date there has been no consensus on the adoption of the appropriate measurement tools. The *CONSEC* model developed in this paper is an endeavor to introduce such a tool. Our model identifies and measures the gaps between stakeholder expectations and their perceptions of security, and in this way it highlights policy directions aiming at bridging disparities associated with dry port security.

With the use of the Delphi technique, we construct a questionnaire covering 5 dimensions and 26 service items, taking into account the opinions of the various stakeholders. We broadly divide dry port customers into three major groups, depending on the kind of services rendered to them. The questionnaire is further validated with the help of Exploratory Factor Analysis (EFA) and, following this, the service items are reduced to 24. The groupings of the service items, under their respective dimensions, are summarized below.

Equipment

1. Adequacy of the quantity of equipment
2. Achievement of objectives/targets
3. Appropriateness of maintenance programs
4. Regularity of equipment upgrades
5. Justification of investments
6. Functionality of IT and surveillance systems

Personnel

1. Adequacy of the number of personnel
2. Competency of personnel to implement security programs
3. Clarity of organizational structure
4. Appropriateness of salary levels paid to security personnel

Policy and Planning

1. Adequacy of security plans
2. Necessity of approval by an independent authority
3. Need for a mandatory appointment of a security officer
4. Understanding of responsibilities and liabilities by employees
5. Employee guidelines for rewards and punishment for security awareness
6. Necessity of benchmarking of dry port security

Drills and Training

1. General accessibility of security plans
2. Professionalism in personnel training on security matters
3. Necessity of certification of training programs
4. Periodic reviews of security policies

Security Audit

1. Length of the audit period
2. Security audits are carried out objectively by independent auditors
3. Audit findings are accepted without prejudice
4. Mandatory action is necessary for implementing security audit guidelines
5. Adequacy of procedures for the appointment of auditors

Data was collected through personal interviews, with the use of structured questionnaires. The first questionnaire was administered to 200 randomly selected addressees who patronize dry ports. The only criterion used in the selection of the respondent company was a throughput of a minimum of 100 containers per annum. The criterion used for the selection of the respondent employee was a minimum service time in the dry port of 12 months. Respondents were classified in the categories shown in Table 1.

Table 1: Details of Respondents

Categories of Respondents	No. of Respondents
Shipping lines /NVOCC operators	28
Surveyors	32
Consignees/clearing agents/freight forwarders	24
Dry port management personnel	21
Dry port employees	27

Customs officers	25
Dry port security personnel	20
Total	177

To evaluate the constructs of security quality -i.e. the individual dimensions and items which influence dry port security- we performed an Exploratory Factor Analysis to confirm the underlying factors embedded in the survey data, constituting the different drivers for the customers who patronize dry ports. Factors were extracted using the maximum likelihood method. To purify the original list of 26 items, those with factor loadings of 0.10 and above, on more than one factor, were eliminated. Table 2 below includes the purified list of 24 items representing the aspects which affect dry port security. These items explain 90% of the variance. The 24 service items were anchored on a 7-point Likert scale (i.e. 7= strongly agree and 1= strongly disagree).

Table 2: Results of Exploratory Factor Analysis

	Items	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5
1	Number of equipments	0.888	0.441	0.324	0.462	0.322
2	Purpose being served	0.892	0.325	0.421	0.410	0.523
3	Maintenance program	0.736	0.532	0.232	0.423	0.541
4	Equipment upgrading	0.891	0.145	0.216	0.436	0.563
5	IT and surveillance systems	0.462	0.857	0.254	0.425	0.413
6	Number of personnel	0.542	0.809	0.366	0.236	0.236
7	Competency of personnel	0.314	0.792	0.256	0.315	0.436
8	Staff qualifications	0.231	0.881	0.214	0.341	0.355
9	Organizational Structure	0.462	0.576	0.851	0.301	0.430
10	Staff salaries	0.451	0.264	0.872	0.236	0.520
11	Security plans	0.321	0.356	0.749	0.532	0.531
12	Approval of plans	0.134	0.452	0.802	0.420	0.234
13	Security officer	0.212	0.536	0.200	0.855	0.244
14	Procedural guidelines	0.112	0.301	0.106	0.814	0.361
15	Benchmarking security	0.342	0.533	0.201	0.756	0.540
16	Accessibility of plans	0.314	0.361	0.321	0.933	0.610
17	Training	0.241	0.245	.0322	0.189	0.800
18	Program certification	0.9624	0.261	0.253	0.456	0.714
19	Periodic reviews	0.309	0.323	.0421	0.411	0.966
20	Audit period	0.322	0.543	0.329	0.165	0.899
21	Independent auditors	0.345	0.436	0.132	0.222	0.752

22	Acceptance of audits	0.624	0.542	0.712	0.221	0.102
23	Mandatory action	0.722	0.314	0.115	0.221	0.423
24	Appointment of auditors	0.511	0.523	0.245	0.519	0.104

The 24 service items, covering the five dimensions, reveal the differences between the expectations and perceptions of the respondents. The average dimension scores of expectations and perceptions are tabulated, with the difference between the two scores revealing the gaps. The total of the products of weights (allotted by respondents according to their own perceived significance) and the average dimension scores divided by five, gives the weighted *CONSEC* score, shown in Table 3.

Table 3: Statistical Analysis of Dry Ports

	Number of Equipment	Number of Employees	Terminal Area (sq.m)	TEU Throughput	Container Security <i>CONSEC</i> Score
Mean	2.961538	20.73077	77801.96	54356.98	-0.440
Std Dev	1.825329	7.973277	70759.38	46871.02	0.368201
Median	2.5	21.5	50000	37447.5	-0.81
Minimum	1	9	20000	10426	-1.63
Maximum	7	39	364000	184561	-0.023

Table 4: CONSEC Score of Dry Ports

Dry Port	CONSEC Score
1	-0.78
2	-0.50
3	-0.34
4	-0.04
5	-0.37
6	-0.65
7	-0.55
8	-0.21
9	-0.11
10	-0.35
11	-0.88
12	-0.51
13	-0.27
14	-0.09
15	-0.39
16	-0.77
17	-0.57
18	-0.32
19	-0.12

20	-0.39
21	-0.81
22	-0.61
23	-0.33
24	-0.14
25	-0.42
26	-0.91
Mean	-0.440

6. Conclusions

It is obvious from the CONSEC scores of dry ports shown in table 4 that the container security of public sector dry ports is much less satisfactory as compared to the private sector dry ports. This is especially so if a dry port is allowed to absolve itself of almost entire liability (including third party) for ensuring the correctness of the cargo particulars declared by the consignor. Such lacunae could be rectified as and when the Government of India ratifies the Rotterdam Rules (Rules) and saddles the dry port operator with the responsibilities and liabilities of a “performing party” as envisaged in the Rules.

The regulations of ISPS regime are appropriate to meet the requirements of the AEO. Having an ISPS status in principle is the same as having the AEO status. Some dry ports in Europe comply with the ISPS regulations and have accordingly been recognized to have the ISPS status. Thus it would be logical to state that it would be in the interest of the all the stakeholders to bring all dry ports within the purview of ISPS Code. Government of India is yet to prescribe the minimum standards of security a dry port operator is required to maintain. Lack of visible and certified security is resulting in poor patronage of dry ports and perhaps also in higher risk premiums paid to Insurance companies.

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Rethinking Basic Maritime Economic Theory: A Test of the Lower Bound of Spot Freight Rates in Bulk Shipping

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Abstract

Classic maritime economic theory suggests that the spot freight rate in bulk shipping is set in a perfectly competitive market and is governed by the level at which the marginal ship will leave the operational fleet through layup. However, in the very short run, rational shipowners will accept any offer that covers the marginal cost of performing an additional voyage, that is, voyage costs. We therefore postulate that because the spot rate process is by definition a result of a series of such immediate market equilibria, the lower bound of the spot freight rate process will always be governed by the voyage cost of the marginal employed vessel and not the layup trigger level. However, the lay-up decision will affect the spot rate process indirectly through adjusting the composition and maximum capacity of the fleet available for transportation at any point in time. The volume of the fleet in lay-up can thus best be interpreted as a “shadow orderbook” that can be delivered back into the active fleet. The objective of this paper is to test the empirical validity of our modified interpretation of maritime economic theory. We do this by recreating the historical daily market supply curve for the backhaul Asia/South Africa-to-Europe coal trade in the Capesize market, as defined by the voyage costs for all the vessels in the fleet. Our sample covers the period since May 1998 and includes the technical specifications (fuel consumption, service speed, DWT etc.) for the approximately 1,768 Capesize ships (100,000DWT+) that have been in existence since then.

The empirical results suggests that the spot freight rate never falls below the marginal cost of the most efficient ship in the fleet but can frequently fall below levels usually associated with the trigger level for layup. Moreover, the fleet has become increasingly homogeneous in terms of technical specifications, leading to a flattening of the market supply curve which, we argue, will result in a clearer clustering of volatility in time series of spot freight rates. Moreover, the spot freight rate has remained above the marginal cost level of the least efficient ships over 50% of the time, leaving classical economic theory largely unable to explain its dynamics. We also show empirically how fleet efficiency has increased over time by removing the volatile bunkers price component and focusing on the effects of changes in technology.

Keywords: spot rates, bulk shipping, marginal cost

1. Introduction

The freight markets in bulk shipping are usually held as textbook examples of perfectly competitive markets (Norman, 1979; Stopford, 1997). The requirements for a perfectly competitive market are usually summarised as follows:

- **There is a large number of buyers and sellers**, each of insignificant size and with no opportunity to collude. This will tend to hold true in the bulk freight markets (drybulk and tankers) where there are a large number of independent shipowners and a large number of shippers.
- **Each producer offers a homogeneous product/service**. Aside from possible port restrictions on ship dimensions and age, all ships of a certain type and similar size range will provide a transportation service that is fungible (perfect substitution). There is very little scope for service differentiation.

- **All participants have perfect information** about all prices and transportation services on offer and can access this information at zero costs. With a well developed and active shipbroker network providing market information to their clients on an ongoing basis this will also tend to hold true in the major bulk freight markets.
- **Perfect freedom of entry and exit from the industry.** Firms face no sunk costs - entry and exit from the market is feasible in the long run. With generally liquid markets for the construction, demolition and second-hand sale of ships this requirement will also tend to hold true, though transaction costs do exist and the adjustment process where ships enter and exit the fleet will necessarily take some time.

In a perfectly competitive spot freight market, the freight rate is normally determined by the marginal cost of the marginal vessel required to satisfy the demand for transport. The short-term supply curve indicates the amount of transport willingly supplied by the fleet at a given freight rate. In the classic maritime economic literature, starting with Tinbergen (1934) and Koopmans (1939), the short-term supply curve in bulk shipping is characterised by two distinct regimes, distinguished by whether or not the fleet is fully employed. When all vessels in the fleet are employed, the only possibility to increase the supply of sea transport in the short term is through higher utilisation of the existing ships. This can be achieved through higher vessel speed, reduced port time, shorter ballast legs, or by delaying regular maintenance. However, this increase is limited by technical constraints and implies a higher marginal cost of operation due to higher fuel consumption and increased wear and tear. When the entire fleet sails at close to the maximum capacity, the aggregate supply function becomes almost perfectly inelastic with the result that demand rationing takes place through very high freight rates. Conversely, when the available supply exceeds demand, leading to lower freight rates and vessel unemployment, the least cost-efficient vessels will withdraw from the market, resulting in a series of perfectly elastic steps in the short-term supply function. Accordingly, Koopmans (1939) proposed a short-term supply curve that is very elastic when tonnage is unemployed (low freight rates) and very inelastic during periods with full employment (high freight rates). This characteristic shape has later been confirmed in several empirical works (Zannetos, 1966; Devanney, 1973; Norman and Wergeland, 1981).

In the classic literature, the ‘refusal rate’ below which the vessel no longer supplies transport is assumed to be its lay-up point, that is, the timecharter-equivalent (TCE) spot freight rate at which the shipowner is indifferent between lay-up and operation. As there are switching costs related to laying up the vessel, this threshold rate must be lower than the daily operating cost less the daily lay-up cost (Mossin, 1968; Dixit, 1989). For many such cost combinations it could be optimal to scrap a ship directly instead of laying it up even if the daily lay-up cost is significantly lower than the daily operating cost: see Dixit and Pindyck (1994). Koekebakker et al (2006) note that under certain conditions the threshold rate for exit (lay-up or scrapping) may even be negative, but it will be bounded from below because steadily more vessels will leave the market as demand turns down.

Consider next the functioning of the spot freight market in the very short run. As ships and cargoes are distributed unevenly around the globe and because ships move relatively slowly, the “momentary” spot freight market equilibrium is a geographical regional equilibrium. Here the demand for transport is given by the immediate transport requirements in a particular exporting region (say, the Arabian Gulf for crude oil or West Australia for iron ore). The supply of transportation is given by the number of vessels willing and capable of presenting for loading in this geographical region within a particular window of time (termed laydays). It is worth noting that the fixing of ships (that is, the negotiation and agreement to the charter party, the contract of carriage) will generally occur on a forward basis, often a few weeks prior to the desired shipment date. Moreover, how far forward fixing occurs can have a substantial impact on the freight rate agreed for the business, and the shape of this “term structure” of spot freight rates will depend on market conditions. However, for the purpose of spot freight rate reporting by bodies such as the Baltic Exchange, and consequently our empirical work, the period between fixing and shipment is assumed to be constant. As noted by Zannetos (1966), both shippers and shipowners have some leeway in when to fix, and this potential for inter-temporal substitution of supply and demand is likely to contribute to the observed positive autocorrelation in spot freight rate changes.

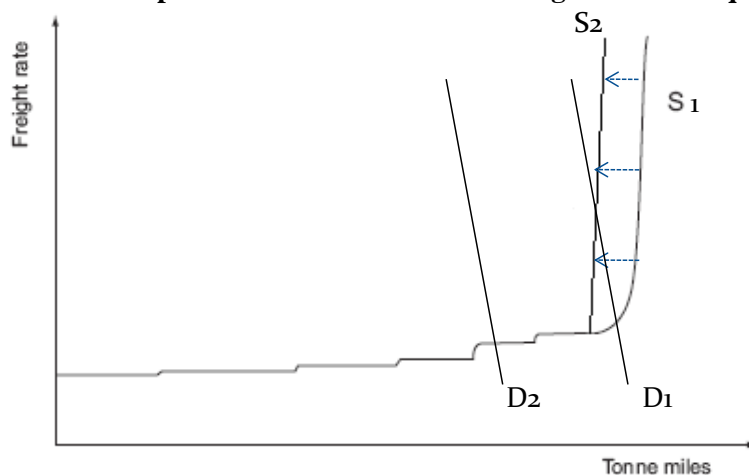
In the “momentary” spot freight market described above, the unit of production is a single voyage and, accordingly, the marginal cost is equal to the costs incurred by accepting the voyage: fuel costs, port and canal fees. Operating costs such as crew and insurance can be considered fixed or sunk as long as the vessel is maintained fully operational. Consequently, in a one-period setting, the choice every shipowner is faced with is binary: either idle the ship or accept the voyage. While there may be several voyages on offer from several shippers, the perfectly competitive nature of the market will ensure that there is only one “market rate”. As we will discuss at the end of the paper, the “one period” assumption is important because otherwise, as is likely the case in practice, the shipowner will also consider the destination of the ship and the likely impact this will have on the revenue of the vessel in the next period and so on. All told, economic theory tells us that a rational shipowner will accept to perform the additional voyage as long as all voyage costs are covered. In the very short run the spot freight rate is therefore set by the marginal cost (voyage costs) of the marginal vessel required for transportation. So far there is nothing new or controversial in our setup. However, let us add new twist to the interpretation of classical maritime economic theory with the hypothesis below:

Hypothesis:

Because all time horizons are by definition a sequence of momentary equilibria it is *always* the voyage cost of the marginal vessel that sets the spot freight rate. As a corollary it must also be the case that the lower bound of the spot freight rate process is equal to the voyage cost of the *most* cost efficient vessel.

If the above hypothesis holds then the impact of the layup decisions of owners (in aggregate) on the market freight rate is somewhat different than the classical short-run market equilibrium. Consider the supply and demand curves illustrated in Figure 1 below.

Figure 1: An Interpretation of the Short-Run Freight Market Equilibrium



Whereas classical maritime economic theory would state that, in the short run, the elastic part of the supply curve is determined by the layup trigger level we suggest that the only impact of layup is on the aggregate *capacity* of the *operational* fleet, effectively a horizontal shift of the inelastic part of the supply curve. If there is a net increase in the number of ships in layup, the supply curve shifts from S_1 to S_2 and vice versa in the case of a reduction in the laid-up fleet. The elastic part of the supply curve is always determined by the marginal cost (voyage cost). Consequently, whenever there is oversupply of operational ships (D_2), the layup decision has no bearing on the spot freight rate level irrespective of the time horizon. The laid up ships can be thought of as a “shadow orderbook” that can be redelivered into the operational fleet.

While there is no clear cut statistical test to accept or reject the above hypothesis we can at least provide supporting empirical evidence. Such evidence would take the form of:

- i) The observed spot freight rate on a particular route never declines below the marginal cost of the most efficient vessel; and

- ii) The spot freight rate remains below levels that would traditionally be associated with the layup trigger level for long periods of time (beyond the time required to put ships into layup – in the order of 2 – 3 weeks).

In the next section we proceed to recreate historical “momentary” market supply curves in an effort to assess empirically the validity of this modified interpretation of classical maritime economic theory. Our work is related to that of Adland and Strandenes (2007) who develop a discrete-time partial equilibrium model of the spot freight market for large tankers using the classical marginal cost argument for the supply function. However, their model considers the “short run” equilibrium with time steps equal to one month and it is assumed that the refusal rate is related to operating and layup cost levels, thus following the classical school of thought.

2. Empirical Methodology and Data

As the estimation of the marginal cost or voyage costs is route dependent we must first chose a particular vessel type and geographical trade. In principle any size bulk carrier or tanker can fit the bill but in this paper we focus primarily on the Capesize drybulk sector and the corresponding backhaul coal trade from South Africa (Richards Bay port) to Europe (Rotterdam), also known as the Baltic Capesize index Route 4 or C4 for short. By limiting the analysis to a particular size segment, in this case all bulk carriers above 100,000 DWT, we consider only the partial equilibrium case where it is implicitly assumed that other (smaller) sizes not compete on the same trade. The degree of integration between the freight markets for different vessel sizes has been investigated in the literature but empirical results are limited to the tanker markets (see, for instance, Strandenes, 1981, and Glen, 1990). Glen suggests that the tanker business became segmented during the 1970s. He argues that the large spread in vessel size implies that several vessel classes are no longer substitutable between routes due to draft restrictions in ports and canals. On the other hand, Strandenes (1981), using data from the 1960s and 1970s, argues that changes in the supply/demand balance in one subsector will ripple through to the other subsectors and that the freight market is integrated. However, because Capesize vessels enjoy economies of scale – they are generally twice as large as the next size down, the Panamax vessel – their marginal cost level will be lower. Consequently, while competition from smaller vessels is important in a strong freight market, as it effectively sets a (momentary) ceiling to the spot freight rate at the level where other vessels can compete, our analysis concerns only weak market conditions, where the spot freight rate is set by the marginal cost¹.

It is also a well known result in the literature (see, for instance, Kavoussanos, 1996) that the freight rates of larger vessels exhibit greater volatility and more pronounced peaks and troughs than the smaller sizes. As our goal is to assess how spot freight rates behave in relation to the marginal cost of transportation, in particular their lower bound, it is necessary to investigate a market that can experience truly depressed spot freight rate levels and the Capesize market fits this requirement better than the smaller ship sizes.

Finally, it is worth noting why we chose the backhaul route as the primary subject of empirical investigation. The freight market for Capesize drybulk tonnage can broadly be divided into four main long-haul trips: trans-Pacific, trans-Atlantic, Fronthaul and Backhaul. A vessel chartered on a fronthaul voyage in this context would ballast from Europe, pick up a cargo in the Americas and sail fully loaded to North-East Asia. A backhaul trip would entail ballasting from North-East Asia, picking up a cargo in Australia or, more commonly, South Africa, and proceed fully loaded to Europe. As the cargo volume on the fronthaul trade is much greater than on the return trip, and because the Atlantic is therefore generally seen as a more desirable destination, spot freight rates on the backhaul voyage will nearly always² be the lowest of the four main trades on a comparable TCE basis. It follows that for our purpose, where the goal is to investigate behaviour near the marginal cost levels, the backhaul spot voyage rate will be the appropriate starting point.

¹ The only case where the partial equilibrium assumption would produce erroneous results is where the most efficient Panamax vessel has a lower marginal cost than the least efficient Capesize vessel. This might occur early in the sample when some turbine-driven combination carriers existed in the Capesize fleet.

² In our 14 year sample, the backhaul rate is the lowest of the four tripcharter rates about 92% of the time.

In order to estimate the market supply curves for this particular voyage, consider the standard calculation of the TCE spot freight rate in Equation 1 below.

$$TCE = \frac{U \cdot DWT \cdot R \cdot (1 - C) - FC - PC}{T} \quad (1)$$

where

U	is the cargo load factor
DWT	is the design deadweight of the vessel [tonnes]
R	is the spot freight rate on a voyage basis [\$/tonne]
C	is the broker commission [3.5%]
FC	is the fuel cost for the trip
PC	is the total port and canal costs for the trip
T	is the total trip duration (including ballast, port and loaded days)

We are looking for the point where, for each ship, the spot freight rate equals the voyage costs on a \$/tonne basis. This is tantamount to saying that the $TCE = 0$. Rearranging Equation 1 we get the following equation for the marginal cost:

$$R_0 = \frac{FC + PC}{U \cdot DWT \cdot (1 - C)} \quad (2)$$

It is worth noting that trip duration is still present in the equation within the fuel cost calculation ($FC = \text{sailing days} \cdot \text{fuel consumption/day}$). We ignore bunkers consumed in port and further assume that consumption in the loaded and ballast conditions are both equal to the stated consumption at the design draft. The calculation in Equation 1 is made for each ship that existed in the fleet on every working day at the prevailing bunker price to generate a daily market supply curve.

For the sake of simplicity we have made a fair number of strong assumptions in the empirical estimations of Equation 2. Firstly, we assume that the vessels always sail at 95% of their design speed, that is, we allow for a constant sea margin of 5%. In reality, the combination of low freight rates and high fuel prices should rationally result in vessels “slow steaming” to save on fuel costs, in particular in the ballast condition if the vessel is unfixed. Dynamic vessel speed optimisation played an important role in the early supply/demand models of the shipping markets (Norman and Wergeland, 1981; Strandenes, 1986; Beenstock and Vergottis, 1989) as the fleet of large tankers at the time was primarily turbine driven and fuel inefficient with a wide technical range of operating speed. However, this is believed to be less important today both because modern diesel engines have a narrower technical margin of speed adjustment and because, in practice, weather conditions and charter party clauses will often determine the choice of speed. Secondly we assume a constant load factor of 90% (i.e. the cargo intake is always 90% of a ship’s deadweight). In reality we can expect the load factor to be positively correlated with freight market conditions as logistics are more carefully optimised when sea transport is costly. Moreover, “non-standard” sizes or very large vessels may operate with a lower-than-average load factor as end users may prefer a particular range of cargo sizes, or it may be that draft restrictions in the destination port decides the utilisation of the ships deadweight. A 90% load factor is toward the lower end of what we can observe in practice but it is a level commonly seen in low freight market conditions which is the target of this paper. Thirdly, we do not adjust the active fleet for ships in layup as we lack historical detailed data and, fourthly, we assume that port costs are constant over the sample period. The latter is clearly not realistic but follows from the lack of historical data. What we can say is that the port costs are orders of magnitude smaller, and substantially less volatile, than the fuel cost component. Changes in port costs over time are generally a result of local inflation rates, currency exchange rates versus the US\$ and changes in port policy.

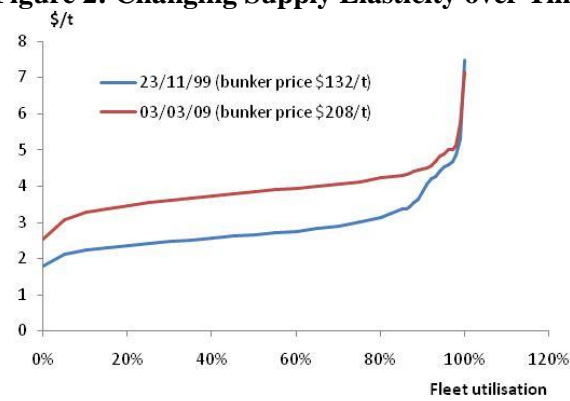
We consider all working days for which a daily spot freight rate quotation exists for the backhaul route described above, resulting in a sample period from 6 May 1998 through 15 March 2012 equivalent to 3,471 observations. Spot freight rate data are provided by the Baltic Exchange. Daily fuel prices for 380cst Heavy Fuel Oil delivered in Rotterdam are provided by Platts/Bloomberg for the same sample period. Port costs for

Rotterdam and Richards Bay for a standard Cape (172,000DWT) valid as of November 2009 were provided by AXS Marine. Finally, the relevant technical specifications (DWT, service speed and fuel consumption) for each of the 1,768 Capesize vessels in existence between June 1985 and January 2012 come from Clarkson Research. The date on which the vessel entered or permanently left the Capesize fleet is provided by Clarkson Research or Equasis.org, whichever is more specific (day as opposed to month).

3. Results and Discussion

The fleet of vessels generally exhibit positive growth rates and supply is commonly measured by the total DWT of all ships. In order to more easily compare market supply curves over time we here denominate the x-axis of the supply function by fleet utilization, or the % of the fleet that will offer sea transport on the route at any given spot freight rate. Figures 2 below shows a snapshot of the estimated market supply curves on 23 Nov 1999 and 3 Mar 2009 respectively. As the cost of fuel has risen almost continuously throughout the sample these dates were chosen to reflect a similar bunker price in the early and later part.

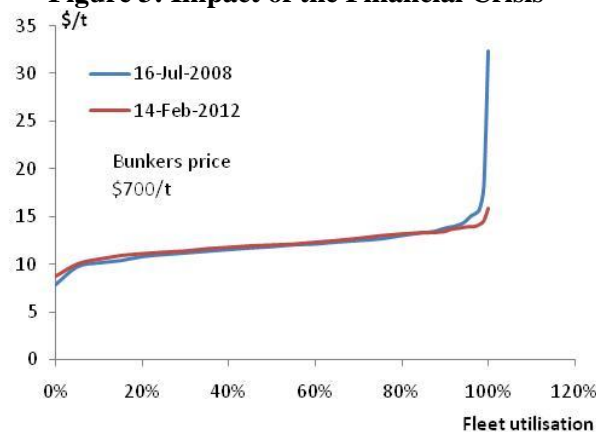
Figure 2: Changing Supply Elasticity over Time



The supply function conforms to the characteristic shape proposed by Koopmans (1939) and subsequent empirical works (Zannetos, 1966; Devanney, 1973; Norman and Wergeland, 1981). Note that the shape of the curves is broadly similar except for the 20% least efficient vessels where the curve was substantially less elastic in the late 1990s. In the above graph it is assumed that all Capesizes are available to trade on the chosen route on any given day. In practice, the loading port Richards Bay does not accept vessels larger than about 220,000 DWT and, moreover, only a small subset of the world fleet will be available for fixing on the backhaul as the fleet is necessarily geographically distributed around the world with certain routes such as the trans-Pacific trade requiring a greater number of vessels.

The impact of changing vessel specifications is even more pronounced if we consider the relatively short time span since the onset of the 2008/09 financial crisis in Figure 3 below. Here the fuel price is identical on the two dates and so any differences are due to the changing mix of vessels in the fleet.

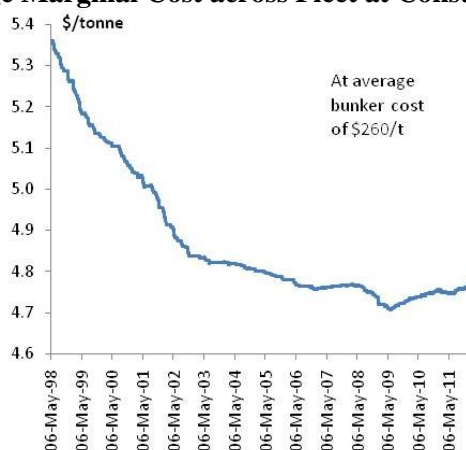
Figure 3: Impact of the Financial Crisis



The combination of low spot freight rates and high fuel costs during this time period has clearly sent many of the high fuel-consumption vessels to the breakers. In addition there were record deliveries of new efficient vessels with very similar specifications. Consequently the market supply function has flattened substantially and is now very elastic until very close to capacity. This has at least two important implications for the behaviour of future spot freight rates. Firstly, as long as oversupply persists there is now much less scope for future increases in the spot freight rate as the marginal cost of the least efficient vessel has dropped by half from above \$30/tonne to only around \$15/tonne at a bunker cost of \$700/tonne. Secondly, for the same reason and assuming the volatility of demand does not change, the volatility of spot freight rates must also be lower going forward.

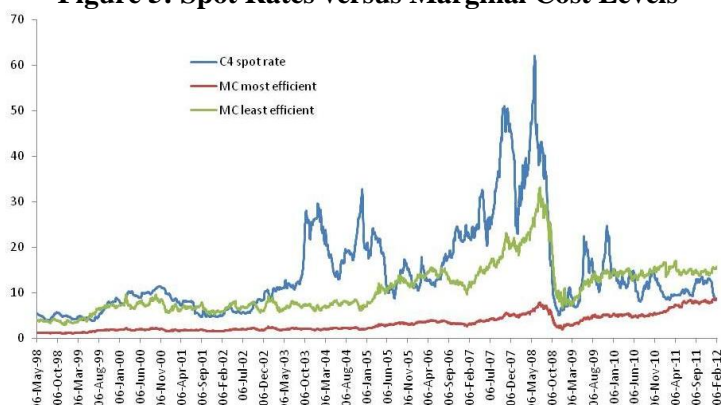
As an aside we can use the same methodology to measure the change in cost efficiency over time as one measure of productivity. If we keep the fuel price constant and equal to the sample average of \$260/tonne we can map the change in the marginal cost over time due to technological innovation only. Figure 4 below shows the change in the *average* marginal cost across the fleet over time. The average gain in cost efficiency has been relatively modest with the average MC falling by 1% p.a. in the past 14 years, with no apparent gains in the past five years. However, gains have been more pronounced if we consider only the least efficient vessels (99th percentile, not shown here), falling by 37% over the same period. Overall, the ten-fold increase in bunker prices has more than offsets these cost efficiency gains, leading to inflation in the underlying trend of the spot freight rate on a \$/tonne basis.

Figure 4: Average Marginal Cost across Fleet at Constant Bunker Price



Finally, Figure 5 below shows the historical spot freight rate and the estimated time series of the marginal cost for the most and least efficient vessels. We see that the marginal cost of the most efficient vessel does indeed act as a lower bound of the spot freight rate. However, the spot freight rate has been higher than the marginal cost of the least efficient vessel about 54% of the time, leaving the traditional supply/demand model unable to explain freight rate dynamics during a large part of the sample. Nevertheless, about 50% of the record-high spot freight rates seen in 2008 can actually be ascribed to the corresponding increase in fuel costs.

Figure 5: Spot Rates versus Marginal Cost Levels



Note that we have here limited the sample of ships to those that will actually call at Richards Bay on a regular basis, i.e. with DWT between 120,000 DWT and 220,000 DWT.

4. Discussion and Suggestions for Future Research

The two most recent years of data in particular in Figure 5 illustrate how spot freight rates fall down to levels associated with covering only voyage costs for the majority of the fleet and for prolonged period of time, seemingly supporting our thesis in this paper. In the final days of the sample only a handful of ships would even cover voyage costs and the majority would have negative TCE spot earnings if they were to fix at the prevailing voyage rates— shipowners would effectively pay charterers to use their ships. In a one period setting this would not be rational behaviour as long as alternatives with positive or zero TCE exists (merely idling the ship). Nevertheless, press reports at the time (Tradewinds, 2012) confirmed that ships were fixed on the backhaul route with substantially negative TCE rates. It is worth noting that our theoretical model is still not violated as long as the marginal cost of the most efficient ship remains a lower bound. However, theory cannot explain why also less efficient vessels would fix at these rates. We can think of at least two reasons in practice: (i) the ship is bound to reposition as a certain place of delivery is stipulated in the charter party and so any contribution towards voyage costs, even if not paid in full, will be acceptable and (ii) ship operation is a multiperiod problem where owners will also consider the revenue of subsequent voyages, not only the negative earnings from the backhaul voyage.

There is also the possibility that the traditional backhaul trades are increasingly irrelevant for price formation in the broader spot freight markets. The trend over the past decade has been declining volumes of coal from Australia and South Africa into the European markets as the growth in energy consumption in China and India has outpaced that in the West. Consequently, very few Capesizes sailing from the Pacific to the Atlantic Ocean will actually be able to obtain a paying cargo and the vast majority will ballast back. A more relevant trade is therefore the China – Brazil return voyage and, although not shown here due to limited space, we achieve similar results. Notably, at market lows only 40 – 60% of the fleet cover voyage costs.

A sequel of this paper should probably relax some of the simplifying assumptions we have made, in particular by introducing market dependent load factors and vessel speeds. Allowing for slower speeds and the corresponding sharp reduction in fuel consumption may substantially lower the marginal cost levels. However, this would require micro analysis of trade patterns and detailed empirical fleet tracking; a substantial effort in itself.

In general, there are a number of important questions raised by this simple exercise in market supply functions that serve as potential topics for future research. Firstly, why is layup such a rare occurrence despite the importance placed on it in classical maritime economics? Is it a result of being an unstable equilibrium from a game theoretical approach - “It will only benefit my competitors so let’s all be worse off”? Perhaps it is rational behaviour if the option value of idling an operational ship is properly accounted for, or perhaps the dynamics of spot rates are such that the trigger level for layup is actually below the marginal cost, giving rise to the observed negative spot earnings. Secondly, if the classical supply/demand model can only explain spot freight rates less than half the time (when rates are low) then what model does maritime economics have for the remainder?

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Container Ship Emissions in World Ports: A Comparative Overview

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Abstract

The share of shipping in global air pollutant emissions is approximately 3% of total emissions, and projected to increase dramatically over the next decades. The places most directly impacted by these emissions are ports and port-cities. There is a handful of studies that have assessed ship emissions in a particular port. To our knowledge, there are only two studies that have calculated the total in-port shipping emissions, but no studies in which the shipping emissions in port areas are compared. This paper fills this gap: it will estimate selected air pollutant emissions from container ships in a set of 571 ports world-wide. This will be done through a bottom up approach, using detailed vessel data from May 2011, which include exact indications of the time each vessel stayed in each port. This element of the calculation of shipping emissions has so far been based on assumptions or inexact information. Our calculations indicate container ship emissions in ports in the order of 1,401 tonnes of PM₁₀, 18,061 tonnes of NO_x and 13,638 tonnes of SO₂. The distribution of these emissions amongst ports is very skewed, with almost half of the container ship emissions taking place in only 25 ports. Approximately 65% of pollutants are emitted in Asian and European ports, which is relatively limited considering that 71% of the port calls took place in these areas. Ports in North America, Africa and Oceania have relatively more emissions per port traffic.

Keywords: shipping emissions, port emissions, container ports, air pollution, port-cities

1. Introduction

The emissions from shipping are substantial; e.g. shipping-related carbon dioxide emissions were estimated to be 3.3% of global emissions in 2007, but are expected to increase with a factor 2 to 3 up till 2050 (IMO, 2009). Although most of these emissions take place at sea, the most directly noticeable part of shipping emissions takes place in port areas and port-cities. Dalsøren et al. (2009) estimate that emissions due to ships' activities around or in ports account for 5% of total emissions from navigation activities. However, relatively little is known about ship emissions in ports. This paper wants to fill this gap, by looking at emissions of container ships in ports, which represents an important and growing part of shipping. It focuses on PM₁₀, NO_x and SO₂ emissions, as these might be considered particularly important environmental impacts in port-cities considering their impact on human health at high concentrations (Saxe and Larsen, 2004).

2. Literature Review

There are two types of literature that have looked at ship emissions in ports. First, there is a fair number of case studies of ports and port-cities that calculate the shipping-related emissions on the area. These studies are available for places like Piraeus, Los Angeles, Kaohsiung, Venice, Ambarli, Mumbai, Barcelona, Victoria, BC, as well as selected Belgian and Danish ports (Saxe and Larsen 2004; De Meyer et al. 2008; Joseph et al. 2009; Deniz and Kilic 2009; Healy et al. 2009; Tzannatos 2010a; Tzannatos 2010b; Matthias et al. 2010; Tzannatos 2011, Starcrest Consulting 2011, Villalba et al. 2011; Contini et al. 2011; Poplawski et al. 2011; Berechman and Tseng 2012). Their findings, methodologies and subjects of studies are diverse, so the outcomes of these studies are difficult to compare with each other (Mueller et al. 2011). Secondly, there is a limited number of studies on global shipping emissions which contain estimations on the in-port emissions, that is ship emissions in ports. The two examples of these studies are Entec 2002 and Dalsøren et al. 2008. The Entec-study estimates emissions from ships associated with movements between ports in European countries; as they assign ship emissions to 50 km by 50 km grid squares the ship-related emissions in port areas are made visible.

The paper of Dalsøren et al. uses an approximation of port time to calculate the in-port shipping emissions, but does not give details on individual ports, except for Singapore. Although these studies certainly have their merits with regards to calculation of ship emissions in ports, they both suffer from relatively inexact data or assumptions on the time that ships spent in a port. The Entec study uses port time data based on a questionnaire survey of ports; and although the Dalsøren et al. paper is more accurate in that it takes actual time in ports, it cannot be very precise because the dataset measures port time in days and not in hours, let alone minutes.

The approach in this paper is to provide a comparative overview of container ship emissions in ports. This makes it possible to compare the different emissions in port-cities and go beyond the incidental case studies whose value are difficult to compare to each other. At the same time, it also refines the literature on global shipping emissions in ports by using a more precise dataset on time spent in ports.

3. Methodology

Several methodologies have been used to estimate emissions from shipping, which can basically be summarized in four models, depending on whether emission evaluation is top-down or bottom up, and whether the geographical characterisation of emissions is top-down or bottom-up (Miola and Ciuffo, 2011). In a full top-down approach, total emissions are calculated without considering the vessel characteristics and are after the calculation geographically located and assigned to the different ships. The first studies on ship emissions took this approach and used international marine fuel usage statistics to estimate ship emissions, but results from this approach were later considered to be unreliable. In the second approach, a full bottom up approach, air pollutants emitted by a ship in a specific position are calculated; aggregating these estimates over time and over the fleet gives an estimation of the total emissions. This approach can be considered much more reliable, but the data required for such an approach have only recently come available, so for the moment there is a limited amount of studies using this approach. As a result, a considerable amount of studies take approaches that are more hybrid. There is a model that is bottom up in the evaluations of total emissions and top down in their geographical characterisation. In this approach, the aggregation of the emissions produced by all the ships gives an estimate of the total emissions; the emissions are then geographically characterised based on assumptions, e.g. ship activities or single geographic cells. The fourth approach is top down in the evaluation of total emissions plus bottom up in the geographic characterisation. In this approach the global activity carried out within a single maritime route or a single geographic cell is evaluated. Emissions from individual cells are aggregated to calculate total emissions and assumptions are made in order to assign total emissions to the different ships.

Our approach here is to use a bottom up-approach with respect to both ship characteristics (horsepower of the engines) and geographical characterisation, that is: the actual time spent in ports (in hours and minutes) by all container vessels. Following Joseph et al. (2009), the following equation is used to estimate shipping-related emissions at ports:

$$E = P * LF * EF * T$$

Where:

E	emissions in units of pollutant
P	maximum power output of auxiliary engine in kW
LF	load factor for auxiliary engines, as a fraction of maximum installed power capacity
EF	emission factor (pollutant specific) in mass emitted per work output of the auxiliary engine in hotelling mode, g/kWh and
T	time in hotelling mode in hours

The principle behind this equation is to apply emission factors to activity rates, as generally the case when estimating emissions. The activity rate of the individual vessels in our database is estimated using rules of thumb indicated and explained below. Ships use auxiliary power whilst being at berth. The maximum power of auxiliary engines in container vessel is estimated based on auxiliary engine power ratios and an estimation of a vessel's main engine horsepower as a function of dead weight tonnage. The auxiliary to main engine

power ratio is assumed to be 0.220 for container vessels, and the estimation of main engine horsepower for container vessel is assumed to follow the equation $(0.80 \cdot \text{dwt} - 749.4)$, based on EPA (2000). The total deadweight tonnage of each vessel in the database is known. The load factor for auxiliary engines in hotelling modes is based on Starcrest Consulting (2004) and considered to be 17% for container vessels. The emission factors for PM_{10} , SO_2 and NO_x for container vessels in hotelling mode are based on ICT (2006) and as follows: 1.14 g/kWh (PM_{10}), 14.7 g/kWh (NO_x), 11.1 g/kWh (SO_2). Note that manoeuvring by vessels in the port is not incorporated in this calculation, so there will be a certain underestimation of shipping-related emissions in ports.¹

4. Dataset

The data used are vessel movements of fully cellular container ships world wide, as collected by Lloyd's Maritime Intelligence Unit (LMIU) for May 2011. This month is considered to be a representative month by Lloyd's Maritime Intelligence Unit. Of the total of 45,075 port calls of 4756 container vessels (larger than 100 gt) some observations were excluded because of missing arrival and departure data and some observations are excluded because they were considered to be extreme values that would skew the results; these are the vessel calls with a stay in one port of more than 10 days. What resulted was a database with 40,458 port calls (in 571 ports), of which 37,707 have precise arrival and departure time in hours and minutes. In order to derive the total time that vessels stayed in a specific port, some less precise measurements (in days, not in hours and minutes) were incorporated for ports with missing values. This is necessary, because for some ports only a very limited set of precise time observations was available, so taking exclusively these and extrapolate these would risk to be inaccurate. For these missing values, it is assumed that the port time for vessels arriving and leaving the same day is 12 hours, leaving the next day is equivalent to 36 hours, with a port stay of 2 days equivalent to 50 hours etc.

5. Results

The total container ship emissions in ports amounted to 1,401 tonnes of PM_{10} , 18,061 tonnes of NO_x and 13,638 tonnes SO_2 in May 2011. If one accepts the assumption that this month is a representative month, the yearly emissions in ports related to container shipping would add up to 17 ktonnes of PM_{10} , 217 ktonnes of NO_x and 164 ktonnes of SO_2 . These calculations make it also possible to rank the ports with highest shipping-related emissions of PM_{10} , NO_x and SO_2 . The 25 ports with highest emissions are indicated in figures 1 and 2, with first positions for Singapore, Hong Kong and Shanghai. In the port of Singapore, the PM_{10} -emissions in May 2011 represented 79 tonnes, the NO_x -emissions 1,023 tonnes and the SO_2 -emissions 772 tonnes, approximately 5.6% of total container ship emissions in ports world wide. Due to the calculation method, the distribution of the different pollutants over port-cities follows a similar pattern (the top 25 ports for PM_{10} -emissions are the same as the top 25 for NO_x and SO_2). As we are most interested in this distribution in port areas, we will in the rest of this paper focus on PM_{10} -emissions, well aware that similar distributions are in place for NO_x and SO_2 .

Figure 1: The 25 Ports with Largest Absolute PM_{10} -Emissions (Tonnes)

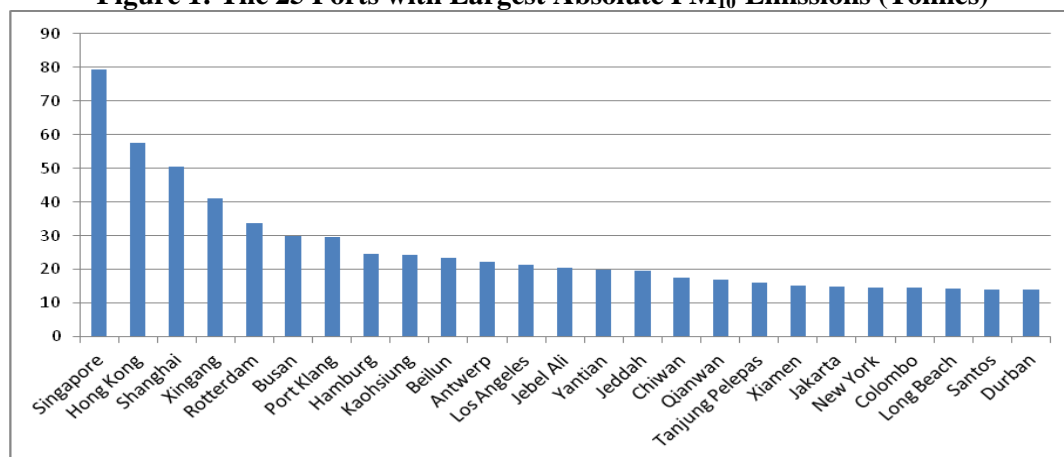
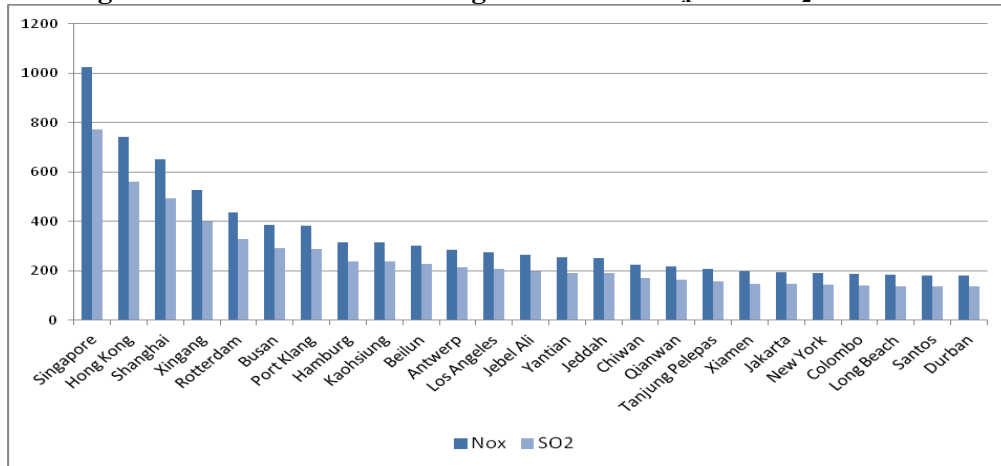


Figure 2: The 25 Ports with Largest Absolute No_x- and SO₂-Emissions



The distribution of emissions of the different ports world wide follows a power-law distribution (figure 3). The 25 largest ports account for around 46.4% of the emissions, whereas the emissions in the second half of the ports only represent 1.8% of the total container ship emissions in ports. The container ship emissions in ports are closely correlated (R^2 value of 0.83) with shipping activity as measured by the number of port calls by container ships: ports with higher number of calls generally have higher ship emissions in the port (figure 4). Similarly, the container ship emissions in ports are also highly correlated to container throughput, as measured in TEUs: the correlation index for the largest European ports is 0.74 (figure 5). For this purpose, TEU throughput-data of Eurostat for the second quarter of 2011 were taken in order to align as closely as possible to the May 2011 data from LMIU.

Figure 3: Distribution of PM₁₀-Emissions in 200 Ports with Largest Emissions

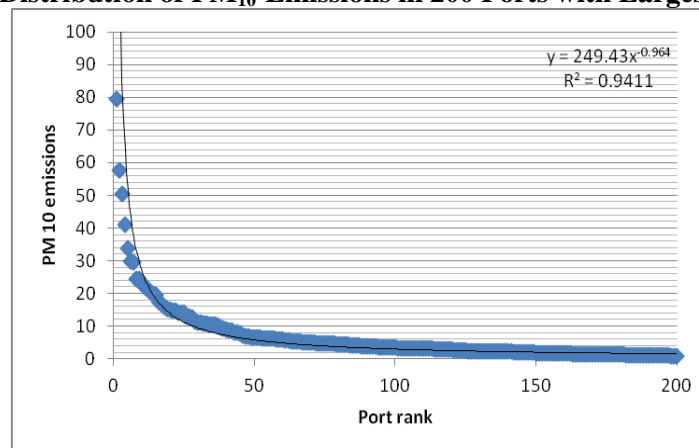


Figure 4: Relation between Container Ship Emissions in the Port and Traffic Size (Port Calls)

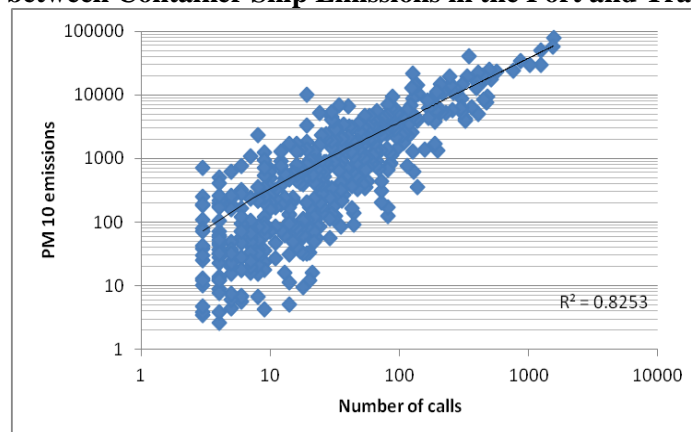
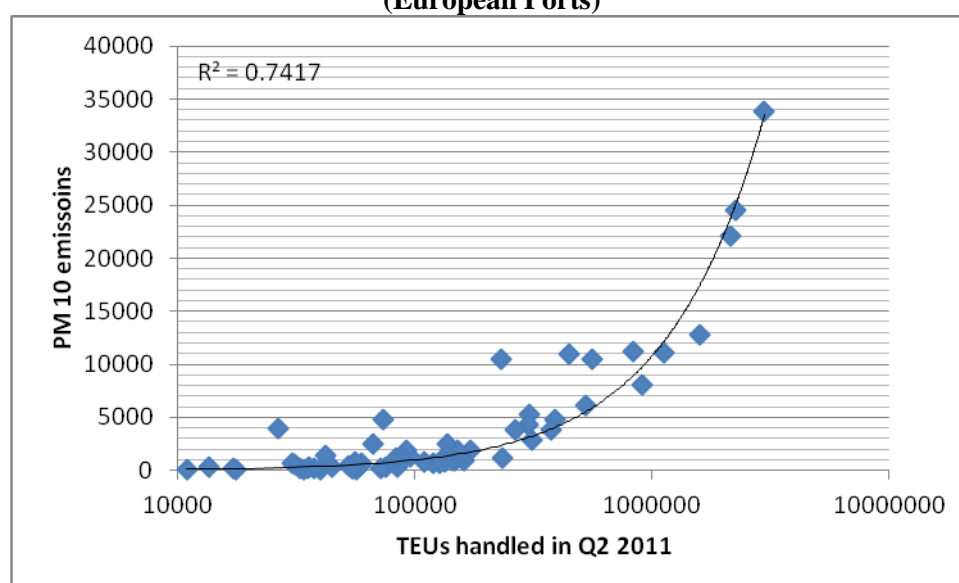


Figure 5: Relation between Container Ship Emissions in the Port and Container Throughput (European Ports)



It is not only possible to calculate the absolute shipping-related port emissions, but also the relative rankings of ports on this. In this article, the relative position is expressed in two different ways: as emissions per call and as emissions per ship volume calling the port. The first measures the average emissions per ship calling the port; the second measure incorporates the volume of the ship calling the port. As large vessels will generally take longer to load or unload one would expect ship emissions to be higher in these cases. Ports that manage to load or unload faster will have lower emissions per ship volume.

The ports with the largest relative container ship emissions in the port are Mombasa (Kenya), Tin Can Island (Nigeria) and Xingang (China). These are the ports with high relative emissions using both definitions: per call and per volume. The port with highest emissions per call is Ngqura in South Africa (with an average of almost 200 kg) (figure 6) and the port with highest emissions per called volume is Kolkata in India (with a score of approximately 0.0075 kg per dwt) (figure 7). The ports with the lowest relative container ship emissions in the port are Japanese ports such as Hiroshima, Fushiki-Toyama, Shibushi and Brunsbuttel (Germany), which have low scores on both indicators (figure 8). The emission score of Hiroshima is around 1.5 kg per call and 0.00025 kg per dwt (figure 9). The two definitions of relative port emissions are to some extent correlated, but the correlation-index is only 0.50 (figure 10).

Figure 6: The 25 Ports with Highest PM₁₀ Emissions (Kg) Per Port Call

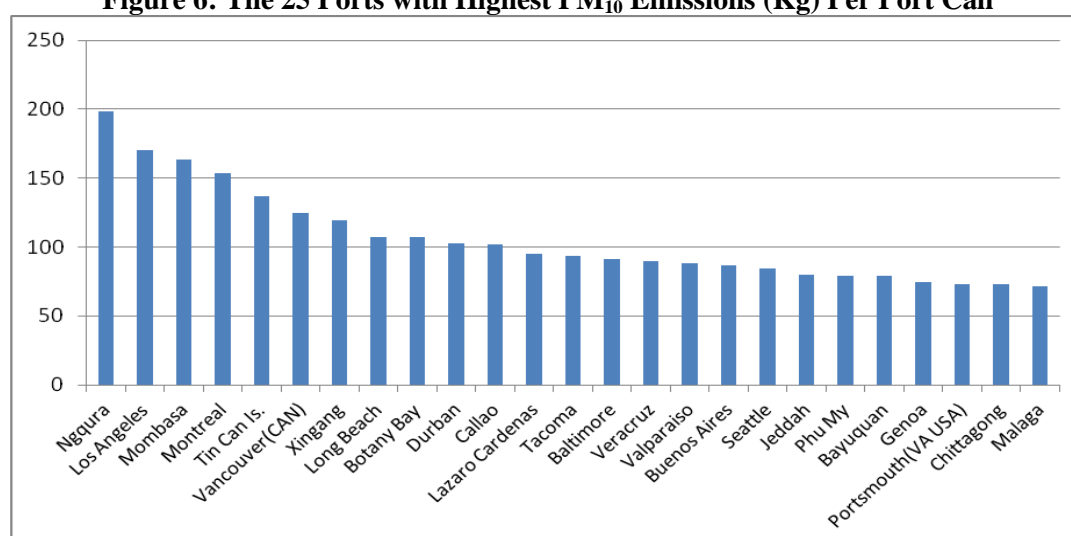


Figure 7: The 25 Ports with Lowest PM_{10} Emissions (Kg) Per Port Call

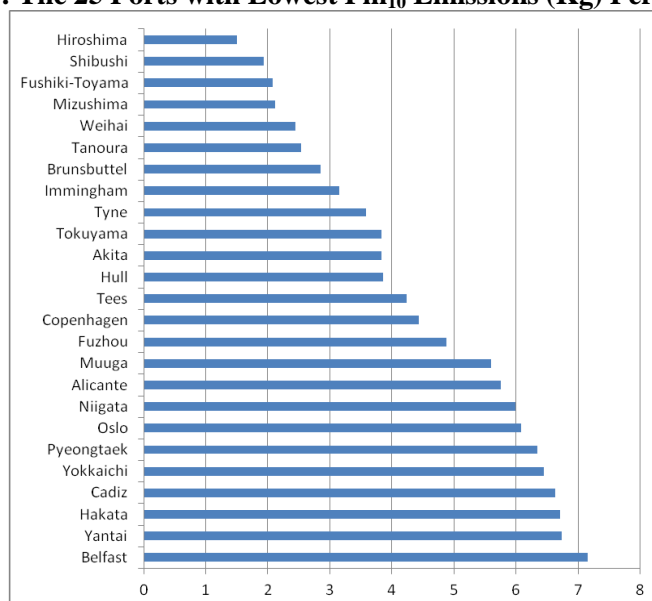


Figure 8: The 25 Ports with Lowest PM_{10} Emissions (kg) per dwt Calling the Port

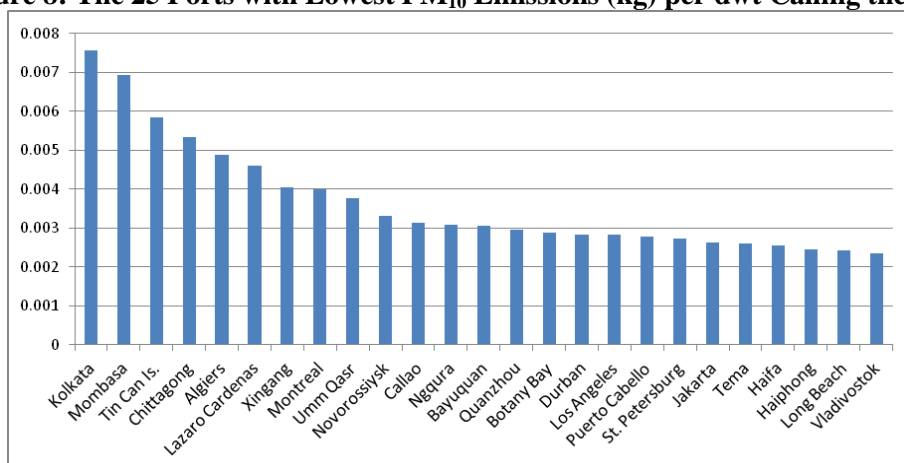


Figure 9: The 25 Ports with Lowest PM_{10} Emissions (kg) per dwt Calling the Port

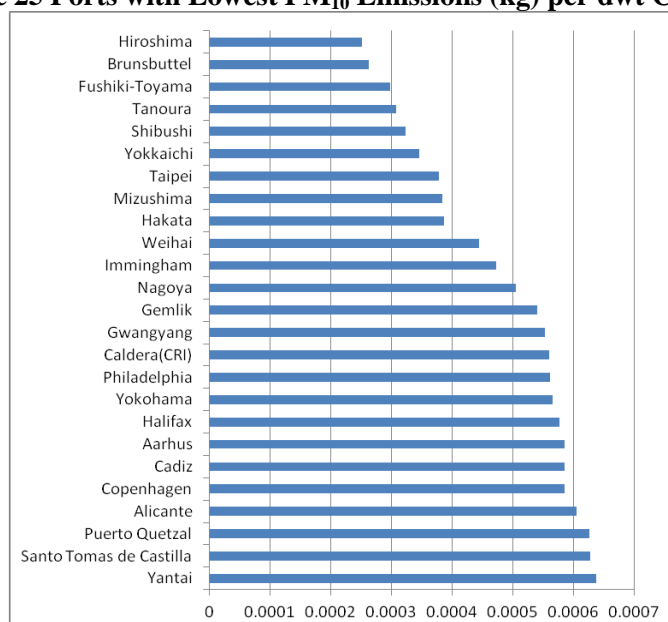
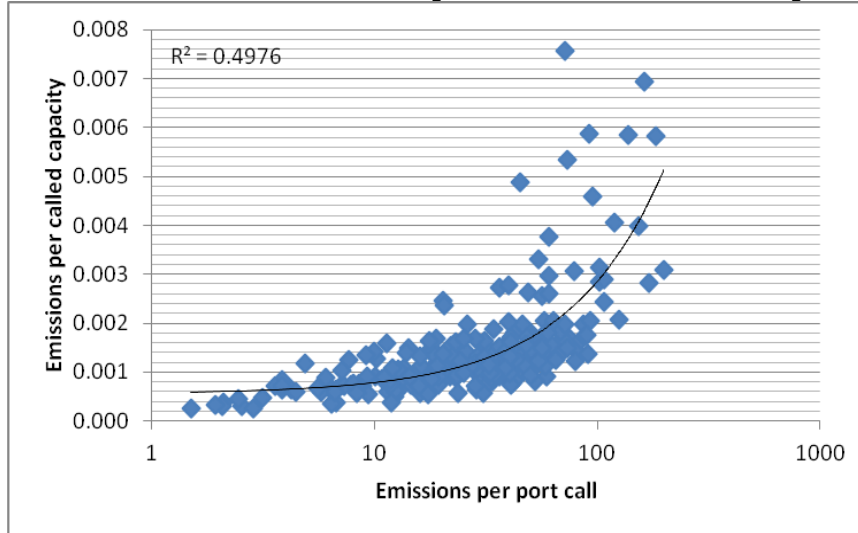


Figure 10: Relation between Emissions per Port Call and Emissions per Volume

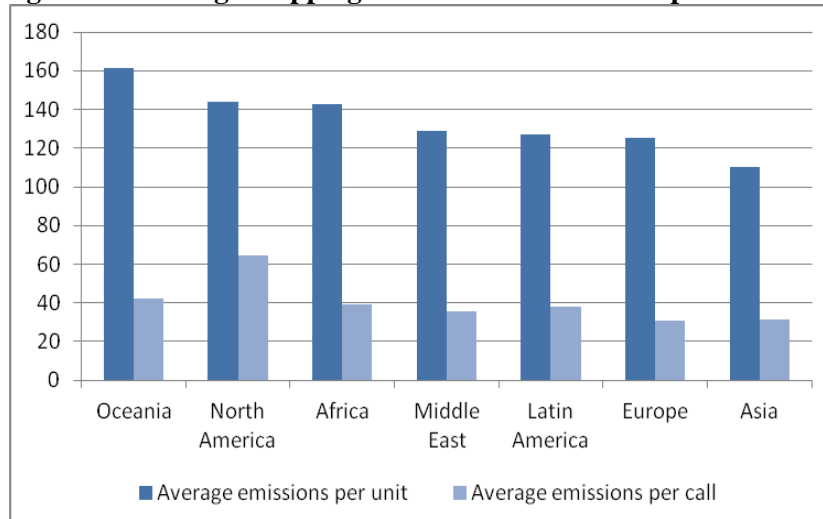


There are considerable geographical differences. Approximately 71% of container port calls are in Asian and European ports representing 69% of total vessel capacity, but only 65% of container ship emissions in ports is generated there; whereas North American ports have 4.9% of total calls, but 9.0% of the emissions (Table 1). This indicates the low relative emission levels in Asian and European ports, in contrast to high relative port emission in North America, as well as Oceania and Africa. The average emissions per call are 32 in Asian ports and 31 in European ports (for PM_{10}), against 64 in North American ports. With respect to average emissions per volume called, the score in Oceania is 0.00161 kg/dwt, in comparison with 0.00144 in North America, but only 0.00126 in Europe and 0.00011 in Asia (Figure 11).

Table 1: Distribution per Continent of Shipping-Related Port Emissions, Port Calls, Port Capacity and Port Time

	Emissions (%)	Port calls (%)	Total ship capacity (%)	Time in port (%)
Asia	46.5%	50.7%	51.0%	46.1%
Europe	18.3%	20.4%	17.6%	19.0%
Latin America	11.0%	10.0%	10.5%	9.8%
North America	9.0%	4.9%	7.6%	4.8%
Middle East	7.2%	7.1%	6.8%	8.5%
Africa	5.7%	5.0%	4.8%	9.5%
Oceania	2.2%	1.9%	1.7%	2.2%

Figure 11: Average Shipping-Related Port Emissions per Continent



The high relative emission levels have different explanations. The main explanation for ports in Oceania and Africa is relatively long port times, indicating limited time efficiency of ports in these continents: 5% of all port calls is in Africa, but 9.5% of the time spent in ports all over the world. A similar observation can be made about ports in the Middle East (7.1% of calls, 8.5% of port time) and Oceania (1.7% of calls, 2.2% of port time). Ports in North America do not appear to be time inefficient, but their main difference with the other ports is the high average ship capacity calling their ports: almost two thirds higher than the world wide average and much higher than any other continent (Table 2). Although this might be a paradoxical finding considering that the largest fleets are generally employed on Asian-European routes, it could be explained by the relatively marginal existence of short sea shipping in North America for which usually relatively small ships are used. In line with this, the relatively small average volume of container vessels calling European ports could be explained by the importance of short sea shipping on that continent. Finally, there are no economies (or diseconomies) of scale with regards to shipping-related port emissions. The correlation between emissions per volume (dwt) and total volume (dwt) calling the port is practically zero; both for world wide total and per continent.

Table 2: Average Volume of Container Vessel Calling Ports

	Average Volume of Vessels Calling the Port (dwt)	Average Number of Calls per Month (per port)	Average Port Time per Month (per port in days)
Asia	28,830	89.2	84.8
Europe	24,637	33.9	33.0
Latin America	29,971	33.0	33.6
North America	44,657	37.2	38.5
Middle East	27,506	40.8	51.6
Africa	27,457	24.3	48.0
Oceania	26,034	19.7	24.8
Total	28,677	48.0	50.2

6. Conclusions

This is the first study with a comparative overview of ship emissions in ports. In using a comprehensive database of vessel movements with detailed and precise data on arrival and departure times of vessels, as well as the volume for each vessel, we have been able to indicate the extent and distribution of emissions in port areas related to container shipping. This dataset will allow us in the future to extend the analysis to other ship types and deepen the analysis for certain regions in the world. This study has of course its limitations: we have applied certain assumptions that are insensitive to ship characteristics and design, as well as certain current practices such as fuel switches by container carriers, on shore power supply and exhaust filters in ports. At the same time, these limitations are not likely to have a large impact on the main findings of our analysis.

We have found that the container ship emissions in ports follow a very skewed distribution pattern, with almost half of the emissions originating from only 25 ports. This points to the concentration of air pollution in selected environmental hotspots, but also suggests that policy interventions with respect to environmental externalities, such as on shore power supply, would be most effective if focussed on these places. Although we did not find indications of economies or diseconomies of scale with regards to relative emissions, there were certainly geographical differences. The shipping-related emissions in Asian and European ports are large in absolute terms, but small in relative terms: they represent 71% of total port calls, and 69% of total vessel capacity calling, but only 65% of shipping-related emissions. The explanation for this is their favourable performance in time efficiency in Asia and Europe: shorter port times mean relatively lower emissions. In contrast, the ports in North America, Africa and Oceania have relatively high emissions. In the case of North American ports this is caused by a much larger vessel capacity calling the port, which might be caused by the relatively underdeveloped short sea shipping market in the US. In the case of African ports, the relatively high emissions are caused by unfavourable performance in time efficiency: vessels have longer port stays than on other continents, so the container ship emissions in port areas are larger. A relatively large literature on port efficiency has generated recommendations on how to improve this. Considering that most of the largest ports in the world are Asian or European ports, that is closer to the efficiency frontier, the opportunities of reducing

global shipping emissions in ports by improving port efficiency remains essential, but might actually have relatively limited impact.

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ⁱ Entec (2002) estimated manoeuvring time of container vessels to be 6.5% of the total time of in-port activities, based on port surveys. Manoeuvring requires more intensive use of auxiliary engines than hotelling.

A Hybrid Model for Short-term Prediction of Times Series Data: Forecasting Monthly Throughput for Hong Kong Port

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Abstract

Short-term demand prediction enjoys a critical position in the planning of business operation, especially in the logistics industry that needs to prepare sufficient capacity to satisfy the immediate future demand.

Conventionally, short-term prediction is done by *ad hoc* time series analysis, such as auto regressive moving average for stationary series, or auto regressive integrated moving average for nonstationary series. One of the underline assumptions in using the estimated coefficients from the time-series model for forecasting is that there are no structural change between the time for model estimation and that for prediction. If there are any new changes in the data generation process, it cannot be reflected in the prediction. In addition, most of the predictions are satisfied if the estimator is BLUE. If the underline assumption about data generation mechanism cannot be satisfied, the prediction accuracy cannot be guaranteed.

The Kalman filter is an efficient recursive filter that estimates the states of a linear dynamic system from a series of noisy observations. It has been used in a wide range of engineering and econometric applications. It takes the least square estimator of state vector from previous time step, uses the current observation to update the new estimator, and then use the updated estimator in forecasting step. With Kalman filter, more weight is being given to the estimates with lower uncertainty. Therefore, once the initial state of model is established, Kalman filter will provide better forecasting results based on the updated observation.

In this paper, we develop a hybrid method that integrates time series analysis with the Kalman filter, to increase the accuracy of the short-term prediction. The developed model is applied in the case study for monthly forecasts of container ports in Hong Kong. The result shows that the hybrid model can significantly increase the prediction accuracy.

Keywords: Hybrid algorithm; Kalman filter; Forecasting; Container throughput

1. Introduction

Hong Kong container port handled the most throughputs 23.7 million TEUs in Pearl River Delta (PRD) in 2010. This presents a challenge for the logistics companies in this region on how to use the limited resources to serve the huge demand for container transportation services in this region. In this regard, a timely and accurate forecast on the monthly throughput of a container port can provide valuable information for the decision makers in logistics industry.

Generally, container port throughput is subjected to the influence of many factors, such as the commodity price in the market, the currency exchange rate, the transportation cost change, geopolitical aspects, global business operation strategy, and market competitions among different ports as well as shipping companies' port choice decisions. There are many existing research that addresses the impact of these factors from different aspects using different approach. Many such studies are focused on the understanding the impact of shippers' behavior in port choice, port choice of liner shipping companies, port choice from the perspective of

supply chain, from transportation networks' perspective, or the result of port competition. Due to the high data requirement, these research are very useful in the long term strategic planning, but not for daily routine activity.

Time series approaches are often adopted to satisfy the data needs with short-time interval and high frequency (Sfetsos and Siriopoulos, 2005). It only needs to have a time series of a single variable to predict the future trends. Most of the time series approach use regression analysis to estimate the relationship between the present value of the variable and its past data using selected sample period, and forecast the future value using the present data. One of the critical requirements for these approaches is that the residuals are assumed to be stationary. Different econometric models are designed to achieve this property, which created a major issue because the underline economic process for generating the data may change gradually and without any notice, which can lead to the prediction error.

This article presents a hybrid approach that combines the traditional time series model with the Kalman filter (de Mol et al., 1999), to overcome the problems in time series analysis and prediction. This approach has been used by (Hu, Prokhorov and Wunsch II, 2007; Wu et al., 2008). The major advantage of this approach is that it always adds accuracy to the traditional time series forecast by recursively modifying the estimated coefficients of the underline time series model.

The rest of this paper is organized as follows. First, we introduce the background for container port development in HK, and the importance in accurate short-term prediction for container port throughput. In Section 2, the general description of the Kalman filter is given. Section 3 presents the forecasting framework of the proposed hybrid model and how the Kalman filter can help the forecast are explained. Section 4 uses the prediction of container port throughput in HK as a case study and compares the result of the hybrid model with the time series model. Section 5 concludes the paper.

2. General Description of the Kalman Filter

The Kalman filter is a method used to improve the prediction accuracy in a linear dynamic system (Mallick and Marrs, 2003) by recursively updating the system state with the newly observed data. A simple linear dynamic system with m state variables and n measurements can be described by the following two equations (Brown and Hwang, 2012).

$$\text{State equation: } \mathbf{x}_{t+1} = \mathbf{H}_t \mathbf{x}_t + \boldsymbol{\eta}_t \quad (1)$$

$$\text{measurement equation: } \mathbf{z}_t = \boldsymbol{\beta}_t \mathbf{x}_t + \boldsymbol{\gamma}_t, \quad (2)$$

Where \mathbf{x}_t is a $m \times 1$ state vector; \mathbf{H} is a $m \times m$ matrix relating \mathbf{x}_t to \mathbf{x}_{t+1} ; $\boldsymbol{\eta}_t$ is a $m \times 1$ state transition error vector; \mathbf{z}_t is a $n \times 1$ vector measurement at time t ; $\boldsymbol{\beta}_t$ is a $n \times m$ matrix specify the ideal connection between the measurement and the state vector, and $\boldsymbol{\gamma}_t$ is a $n \times 1$ measurement noise. Eq. 1 is also called transit equation, because it describes how the system state changes from one state to the next.

The state vector \mathbf{x}_t contains all the information about the present state of the system, but we cannot observe directly. Instead we observe \mathbf{z}_t , which is a function of \mathbf{x}_t and is corrupted by the noise $\boldsymbol{\gamma}_t$. We can use \mathbf{z}_t to estimate \mathbf{x}_t . The estimation of the state variable should satisfy two criteria. First, the expected value of the estimated state variable should equal to the expected value of the true state variable. Second, the estimated state variable should have minimal variance. The Kalman filter is the estimator that satisfies these two criteria (Wu et al., 2008).

The kalman filter assumes that the system variables follow Gaussian distribution, $\boldsymbol{\eta}_t$ and $\boldsymbol{\gamma}_t$ are independent normal distribution with zero-means and fixed variance, i.e., $\boldsymbol{\eta}_t: N(0, \mathbf{Q}_t)$, $\boldsymbol{\gamma}_t: N(0, \mathbf{R}_t)$.

Using the terms in linear regression analysis, Eq. 2 can be looked upon as the statistical equation that stipulates the relationship between dependent variable \mathbf{z}_t and the explanatory variable $\boldsymbol{\beta}$. If we have sufficient

sample size, the linear relationship can be estimated using regression, which is also called linear estimator. On top of the statistical equation, the Kalman filter adds another equation to allow for updating the linear estimator over time. One task in Kalman filter is to find the matrix \mathbf{H}_t that can produce a new estimator \mathbf{x}_{t+1} , which again can lead to a better forecast of \mathbf{z}_{t+1} .

3. A Hybrid Algorithm

3.1. Forecasting Framework

In this paper, we propose a forecasting framework that combines the ordinary least square model with the Kalman filter (hereinafter referred to as the hybrid model) to predicate container port throughput. The Kalman filter is used to improve the estimated parameters of the time series models of the container throughput, therefore the state of system consists of these parameters.

For a monthly time series data, such as the one for monthly container port throughput, one of the possible models is Autoregressive (AR) model:

$$y_t = \beta_0 + \beta_1 period_t + \varepsilon_t \quad (3)$$

$$e_t = \rho e_{t-12} + e_t \quad (4)$$

The y_t and x_t are observed data, β 's and ρ are the least-square coefficients to be estimated, ε_t is the error term, which is corrected with the error term of the same month of previous year, and e_t is the random error with normal distribution with zero mean and variance σ^2 . This model can be expressed as:

$$y_t = \beta_0(1 - \rho) + \beta_1(period_t - \rho period_{t-12}) + \rho y_{t-12} + e_t \quad (5)$$

In order to apply the general expression of autoregressive model in the linear system, Eq. 5 can be expressed as below:

$$y_t = \beta_0(1 - \rho) + \beta_1 period_t - \beta_1 \rho period_{t-12} + \rho y_{t-12} + e_t \quad (6)$$

Which can be rewritten according to the format of the measurement equation (Eq. 2) where $\mathbf{z}_t = y_t$, $\mathbf{x}_t = [\beta_0(1 - \rho) \ \beta_1 \ \beta_1 \rho \ \rho]'$, $\mathbf{\beta} = [1 \ period_t \ period_{t-12} \ y_{t-12}]$, and $\gamma_t = e_t$. This measurement equation describes the relationship between the measurement and the state using the term of Kalman filter, while the state vector actually contains the parameters to be estimated in AR model. Unlike in AR model where these parameters are assumed to be static, in the Kalman filter the state vector is dynamic and changes according to the transition equation (Eq. 1). How the state vector is updated in Kalman filter will be explained next.

3.2. Kalman Filter Process

In the above state-space formulation, the true value of the state vector \mathbf{x}_t is unknown, and the purpose of Kalman filter is to minimize the variance of the estimated with the true one. Suppose \mathbf{a}_t is the *a posteriori* estimator of \mathbf{x}_t after obtained the measurement \mathbf{z}_t , the covariance matrix \mathbf{P}_t can be written as:

$$\mathbf{P}_t = E[(\mathbf{x}_t - \mathbf{a}_t)(\mathbf{x}_t - \mathbf{a}_t)'] \quad (7)$$

There are many different ways on how to update the estimate of \mathbf{x}_t between two time steps. One approach is to update using the *a priori* estimate of \mathbf{x}_t , denote $\mathbf{a}_{t|t-1}$, which is the estimate before obtaining \mathbf{z}_t . The *a priori* estimator and the corresponding covariance matrix is given by:

$$\mathbf{a}_{t|t-1} = \mathbf{H}_t \mathbf{a}_{t-1} \quad (8)$$

$$\mathbf{P}_{t/t-1} = \mathbf{H}_t \mathbf{P}_{t-1} \mathbf{H}_t' + \mathbf{Q}_t \quad (9)$$

These two equations are used in predicting the \mathbf{z}_t . Once \mathbf{z}_t is observed, the *a posteriori* estimator of \mathbf{x}_t can be obtained according to the updating equation below:

$$\mathbf{a}_t = \mathbf{a}_{t/t-1} + \mathbf{F}_t (\mathbf{z}_t - \beta_t \mathbf{a}_{t/t-1}) \quad (10)$$

$$\mathbf{P}_t = E[(\mathbf{x}_t - \mathbf{a}_t)(\mathbf{x}_t - \mathbf{a}_t)'] = (\mathbf{I} - \mathbf{F}_t \beta_t) \mathbf{P}_{t/t-1} (\mathbf{I} - \mathbf{F}_t \beta_t)' + \mathbf{F}_t \mathbf{R}_t \mathbf{F}_t' \quad (11)$$

The \mathbf{F}_t in Eq. 10 is the Kalman gain (or blending factor), which specifies how the *a posteriori* estimator should be constructed based on the *a priori* estimation and the new observation \mathbf{z}_t . Since the objective is to find a minimal variance, differentiate the trace of \mathbf{P}_t with respect to \mathbf{F}_t , it is straight forward to obtain:

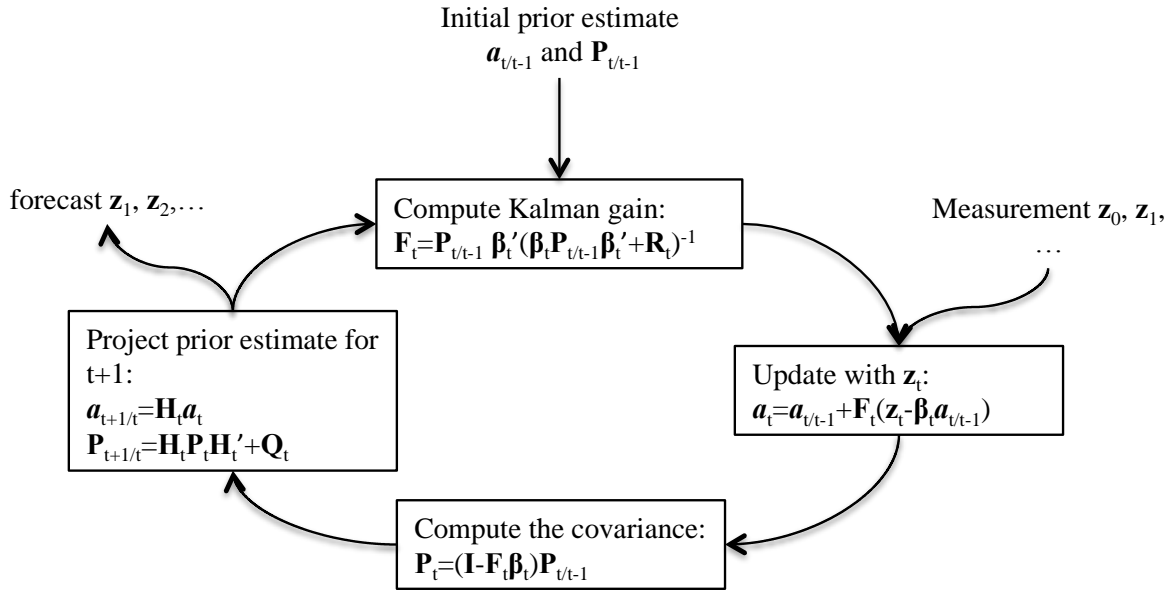
$$\mathbf{F}_t = \mathbf{P}_{t/t-1} \beta_t' (\beta_t \mathbf{P}_{t/t-1} \beta_t' + \mathbf{R}_t)^{-1} \quad (12)$$

From Eq. 12, we can see that if \mathbf{R}_t is large, \mathbf{F}_t is small. This indicates that when the measurement error covariance is large, the impact of the measurement error on updating the state vector will be small. Furthermore, substituting the optimal Kalman gain into Eq. 12, the update equation of the covariance matrix can be written as:

$$\mathbf{P}_t = (\mathbf{I} - \mathbf{F}_t \beta_t) \mathbf{P}_{t/t-1} \quad (13)$$

In summary, Eqs. 8-10, and 12-13 comprise the Kalman filter recursive equations. The use of these equations in the updating the state vector and the forecast the measurement is shown in Figure 1. It is called hybrid model because the initial estimate of the state vector and the covariance matrix is from the AR model.

Figure 1: Kalman Filter for the Hybrid Model



4. Case Study: Forecasting Hong Kong's Containers Throughput

Hong Kong Port (HKP) has been a very busy port in the Southern China region for many years. In 2011, it hosts about 440 container liner services per week and connects to about 500 destinations worldwide. Its total annual throughput has reached 24.4 million Twenty-foot Equivalent Units (TEUs).

For the planning of a business operation, although annual throughput can provide a general indicator on the demand for port services, it is better to have a short-term predication of the container port throughput, in order

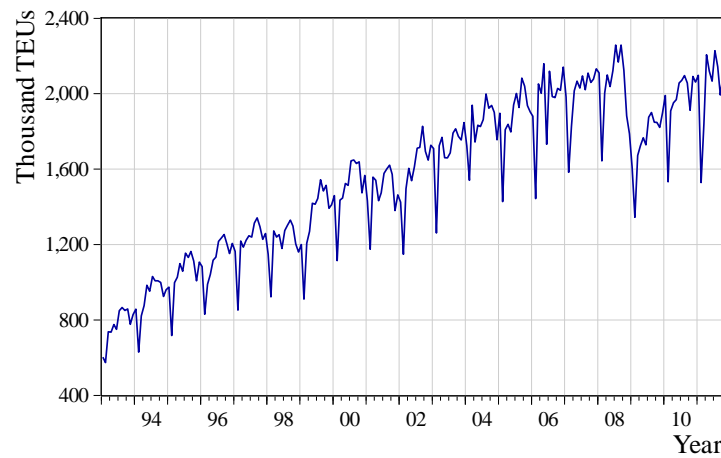
to prepare sufficient capacity to satisfy the short-term demand. In this paper, we forecast the monthly container throughput at HKP using a hybrid model that integrating AR model with Kalman filter.

4.1. Basic Data

This study uses the time series data on the monthly container port throughput at HKP from January 1993 to December 2011 (Hong Kong Port Development Board (PDB)). This time series data is shown in Figure 1, which clearly displays a seasonal variation on top of the generally increasing trend, as well as a huge drop at the 2008 financial crisis.

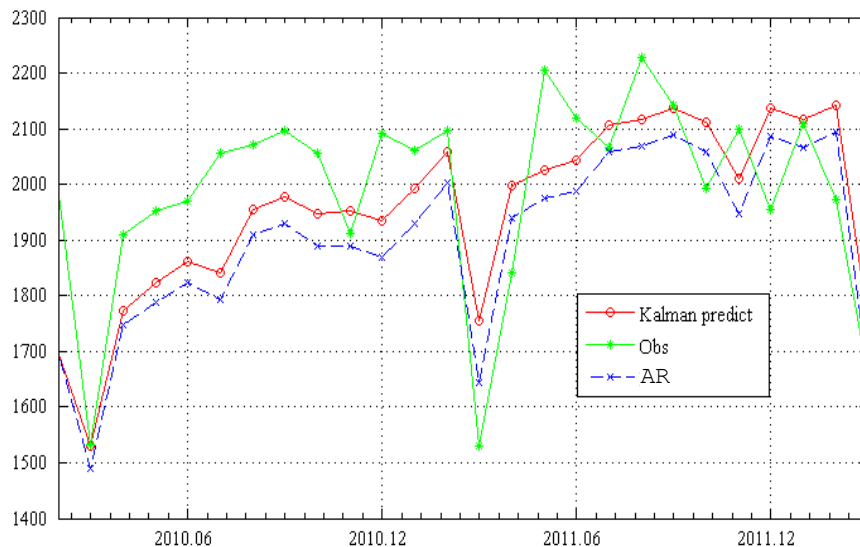
There are many different approaches in how to use the time series data to obtain a statistical model, and to do forecast. To illustrate the use of the Kalman filter, the AR model (eq.3 and 4) is adopted.

Figure 1: Container Port throughput of Hong Kong Port from 1993 to 2011



To compare the prediction accuracy of the AR model with Kalman filter, we first regress the AR model using all the data before 2010, and then use the model to predict the monthly throughput from January 2010 to February 2012. To apply the hybrid model, we first use the data before the 2010 to obtain the initial estimation of the state vector \mathbf{x} and covariance matrix \mathbf{P} . Then, we use the Kalman filter to predict the monthly throughput from January 2010 to February 2012. These two predictions are compared with the actual observation on the monthly throughput of HKP in the time period. The predicted throughputs using Kalman filter, AR model and actual observations are shown in Figure 2.

Figure 2: Short-term Predictions using Kalman Filter and AR Model



From Figure 2, it is obvious that the Kalman predictions are closer to the actual observation in most of the cases. The Mean Absolute Percentage Error (MAPE) for Kalman prediction is 5.89%, while that for the AR model is 6.41%. This gain in the prediction accuracy of Kalman filter is obtained through the use of actual observation to correct the state vector that is used for predicting the throughput in next month. Therefore, it is a short term predict because it actually can only predict the throughput one month in advance.

The above result shows the prediction accuracy of the hybrid model using the new observation at each month. To demonstrate the gain in prediction accuracy using hybrid model, five additional experiments are conducted. In each experiment, the AR model and the hybrid model predict five monthly throughputs of HKP separately using the equal number of observations. For example, in experiment I, we used actual throughput from January 1993 to March 2011 to estimate a AR model, and used it to predict throughputs from April to August, 2011. In applying the hybrid model, the actual data on monthly throughputs from January 1993 to February 2011 were used to estimate the initial state vector and covariance matrix. The throughput of March 2011 is used to update the state vector. This updated state vector is then used to estimate the throughput for coming five months. This experiment design is to ensure that the two forecasting activities are based on the same information. Therefore, if one prediction is more accurate than the other, it is just because of the difference in the prediction method, not the available data. Experiment II-V replicates the experiment I, except that the data used and the prediction period are all offset by one month.

Figure 3: Five Experiments on the Accuracy of Long-term Prediction (K TEUs)

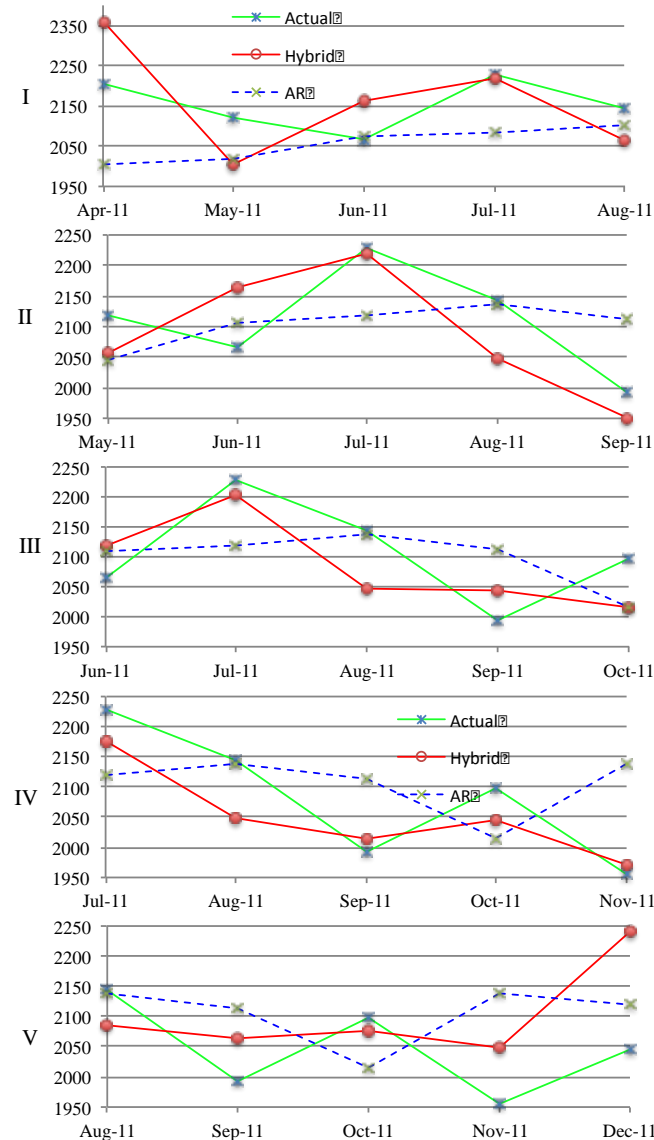


Figure 3 show the forecasts of container throughput of the given by the two methods. It should be noted that overall prediction accuracy is better in this experiment than that in figure 1, may be because it used more data to regress the AR model and initial state vector in hybrid model. In addition, the hybrid model is more accurate than the AR model. The MAPE 3.32% for hybrid model, while that for AR model is 4.16%. Furthermore, AR model usually under-estimate throughputs, while hybrid model provides a more stable prediction.

Table 2 provides the MAPE and Estimated Mean Square Error (EMSE) for the two models, which indicate that both can perform well in forecasting the monthly throughput for HKP. Overall, the hybrid model out performance AR in terms of both EMSE and MAPE, which shows the advantages of apply the hybrid model in short term forecasting of time series data.

Table 2. Comparison on the MAPE and EMSE between the Two Models

Period	Hybrid Model		AR	
	EMSE	MAPE	EMSE	MAPE
Apr-Aug	101.28	4.19%	121.44	4.55%
May-Sep	69.25	2.91%	81.42	3.31%
Jun-Oct	66.3	2.93%	83.26	3.41%
Jul-Nov	55.77	2.25%	115.61	4.90%
Aug-Dec	105.39	4.31%	110.04	4.65%
Average	79.6	3.32%	102.35	4.16%

5. Conclusion

Forecasting monthly container port throughput is critical for container terminal operators in their decisions on regarding the operating of their terminal facilities, as well as for the logistics industries that provide services to the port traffic. However, it is often difficult because there are numerous factors in the monthly variation of the container throughput at a port that beyond the capacity of any economic model.

This paper presents a hybrid model that incorporates the AR model and Kalman filter technology to model the evolution of monthly variation of container port throughput in HKP in a discrete dynamic system. It improves the prediction of the AR model by recursively updating the state vector using the most recent observations. As a result, the most recent events that have affected throughput will be given a higher weight in predicting the future throughput.

Both the short-term prediction using hybrid model with updating and the long-term prediction without using the actual observation in the previous month for update the state vector show that the hybrid model has better performance than the AR model. Besides, the prediction of the hybrid model is more stable than that of AR model.

This research only employed a simple autoregressive model with one-year lag, based on the nature of monthly data. Using the combination of different kind of time-series models may able to improve prediction accuracy. In addition, this paper only applied the basic Kalman filter recursive equations—the discrete Kalman filter. More elaborated Kalman filter technologies can be adopted to explore the possibility of improving the prediction.

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Port Feeder Barge: Advanced Midstream Handling of Containers – Optionally Fuelled by LNG

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Abstract

A new type of harbour vessel, named **Port Feeder Barge** (PFB), has been developed by the author to considerably improve the internal container logistics in many major and minor container ports. The self propelled and double ended pontoon type of vessel is equipped with its own full scale container crane.

The new type of vessel can either be used for pure transport purposes or for undertaking self sustained loading/discharging operations (as a floating crane) or a combination of both. Hence the PFB is also very well suited to especially perform advanced midstream operation, i.e. serving deep sea vessels at anchor (e.g. in Hong Kong) including shuttling the containers between the anchorage and small container wharfs ashore. Even the standard version of the PFB can serve deep sea vessels of more than panamax beam. By introducing such type of vessel midstream operation becomes much safer and much more efficient with less manpower being needed compared to the traditional Hong Kong midstream barges (HK barges).

Due to its special layout as a deck carrier the PFB is also very well suited to be optionally fuelled by LNG¹ which would result into an ultimate "green" harbour vessel.

Keywords: midstream operation, floating crane, floating terminal, intermodal harbour vessel, intraport haulage, LNG

Fig. 1: Traditional Midstream Operation in Hong Kong



¹ Liquefied Natural Gas

1. The 'Port Feeder Barge' Concept

Fig. 2: Port Feeder Barge (Computer Rendering)



Source: Port Feeder Barge, Hamburg

Main Data

Type:self propelled, self sustained, double-ended container barge
Length o.a.:63.90 m
Beam o.a.: 21.20 m
Height to main deck: 4.80 m
Max. draft (as harbour vessel): 3.10 m
Deadweight (as harbour vessel): 2,500 t
Gross tonnage:approx. 2,000 BRZ

Power generation: diesel-/gas-electric
Propulsion: 2 x 2 electrical rudder propeller of 4 x 280 kW
Speed: 7 knots at 3.1 m draft

Class: GL ✕ 100 A5 K20 Barge
equipped for the carriage of containers, Solas II-2, Rule 19 ✕ MC Aut

Capacity: **168 TEU** (thereof 50% in cellguides), 14 reefer plugs
Crane: LIEBHERR CBW 49(39)/27(29) Litronic (49 t at 27 m outreach)
Spreader: automatic, telescopic, 6 flippers, turning device, overheight frame

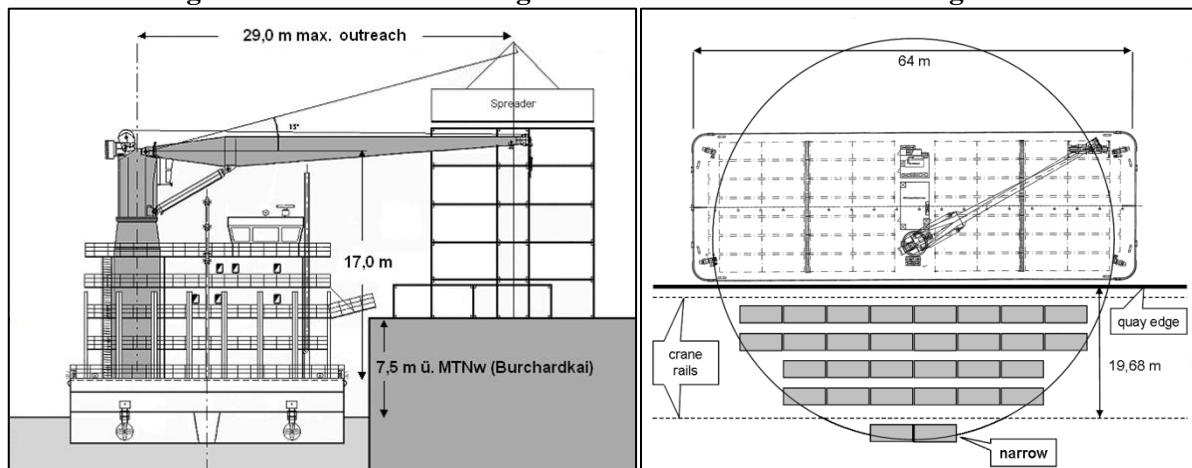
Accommodation: 6 persons (in single cabins)

The internationally patented **Port Feeder Barge (PFB)** design comprises of a self-propelled container pontoon with a capacity of 168 TEU (completely stowed on the weather deck), equipped with its own state-of-the-art heavy-duty container crane mounted on a high column (Fig. 2). The crane is equipped with an automatic spreader, extendable from 20 to 45ft, including a turning device. A telescopic over height frame to handle oversized flats is also carried on board. The barge is of double-ended configuration, intended to make it extremely flexible in connection with the sideward mounted crane. Due to the wide beam of the vessel no operational restrictions (stability) for the crane shall occur. The vessel is equipped with 2 electrically driven rudder propellers at each end in order to achieve excellent manoeuvrability and the same speed in both directions. Hence the vessel can e.g. easily turn on the spot. While half of the containers are secured by cell guides, the other half is not, enabling the vessel to carry also containers in excess of 40ft as well as any over-dimensional boxes or break bulk cargo. 14 reefer plugs allow for the overnight stowage of electrically driven temperature controlled boxes.

The key element of the worldwide unique PFB concept is its own full scale heavy duty container crane. While it looks like a standard shipboard crane, all its mechanical components have been especially designed for continuous operation – unlike standard shipboard cranes, which are designed for operation only every few weeks when the vessel is in port. The crane has a capacity of 40 tons under the spreader, at an outreach of 27 meters (maximum outreach: 29 m).

When berthed, the PFB is able, without being shifted along the quay, to load or discharge 84 TEU in three layers between the rails of a typical quayside gantry crane (Fig. 3 b). This is more than sufficient, with a total loading capacity of 168 TEU. That is why the full outreach of the crane is not always needed. Berthing the vessel with the crane on the opposite side of the quay (see Fig. 3 a) would speed up the crane operation as the turning time of the outrigger is minimised. The height of the crane column is sufficient to serve even high quays in open tidewater ports at low tide while stacking the containers in several layers. Due to its short length of 64 meters the PFB needs only a small gap between two deep sea vessels at the terminals for self sustained operation.

Fig. 3 A+B: Port Feeder Barge: Outreach of Crane and Turning Circle



Source: Port Feeder Barge, Hamburg

The vessel shall fulfill the highest environmental standards. A diesel- or gas-electric engine plant with very low emissions supplies the power either for propulsion or crane operation. The vessel can be operated by a minimum crew of 3 whereas in total 6 persons can be accommodated in single cabins.

The operation of the PFB is not limited to inside sea ports. As the hull is classified according to Germanischer Lloyd's notification for seagoing vessels the operation in (sheltered) open waters off the coast is also possible which opens some interesting opportunities for employment.

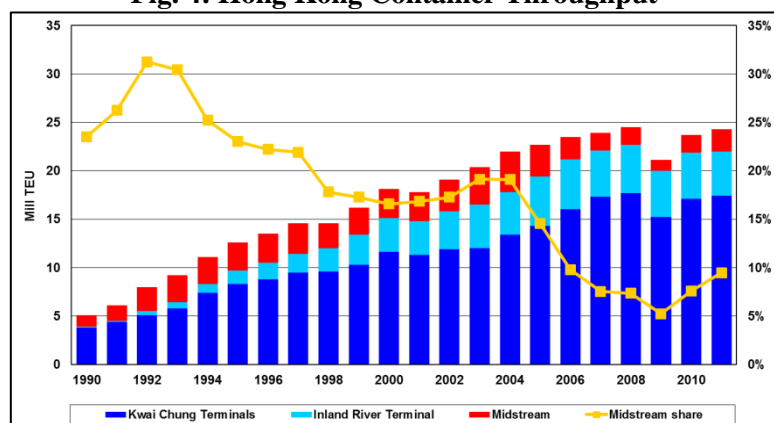
The detailed design of the vessel has been developed in close cooperation with Wärtsilä Ship Design Germany GmbH, Hamburg. The typical Hong Kong midstream operation could very much benefit from deploying

PFBs as they could be used to significantly improve safety and productivity.

2. Midstream Operation in Hong Kong

While more than 30% of all containers were handled midstream in the early 90s today only approx. 10% of the huge port's container throughput of 24 Mill TEU (2011) is being left to this unique method of container handling (Fig. 4) which means that geared barges are directly serving deep the sea vessels (limited to approx. 3,500 TEU size) while laying at anchor (Fig. 1). These traditional midstream barges with a capacity of approx. 50 TEU are equipped with their own cargo gear, but the handling method is far from being sophisticated. The A-frame derricks have a single beam just controlled by wires and are not even fitted with a spreader, but instead rely only on steel wires being fitted manually to the corner castings of the containers. Hence persons need to stay on top of the containers (Fig. 5 a). In fact this is cargo handling technology from the last century and complies hardly with international safety standards. In average 4 fatal accidents are reported each year in connection with midstream operation! Hence such operation is not allowed in Europe, North America and most other ports in the world. Such midstream barges are only operating in Hong Kong. Quite apart from the health and safety issues related to HK barges, they are not self-propelled (not even pushed but towed).

Fig. 4: Hong Kong Container Throughput



Source: Hong Kong Marine Department

Fig. 5 A+B: Midstream Operation & Twin Lift Tower Spreader



2.1. Safety & Productivity

When comparing traditional midstream container operation (Fig. 1) with the PFB concept (Fig. 2) regarding safety and productivity the load cycles (4 phases) have to be investigated in detail (Tab. 1):

1. Picking up of container (either from the seagoing vessel or from the barge)

- Lowering/positioning of lifting attachment:
The PFB takes advantage from the fully automatic and telescopic spreader avoiding any person to be placed on top of the containers. The spreader is equipped with a turning device, an automatic gravity point adjustment and 6 individually controlled flippers which guide the spreader into the right position on top of the container. With the sensitive crane control in combination with its turning device the spreader can be carefully positioned on top of the containers. Meanwhile twin lift capability is even available for tower type spreaders (e.g. for mobile harbour cranes, Fig. 5 b).
- Locking:
Once the spreader is positioned on top of the container the locking of its 4 pins into the corner castings is just a matter of pushing a button in the driver's cabin. HK barges operate without spreaders. Instead 4 loose wire ropes with hooks at their ends have to be manually fastened to the corner castings (Fig. 5 a). For that purpose persons have to work on top of the container and have to leave it quickly (either to adjacent containers or stepping down via ladders) before it is lifted. The persons have to watch very carefully for not being hit by one of the swinging hooks especially when the vessel is rolling.
- Hoisting:
In addition to all the labour accidents a lot of damage to the containers and also to the seagoing vessels is reported from the rough method of midstream container handling. The fact that there is no motion control around the vertical axle of the handled container contributes very much to all the experienced damages. Hence collisions with adjacent containers are unavoidable with HK barges while hoisting the container. Instead the spreader operation of the PFB with its integrated turning device and its sensitive crane control allows for a controlled hoisting minimising any bumps to neighbouring boxes.

2. Slewing beam with load

The slewing of the simple beam of HK barges is controlled by two wire ropes (like old style cargo gear). One rope has to be tightened and the other one has to be eased simultaneously. It is unavoidable that the ropes continuously chafe along the containers stowed on deck.

By nature of its cargo gear the operational area of the beam of the HK barges is limited to less than 90° to each side whereas the crane of the PFB can turn 360° (Fig. 6). Hence HK barges require also more time consuming interruptions of the cargo operation for shifting the barge along the seagoing vessel to reach all required container positions. As a HK barge reaches only one third of the containers on the seagoing vessel compared to the PFB (without being shifted) the time for shifting will be more than triple (see below).

3. Dropping off container

- Positioning of container:
With the sensitive crane control in combination with the turning device of the PFB it is much easier to exactly reach the final stowage position of the container compared to the old fashioned cargo gear of the HK barges – even when the vessels are rolling. When lowering the container to its final stowage position the turning device of the PFB becomes the decisive tool to avoid collisions with other containers.
- Unlocking:
Again it needs only a touch of a button in the crane driver's cabin to unlock the container from its lifting attachment when operating a PFB. With a HK barge persons have to climb on to the top of the container to unfasten the 4 wire ropes. This is time consuming and very dangerous as the statistic of labour accidents shows.
- Empty hoisting:

Only the hoisting of the 4 hanging down wire ropes appears to be easier than of an empty but bulky spreader. However the sensitive crane control and the turning device allows to avoid collisions with adjacent containers.

4. Slewing beam without load → see 2. (above)

Tab. 1: Load Cycle Analysis

Phase		HK Barge	PFB
1. Picking up	Lowering/positioning of lifting attachment	Precise positioning not required +	Precise positioning of spreader by sensitive crane control and turning device
	Locking	4 wire ropes to be fastened manually	Button touch +
	Hoisting of container	No motion control around vertical axle !	Sensitive crane control and turning device to avoid collisions with other containers ++
2. Slewing beam with load		Restricted area of operation	360° operation circle +
3. Dropping off	Lowering/positioning of container	No motion control around vertical axle !	Precise positioning of spreader by sensitive crane control and turning device ++
	Unlocking	4 wire ropes to be untied manually	Button touch +
	Empty hoisting	Precise hoisting not required +	Sensitive crane control and turning device to avoid collisions with other containers
4. Slewing beam without load		Restricted area of operation	360° operation circle +
Conclusion (evaluation points)		++	++++++

2.2. Rolling

The operation of HK barges as well as of PFBs are both affected by rolling motions against the seagoing vessel which would slow down the operation, especially the positioning process. As seaway induced motions are generally of regular type the crane drivers of both types of vessel can prepare for finding the right moment for the final slope of the container or empty spreader.

However the active usage of its turning device and the sensitive crane control of the PFB allows for much better and precise compensation of the rolling motions and prevents from damages.

To further cope with the rolling motions of the two vessels moored alongside each other the PFB concept allows for the installation of an additional so-called 'stabilising winch' which is offered by some crane manufacturers (e.g. Liebherr). Such device is mounted on the crane's beam (close to the column) to tighten a wire rope which is directly connected to the turning device (just above the spreader). Hence the swinging motions of the spreader are significantly dampened.

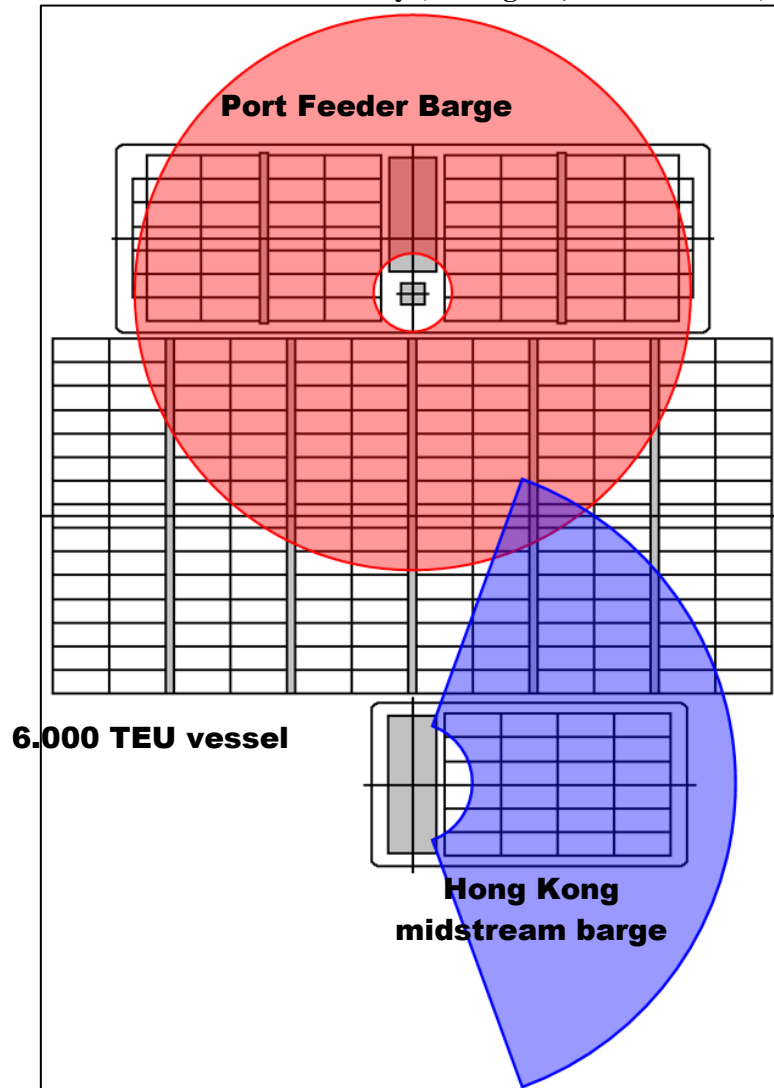
2.3. Accessibility

A comparison has been made between the PFB and a typical HK barge regarding the slot accessibility while serving a typical 6,000 TEU vessel (on deck: 15 rows, 7 layers; in holds: 13 rows, 8 layers).

From a geometric analysis (Fig. 6) it is obvious that the PFB benefits from the 360° operational circle of its crane regarding the horizontal slot accessibility whereas a typical HK barge is limited to even less than 90° to each side. Furthermore, even if both beams would be of the same length, the PFB takes advantage from a wider operational area due to its sideways mounted crane (Fig. 7 + Fig. 8).

Due to the fact that the beam fulcrum of the PFB is by principle located at least 4 container layers higher compared to a HK barge much better accessibility to many containers stowed on deck is achieved especially when containers have to be positioned behind other containers (Fig. 7).

Fig. 6: Hong Kong Midstream Barge vs. Port Feeder Barge
- Horizontal Slot Accessibility (serving a 6,000 TEU vessel) -



As HK barges are working without spreaders a lot of utilisable height of the hoisting rope is lost for the lifting attachment, especially when 40ft containers are handled (the angle of inclination of the wire ropes is recommended to be under 45°) whereas the height of the spreader (incl. its turning device) is much less (Fig. 7).

The results of the horizontal and vertical accessibility have been summarised in terms of numbers of accessible containers with both types of barges (Fig. 8): It is quite obvious that the PFB has access to roughly the triple number of containers than a typical HK barge (without being shifted alongside the deep sea vessel)! Furthermore there is much more flexibility in stowage planning as even with 6,000 TEU vessels the first three layers on the hatch covers can be stowed without being forced to follow a certain loading/discharging order which is not the case with typical HK barges.

Normally HK barges are restricted to moor alongside seagoing vessels only in the midship area where the hull is plane and vertical. Containers stowed at the vessel's bow or stern are difficult to load/discharge as the barge has to be positioned under the overhanging hull lines. Hence not all slots of seagoing vessels are accessible to HK barges. However the self propelled PFB allows also for being moored in the bow and stern area of the seagoing vessel: By using its rudder propellers the thrust can push the PFB away from the vessel while keeping the mooring lines tight. Due to the higher horizontal slot accessibility of the PFB and its superior

The diagram illustrates the concept of beam fulcrum for two different barge configurations. The central element is a large rectangular area divided into a grid of colored squares (blue, red, and purple), representing a cargo hold or a specific area of interest. To the left, a smaller barge labeled "Hong Kong midstream barge" is shown. It has a crane with a blue beam. A blue dashed line indicates the beam's path, and a blue dot marks the "beam fulcrum". A vertical double-headed arrow indicates a height of "4 layers". To the right, a larger barge labeled "Port Feeder Barge" is shown. It has a crane with a red beam. A red dashed line indicates the beam's path, and a red dot marks the "beam fulcrum". A red diamond symbol is also present near the red beam. The diagram shows how the beam fulcrum position and the beam's path differ between the two barge types, affecting the stability and distribution of the cargo load.

Hong Kong midstream barge:

4	4																
4	4	4															
4	4	4	4														
4	4	4	4	3	3												
4	4	4	4	3	3												
4	4	4	4	3	3	3											
4	4	4	4	3	3	3	1										

TEU 307 28 60 56 52 36 36 30 9

Port Feeder Barge:

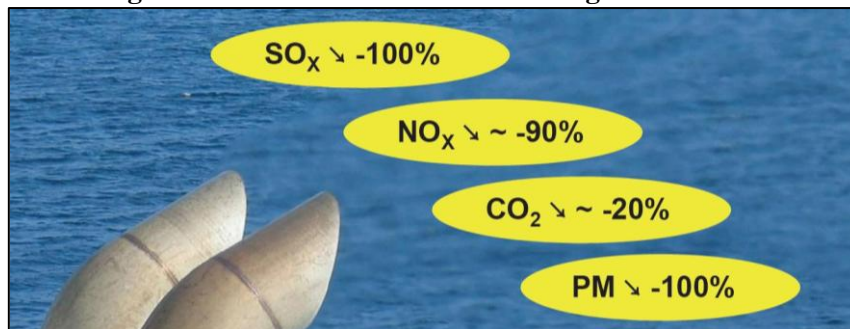
								6	8	8	8	8	8	8	10		
								6	6	8	8	8	8	8	8	10	
								6	6	8	8	8	8	8	8	10	
								4	6	6	8	8	8	8	8	8	10
								4	6	6	8	8	8	8	8	8	10
								2	4	6	6	8	8	8	8	8	10
								2	4	6	6	8	8	8	8	8	10
								2	4	6	6	8	8	8	8	8	8

TEU 912 20 48 84 90 120 120 120 120 120 70

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LNG as fuel (Fig. 9). Due to the immense resources and its environmentally friendly combustion process LNG is said to be the maritime fuel of the future.

Fig. 9: Effects on Emissions when Using LNG as Fuel

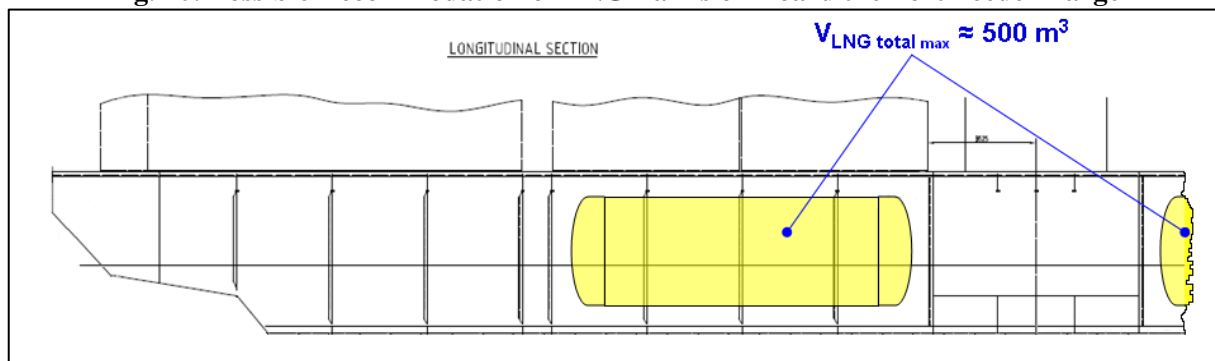


Source: Flensburger Schiffbau Gesellschaft, 2010

The PFB would be an ideal demonstrator for LNG as ship fuel:

- As a harbour vessel it does not rely on a comprehensive network of bunker stations. Only one facility is sufficient. The PFB – being a launching customer for this promising new maritime fuel – could at first even be supplied out of tank trucks paving the ground from the demand side for a special LNG infrastructure to be introduced (solving the chicken-egg-dilemma).
- As the PFB is of pontoon type there is plenty of void space below the weather deck. Hence the accommodation of the voluminous LNG tanks would not result in any loss of cargo as it would be the case with many other types of (harbour) vessels (Fig. 10).

Fig. 10: Possible Accommodation of LNG Tanks on Board the Port Feeder Barge



Source: Port Feeder Barge, Hamburg

3. Conclusion

Although the lowering and the hoisting of the empty lifting attachment appears to be easier with a HK barge (4 hanging down wire ropes vs. a bulky spreader) the more relevant lowering, hoisting and fastening/unfastening of the containers itself is definitely much easier, safer and faster with the PFB!

The detailed analysis of the motion sequences has revealed that the safety and the productivity is expected to be much higher and the danger of damages to be much less with the PFB compared to the traditional Hong Kong style of midstream operation (Tab. 1). The productivity can be further increased by using a twin lift spreader which allows for 2 x 20ft operation (Fig. 5 b).

Furthermore it can be concluded that the PFB easily allows to serve even vessels of 6,000 TEU size midstream (by further heightening the crane column even bigger vessels could be served). Hence the PFB still allows also for midstream operation with seagoing vessels which are simply too big for the existing HK

barges.

Summarising the comparison between the traditional HK barge and the PFB for midstream operation it can be concluded that the deployment of PFBs is expected to provide the following valuable advantages which could contribute to a recovered share in Hong Kong's container throughput:

- More safety (less labour accidents, less damage to containers and vessels)
- Less interruptions
- More load cycles per hour
- Less barge shiftings along the seagoing vessel necessary
- More slots of the seagoing vessel are accessible for midstream operation
- More stowage flexibility on the deep sea vessel and on the barge
- Possibility for twin lift operation
- Bigger vessels can be served midstream
- Less manpower necessary
- Not dependent on tug boats
- Best possible manoeuvrability (by 4 rudder propellers)
- More container stowage capacity on the barge

Besides midstream operation the PFB could be used in many other container ports to ...

- shift container trucking within sea ports to the waterway,
- ease feeder operation within multi terminal ports,
- improve the intermodal connectivity of inland navigation within sea ports (acting as a floating terminal for inland barges and relieving the deep sea terminals from inefficiently serve the numerous small vessels with their huge gantry cranes).

By using LNG as fuel the PFB concept could be considered as a 'smart & green innovation for advanced container logistics within sea ports'.

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Linkage between Insurance Subrogation and Original Claim under Chinese Law^{*}

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Abstract

Insurance indemnities and insurance subrogation have their distinct features. “Actual loss” is the premise of insurance indemnity, while insurance subrogation is the continuance of insurance indemnity. Insurance subrogation means the inheritance of the insured’s rights against the third party; it has the nature of “correlativity” and has both substantial and procedural meanings. The insured has the discretion to claim for damages against the liable third party, or claim for insurance indemnities against the insurer, or respectively claim for damages against the liable third party and claim for insurance indemnities against the insurer. The separate claims against the liable third party and the insurer do not constitute repeated litigation or two lawsuits for one case. No matter whether the original insurance claim is made earlier or later, the insurer may, after paying insurance indemnities, enjoy the subrogation and may directly initiate, continue or join the procedures of claiming against the liable third party. Before the liable third party pays the actual damages, the judgment in favor of the liable third party can not stop the insured from claiming for insurance indemnity against the insurer.

Keywords: actual loss, insurance indemnity, subrogation, substantial meanings, procedural meanings

1. Source of Issue

“Donglong 166” had a collision with “Zhepuyu 71335” and caused property loss. The owner of “Donglong 166” brought a lawsuit against the owner of “Zhepuyu 71335” at Ningbo Maritime Court, claiming for damages; the former also brought a lawsuit against China Life Lianyungang Lianyun Sub-branch, the insurer of “Donglong 166”, at Shanghai Maritime Court and claimed for insurance indemnities. In the first case, the courts for the first instance and the second instance both ruled that the owner of “Donglong 166” wins the lawsuit, and the owner of “Zhepuyu 71335” shall compensate for the loss of the owner of “Donglong 166”. In the second case, Shanghai Maritime Court ruled that the insurer shall pay insurance indemnities to the insured. To sum it up, the insured (owner of “Donglong 166”) may separately bring a lawsuit against the liable third party (owner of “Zhepuyu 71335”) and bring a lawsuit against the insurer; especially after the insured obtained a favorable judgment against the liable third party, the insurer can not refuse to pay insurance indemnities with the judgment as an excuse. Shanghai Maritime Court further ruled that after the insurer pays insurance indemnities, the insured’s right of applying for the enforcement of the judgment against the liable third party shall correspondingly be transferred to the insurer.¹ The insurer appealed, and the court for the second instance closed the case with mediation.

Differently, in the “Case of Ningbo Iron & Steel Co., Ltd. vs. Ningbo Branch of Ping An Property & Casualty Insurance Company of China, Ltd. on Dispute concerning the Ocean Marine Cargo Insurance Contract”,

^{*} This article is a revision of the thesis winning the First Prize in the 20th National Maritime Trial Seminar (September 2011, Shanghai).

¹ Refer to (2005) H.H.F.S.C.Zi No. 9 Civil Judgment by Shanghai Maritime Court for the Case of Plaintiffs Gao Yangda & Fujian Pingtan Quanxing Shipping Co., Ltd. vs. PICC P&C Lianyungang Lianyun Sub-branch on Dispute of Loss Damages concerning the Ship Insurance Contract.

Ningbo Maritime Court ruled that after the insured wins the favorable judgment on its claim against the liable third party, it shall not sue the insurer again, or the repeated litigation is constituted.² The insured made an appeal, and the court for the second instance dealt with the case as automatic withdrawal of lawsuit.

It can be discovered that the interpretation of relevant provisions in Article 60 of the *PRC Insurance Law* (Amended in 2009) and Articles 252 and 254 of the *PRC Maritime Law* has material influences on the initiation of proceedings and the substantial trial of a case. Art. 60 of the *PRC Insurance Law* stipulates that, “the insurer shall, starting from the date of paying the indemnities, subrogate the insured to exercise the right to indemnities from the liable third party...If the insured has already obtained indemnities from the third party, the insurers may pay the indemnities in the amount after the indemnities paid by the third party to the insured are deducted”. Art. 252 states that, “the right of the insured to demand compensations from the third person shall be subrogated to the insurer from the time the indemnities is paid”. As stipulated in Art. 254 of the *PRC Maritime Law*, “...in effecting payment of indemnities to the insured, the insurer may make a corresponding reduction therefrom of the amount already paid by a third person to the insured”.

While the insured brings a lawsuit against the liable third party or even wins such lawsuit, whether the insured could or not initiate a lawsuit against the insurer under the insurance contract is a hot question in judicial field.

There are two different views:

The (2005) *H.H.F.S.C.Zi No. 9 judgment* expresses the “affirmation view”. According to this kind of view, lawsuits brought by the insured separately against the liable third party and against the insurer do not constitute two lawsuits for one case. Even if the insured wins the lawsuit against the liable third party, such a fact shall have no direct influence on the lawsuit against the insurer brought by the insured. That is to say, the insured could bring a lawsuit against the insurer.

The (2008) *Y.H.F.S.C.Zi No. 137 judgment* seems to take the “Negation view”. According to this kind of view, if the insured wins the lawsuit against the liable third party (with no actual enforcement of the judgment), the lawsuit against the insurer brought by the insured shall constitute repeated litigation. Therefore, the insured should not bring a lawsuit against the insurer if he wins the lawsuit against the liable third party.

Two questions relates to the “affirmation view”. One is whether the time for the initiation of insurance subrogation shall be limited to before and during the lawsuit against the liable third party brought by the insured or shall include the period for the enforcement of the judgment. Another is that, while the judgment is not actually enforced, whether the insurer shall subrogate the insured in applying for the enforcement of the judgment against the third party.

The question relates to the “Negation view” is that, if the lawsuit against the insurer brought by the insured after the latter wins the lawsuit (against the liable third party) is confirmed as repeated litigation and should not be permitted, will it materially block the approach of the insured to bring a lawsuit against the liable third party and even further affect the protection of limitation of action for the claim against the third party after the insurer obtains subrogation?

The above questions are not discussed in relevant theoretical literature. There are no direct provisions in relevant laws and judicial interpretations either, such as the *PRC Maritime Law*, the *PRC Insurance Law*, the *PRC Maritime Procedure Law*, the *Judicial Interpretation of the PRC Maritime Procedure Law*, and the *Judicial Interpretation of Maritime Insurance*. Different opinions exist in the judicial practice, which even led to completely different judgments as mentioned above. The judicial authority could be severely impeded.

Therefore, it is necessary to carry out serious analysis and research, taking into consideration of the purposes, features and legal principles of insurance indemnities, so as to achieve correct comprehension of laws, to

² Refer to (2008) *Y.H.F.S.C.Zi No. 137 Civil Judgment* by Ningbo Maritime Court for the Case of Plaintiff Ningbo Iron & Steel Co., Ltd. vs. Ningbo Branch of Ping An Property & Casualty Insurance Company of China, Ltd. on Dispute concerning the Ocean Marine Cargo Insurance Contract.

unify the measurement of judgment and maintain the judicial authority. Specifically, this article proposes to discuss such issues as “payment of insurance indemnities by the insurer”, “the insured’s right of claiming for indemnities against the third party”, features and legal principles of insurance subrogation, and the linkage between insurance subrogation and original claim in different stages, so as to balance the interests of the insured, the insurer and the liable third party, to clarify certain legislations, and to coordinate the judicial operations. The Guiding Opinions of Zhejiang Provincial Higher People’s Court on Several Issues in the Trial of Cases on Disputes Concerning the Maritime Insurance Contract issued on June, 2011, will be analyzed and reviewed also.

2. Features and Attributes of Insurance Indemnity and Insurance Subrogation

2.1 Insurance indemnity is a behavior of contract performance

Insurance indemnity is a behavior of contract performance. It is a basic contract obligation of the insurer agreed by the parties in the insurance contract. Insurance indemnity is not a compensation liability that the insurer should bear towards the insured for breach of contract or tort actions. There are essential differences between it and general contract breach liabilities or tort liabilities.

2.2 Insurance indemnity takes “actual loss” as its premise

Payment of insurance indemnities under property insurance (including marine insurance) has the aleatory and contingent nature. Among multiple conditions of payment, the most important one is whether the insured actually suffers the loss agreed in the insurance contract. “Actual loss” is the necessary premise for the “payment of indemnities” by the insurer. This character embodies the essence of the principles of insurance indemnity. If the insured obtains whole or partial compensations from the liable third party after suffering loss because of the insurance accident, the “actual loss” of the insured shall decrease accordingly. As a result, according to Article 60 of the *PRC Insurance Law* and Article 254 of the *PRC Maritime Law*, the insurer shall have the right to deduct the amount of compensations the insured obtained from the third party when paying insurance indemnities.

“Compensations obtained from the third party” shall mean the actually obtained compensations. Even if the insured obtains a favorable judgment against the liable third party, the judgment itself shall not replace the “compensations obtained from the third party”. Only when the liable third party actually enforces such a judgment, the whole or partial actual compensations paid to the insured can be the “compensations obtained from the third party”. Guangdong Provincial Higher People’s Court also made it clear in its guiding opinions that the “compensations obtained from the third party” shall mean the actually obtained compensations.³

2.3 Insurance subrogation is the continuance of insurance indemnity, taking “actual loss” and “actual payment of indemnities” as the premise

As the continuance of insurance indemnity, Insurance subrogation is another important embodiment of the principles of insurance indemnity. It takes the insured “actually suffers loss” and the insurer “actually pays indemnities” as the premise also.

In the first years after the enactments of the *PRC Maritime Law* and the *PRC Insurance Law*, there are intense discussions on the preconditions for the insurer to obtain subrogation. Finally, Article 96 of the *PRC Maritime Procedure Law* and Article 68 of the *Judicial Interpretation of the PRC Maritime Procedure Law* made the clarification, requiring the insurer to provide certificates for the actual payment of insurance indemnities, such as the insured’s receipt of indemnities and the bank’s payment document. These provisions take the “actual payment of indemnities” as an importance foundation and premise for the obtainment and enforcement of

³ Article 26 of the Guiding Opinions of Guangdong Provincial Higher People’s Court on Several Issues in the Trial of Cases Concerning Insurance Disputes (Y.G.F.F. [2008] No. 10) stipulates: “After the occurrence of an insurance accident, if the insured sues the infringer but fails to get actual indemnities or gets insufficient indemnities, the insured is entitled to claim the part that is not indemnified against the insurer. But the insurer’s responsibility of paying indemnities is limited to the actual amount of the part that is not indemnified or the limit stipulated in the insurance contract.”

insurance subrogation. Only the right transfer document issued by the insured cannot act as the factual basis for the insurer to obtain subrogation.

2.4 *Insurance subrogation inherits the insured's rights against the third party and with the "correlativity" nature*

The establishment of the subrogation system has two essences. One is to maintain the damage compensation system in general private law and prevent exempting the responsibilities of the liable third party for illegal behaviors just because the insured obtains insurance indemnities. The other is to prevent the insured from obtaining unjust enrichment.⁴

The liable third party is the final responsible person, and there shall be no change to such a fact whether there is an insurance contract between the insured and the insurer or not. The insured should have the right to enjoy the "original" right of asking the liable third party to shoulder his responsibility. If the insurer actually indemnifies the corresponding loss, the insurer shall obtain the "inherited" right of asking the liable third party to shoulder its responsibility.⁵

Whenever the liable third party does the illegal behavior and causes the damages consequently, the insured, as a victim, could enjoy the right of asking for damage compensation by the liable third party. This kind of right ends up when the third party finally shoulders its compensation responsibility under the guarantee of judicial (quasi-judicial) systems such as litigation, arbitration and enforcement, i.e. the "actual payment of indemnities" of the liable third party. Legislations not only confirm the substantive right enjoyed by the victim (insured), but also safeguard the procedural realization of his substantive right.

On this regard, the insurance subrogation is correlated with "actual payment of indemnities". It is the inheritance and continuance of the insured's original right against the liable third party. Both the *PRC Insurance Law*⁶ and the *PRC Maritime Law*⁷ have specific provisions on such a fact. Article 93 of the *PRC Maritime Procedure Law* clearly stipulates: "after the insurer...pays insurance indemnities...it may subrogate the insured to exercise the right to indemnities from the third party", which sets the keynote of the procedural safeguard for the enforcement of insurance subrogation.

2.5 *Insurance subrogation has both the connotation of substantive right and the connotation of procedural right*

As mentioned above, insurance subrogation is the inheritance and continuance of the insured's "original" right of claiming for damages against the liable third party. Such an original right shall start when the liable third party does the illegal behavior, and shall end when the liable third party pays the "actual compensations" guaranteed by such judicial (quasi-judicial) systems as litigation, arbitration and enforcement.

Therefore, theoretically, the insurer may obtain insurance subrogation because of its "actual payment of indemnities" at any "time point" during such a process, base on which to continue the whole process of claiming for damages against the liable third party. Thus insurance subrogation has both the connotation of substantive right and the connotation of procedural right.

Relevant provisions of the *Maritime Procedure Law*, the *Judicial Interpretation of the Maritime Procedure Law* and the *Judicial Interpretation of Maritime Insurance* provide the specific procedural safeguards for the

⁴ Jiang Chaoguo: *Basic Theories of Insurance Law*, China University of Political Science and Law Press, 2002, pages 388-389.

⁵ In accordance with the English Marine Insurance Act 1906, the insurer may bring a subrogation lawsuit in the name of the insured. In the UK, the insured has the absolute right of claim against the liable third party according to the principle of relativity of the contract, and the insurer is prohibited to execute the subrogation in its own name, i.e. the insurer has no right against the liable third party. Generally, the insurer makes the claim against the third party by "standing in the shoes of the insured".

⁶ Article 60.1 of the *PRC Insurance Law* provides that, "...the insurer may, from the date of payment of indemnities to the insured, exercise the insured's right to claim compensation from the third party by subrogation within the amount of indemnities."

⁷ Article 252.1 of the *PRC Maritime Law* provides that, "...the right of the insured to demand compensation from the third person shall be subrogated to the insurer from the time the indemnity is paid."

realization of such a right. For example, Articles 94 and 95 of the *Maritime Procedure Law* confirm that the insurer shall have the right to directly initiate, inherit or join relevant procedures of claiming against the liable third party. Article 67 of the *Judicial Interpretation of the Maritime Procedure Law* confirms that the insurer shall have the right to inherit the insured's relevant property preservation interest or security interest against the liable third party. Article 15 of the *Judicial Interpretation of Maritime Insurance* confirms that the insurer shall have the right to inherit the insured's interest for the interruption of limitation of action obtained in the relevant lawsuit.

Regrettably, relevant laws and judicial interpretations fail to make specific provisions on the matter whether the insurer should pay insurance indemnities and inherit the insured's relevant rights in the enforcement phase. To be more specific, the laws and judicial interpretations fail to stipulate whether the insured has the right of claiming for insurance indemnities against the insurer and then the insurer obtains insurance subrogation after the insured sues the liable third party and obtains a favorable judgment but before the complete enforcement of the judgment, i.e. before the liable third party actually performs its responsibility of paying damages to the insured. Such a "failure" leads to completely different opinions and operations in the judicial practice as mentioned above, causing significant influences to the interests of the relevant parties (refer to the discussion below).

However, we can still draw a conclusion from the above legal principles and the provisions in Article 93 of the *Maritime Procedure Law*: the insured still has the right of claiming for insurance indemnities against the insurer and then the insurer obtaining subrogation after the insured obtains a favorable judgment against the liable third party but before the complete enforcement of the judgment.

3. Linkage between Insurance Claim, Insurance Subrogation and Original Claim on Time of Starting Proceedings

3.1 Time of Starting Proceedings of the Insurance claim and the "original" claim against the liable third party

Whenever the third party causes damage to the subject of insurance, the insured may claim against the third party. If such damage is covered by the insurance contract, the insured may claim against the insurer in accordance with the insurance contract. The former is the civil responsibility that the liable third party should shoulder for its illegal behavior, while the latter is the basic contract obligation that the insurer should shoulder in accordance with the insurance contract. Apart from the fact that the involved damage is the same, the insured's rights of claim in the two kinds of legal relation are quite different. Therefore, the laws shall, while respecting the insured's discretion of claim, prevent the consequence that the insured obtains compensations from the liable third party and the insurer's insurance indemnities simultaneous, thus obtaining additional benefit.

That is the real intention of the insurance subrogation system. As mentioned above, the establishment of the insurance subrogation system is to, on the one hand, prevent the liable third party exempting his responsibility for illegal behaviors; and to, on the other hand, prevent the insurer from exempting or reducing its obligation of paying insurance indemnities and prevent the insured from obtaining unjust enrichment. Therefore, the insured shall be permitted to, according to its own situation, decides for itself to only claim for damages against the liable third party, to only claim for insurance indemnities against the insurer, or to separately claim for damages against the liable third party and claim for insurance indemnities against the insurer. The separate lawsuits against the liable third party and the insurer do not constitute repeated litigation or two lawsuits for one case; and the acceptance of the lawsuits by the court does not violate the principle of "ne bis in idem".

If he decides to bring separate lawsuits against the liable third party and the insurer respectively, the insured shall have the right to decide whether to sue the liable third party first and then sue the insurer, or to sue the insurer first and then sue the liable third party.

3.2 Linkage in time between insurance subrogation and "original" claim

No matter whether the prosecution time of insurance claim is earlier or later, once a conclusion has been reached on the case, the insurer shall obtain subrogation after paying insurance indemnities, and may directly initiate the legal proceedings of claiming against the liable third party which the insured has not initiated yet, or continue the lawsuit of claiming against the liable third party which the insured has already initiated. If insurance indemnities only make up a part of the insured's loss, the insurer may join and complete the lawsuit of claiming against the liable third party which the insured has already initiated. Articles 94⁸ and 95⁹ of the *PRC Maritime Procedure Law* have specific provisions on such a matter.

(III) Article 12 of *Zhejiang Maritime Insurance Contract Guiding Opinions*

Zhejiang Provincial Higher People's Court enacted the *Guiding Opinions of Zhejiang Provincial Higher People's Court on Several Issues in the Trial of Cases on Disputes Concerning the Maritime Insurance Contract* issued on June, 2011, aiming to solve the above-mentioned procedural dilemma.

Article 12 of the *Guiding Opinions* stipulates¹⁰ that if the insured brings a separate lawsuit and claims for damages against the liable third party after suing the insurer for insurance indemnities, the lawsuit of claiming against the liable third party shall be "suspended" till the judgment of the dispute concerning the insurance contract is made. The intention of such provisions seems to urge the conclusion of the case on insurance claim, so as to confirm the linkage in time between insurance subrogation and the "original" claim as soon as possible.

However, such an article fails in two aspects.

Firstly, it only stipulates the situation that insurance claim starts first while the claim against the liable third party starts afterwards, but fails to stipulate the situation that the claim against the liable third party starts first while insurance claim starts afterwards.

Secondly, it requires suspending the trial of the case against the liable third party till the judgment of the dispute concerning the insurance contract is concluded, it is like putting the cart before the horse. As mentioned above, the liable third party is the final shoulder of responsibility no matter what kind of entanglement of interests exists between the insured and the insurer. The timely trial of the case on damages against the liable third party can facilitate the early settlement of the dispute. Whether the insured initiates the lawsuit of damages against the liable third party or the insurer initiates, continues or joins such a lawsuit will not influence the material consequence of whether or how should the third party shoulder the responsibility. Therefore, suspending the trial on damages against the liable third party seems exactly the same as delaying the trial, which is not good for the earlier determination of responsibility and settlement of dispute and deviates from the purposes of establishing the maritime litigation system.

⁸ Article 94 of the *PRC Maritime Procedure Law* provides that, "(w)hen an insurer exercises the right to indemnity by subrogation, if the insured does not bring an action against the third party causing the insured event, the insurer shall, in the name of itself, bring an action against the third party."

⁹ Article 95 of the *PRC Maritime Procedure Law* provides that, "(w)hen an insurer exercises the right to indemnity by subrogation, if the insured has brought an action against the third party causing the insured event, the insurer may request the court entertaining the case to change the party so as to exercise by subrogation the right of the insured to demand indemnity against the third party. Where the insurance indemnity obtained by the insured cannot make up all the losses caused by a third party, the insurer and the insured may, as joint plaintiffs, demand indemnity from the third party."

¹⁰ Article 12 of the *Guiding Opinions of Zhejiang Provincial Higher People's Court on Several Issues in the Trial of Cases on Disputes Concerning the Maritime Insurance Contract* (Z.G.F. [2011] No. 183) stipulates: "If the insured brings a separate lawsuit and claims damages against the third party after suing against the insurer for insurance indemnities and before any judgment is made, the people's court shall accept the case and suspend the trial of the previous case till the judgment of the case on dispute concerning the insurance contract is made. If the insurer is judged to shoulder the insurance indemnities, it shall, in accordance with relevant provisions of the Special Maritime Procedure Law of the People's Republic of China, become a relevant party in the lawsuit against the third party brought by the insured. If it is judged that the insurer should not shoulder the insurance indemnities or the insurance indemnities is insufficient to compensate the actual total loss of the insured, the insured may apply to the people's court for continuing the trial of the lawsuit against the third party concerning the part that is not indemnified." Though actual payment of indemnities and subrogation are not mentioned in this article, the summary words "in accordance with relevant provisions of the Special Maritime Procedure Law of the People's Republic of China" constitute the conditions for the insurer to exercise insurance subrogation, including providing the evidence of actual payment of indemnities.

The authors' view is that, insurance subrogation has both the connotation of substantive right and the connotation of procedural right, such a feature decides that there is no need to artificially intervene the trial process of the case by such means as the suspension of trial, the case on insurance indemnities against the insurer and the case on damages against the liable third party may be "naturally" accepted and tried. If a conclusion is first reached on the former, the insurer may initiate, continue or join the legal proceedings against the liable third party with the certificates of actual payment of indemnities and other relevant documents; if a conclusion is first reached on the latter and the insured has obtained compensations, the insurer may correspondingly deduct the amount of insurance indemnities; if the insured fails to obtain the compensations in full amount, the insurer may inherit the insured's right of claiming for damages against the liable third party after paying insurance indemnities (refer to the following discussion).

4. Linkage in Enforcement Phase of Judgment against the Liable Third Party

As mentioned above, relevant laws and judicial interpretations fail to make specific provisions on whether the insured has the right of claiming for insurance indemnities against the insurer after the insured sues the liable third party and obtains a favorable judgment but before the liable third party actually pays the damages, and there are completely different opinions and operations in the judicial practice, such as the "affirmation view" expressed in the (2005) *H.H.F.S.C.Zi No. 9 judgment* and the "Negation view" expressed in the (2008) *Y.H.F.S.C.Zi No. 137 judgment*.

4.1 Affirmation

According to the "affirmation view", the favorable judgment does not equal to the fact that the loss has been compensated. "The amount already paid by a third person to the insured" stipulated in Article 254 of the *PRC Maritime Law* is the actual compensations, while the favorable judgment is the confirmation of the insured's right of claim that can be applied to the court for enforcement. If the liable third party fails to actually enforce the judgment of the court and the insured has not actually obtained compensations from the liable third party, then there is no legal or ethical obstacle for the insured to claim insurance indemnities against the insurer. That is to say, the insured still can claim insurance indemnities against the insurer. After the insurer makes actual payment of indemnities, it obtains subrogation and may apply to the court for obtaining the insured's right of applying for compulsory enforcement against the liable third party. We agree with this point of view.

Both Article 254 of the *PRC Maritime Law*¹¹ and Article 60(2) of the *PRC Insurance Law*¹² stipulate that the insured cannot repeatedly obtain compensations from the liable third party and the insurer's insurance indemnities. Therefore, even if the insurer fails to apply for obtaining the right of applying for compulsory enforcement, the insurer still can require the insured to pay back the amount of insurance indemnities that are paid repeatedly when the insured applies to the court for compulsory enforcement and obtains compensations from the liable third party.

Whereas some of the insured only apply for the enforcement of the judgment in favor of him against the insurer when he simultaneously obtain a favorable judgment against the liable third parties and a favorable judgment against the insurers. As a result, the liable third parties may be able to avoid their responsibilities for illegal behaviors and this will be contrary to the purposes of both Maritime Law and Insurance Law.

To avoid such unreasonable results, the insurer, after insurance indemnity, shall be clearly granted the right of applying for the compulsory enforcement of the insured's favorable judgment the insured obtains beforehand against the liable third party. As mentioned above, insurance subrogation has both the connotation of substantive right and the connotation of procedural right. It shall not be limited only to the substantive right

¹¹ Article 254 of the *PRC Maritime Law* provides that, "(i)n effecting payment of indemnity to the insured, the insurer may make a corresponding reduction therefrom of the amount already paid by a third person to the insured."

¹² Article 60 (2) of the *PRC Insurance Law* provides that, "(w)here the insured has already obtained damages from the third party following the occurrence of an insured event mentioned in the preceding paragraph, the insurer may, when paying the indemnities, appropriately deduct the amount of compensation obtained by the insured from the third party."

before the proceeding and the procedural right after the proceeding start but before the judgment being concluded. Procedural right during the process of judgment enforcement shall also be one part of the meaning of the insurer's subrogation.

Judges Wang Yongdong and Huang Chungen take the view that insurance law only empowers the insurer such a subrogation that the realization of which needs to be confirmed by the lawsuit. Without such confirming lawsuit, the insurer cannot apply to the court for enforcement and the court cannot list the insurer as an applicant of enforcement either.¹³

It is our view that such confirming lawsuit is not necessary, and the court may directly list the insurer as an applicant of enforcement based on the insurer's application. Article 14 of the *Judicial Interpretation of Maritime Insurance* states that, "(t)he people's court accepting the case on the dispute concerning the insurer's subrogation shall only try the legal relations between the third party causing the insurance accident and the insured." The insurer only needs to submit the certificates of actual payment of indemnities and other documents that should be submitted for participating in the lawsuit to subrogate the insured. The judgment in favor of the insured against the liable third party is the judicial determination of the court after trying the legal relations between the liable third party and the insured. Therefore, the insurer does not need to apply to the court for trying such legal relations again. It can directly apply to the court for being listed as an applicant of enforcement with the certificates of actual payment of indemnities and other relevant documents, and realize the intention for the establishment of the insurance subrogation system through the enforcement of such favorable judgment.

Article 1 "Scope of Changes to Creditors" of the *Several Provisions of the Supreme People's Court on Changing and Adding Relevant Parties of Enforcement (Draft for Soliciting Opinions)* stipulates that, "(e)xcept for the creditors specified in the enforcement basis, the following persons may apply for enforcement or apply for continuing the enforcement procedures already started." Item 8 of the article lists the assignee of the creditor's right determined in the enforcement basis as a relevant party of enforcement. Such provisions are consistent with the intention for the establishment of the insurance subrogation system and the provisions in Article 93 of the *Maritime Procedure Law*. It is clear that after the insurer makes actual payment of indemnities, it not only obtains the insured's substantive right of claim against the liable third party, but also obtains the insured's right of applying for the enforcement of the favorable judgment against the liable third party.

4.2 Negation

According to the "Negation view" expressed in the (2008) *Y.H.F.S.C.Zi No. 137 judgment*,¹⁴ if the insured sues the insurer after claiming against the liable third party and obtaining the favorable judgment, the repeated litigation is constituted which should be avoided. When the insurance accident occurs, if the insured want to obtain insurance indemnity, he should sue the insurer first, not sue the liable party first. Otherwise, the insured should not be able to transfer his compensation against the liable third party to the insurer. Provisions in the *PRC Maritime Procedural Law*, concerning the marine insurer's exercising the subrogation for damage compensation, only extend the insurance subrogation from the time before the insured sue the liable third party, to the time when the proceeding against the liable third party in undergoing. It does not extend to the time after the judgment that the liable third party should pay compensation to the insured is concluded.

This point of view is not acceptable. Such an assertion is actually a misunderstanding of the functions and natures of insurance indemnity and insurance subrogation. As mentioned above, insurance indemnity takes the insured's "actual loss" as the premise. If the insured suffers loss due to the liable third party, the insured may claim against the liable third party, and the favorable judgment that the insured thus obtains is the foundation for the insured to obtain compensations for its loss. However, only when the liable third party actually pays

¹³ Refer to Wang Yongdong, Huang Chungen: Whether Subrogator be Changed to Applicant of Enforcement, <http://jxfy.chinacourt.org/>, September 8, 2009, <http://jxfy.chinacourt.org/public/detail.php?id=37320>, last access time: 2011-07-20.

¹⁴ Wu Yongqi: *Case of Ningbo Iron & Steel Co., Ltd. vs. Ningbo Branch of Ping An Property & Casualty Insurance Company of China, Ltd. on Dispute concerning the Ocean Marine Cargo Insurance Contract*, Maritime Justice Forum, 4th Issue, 2010, pages 20-24.

damages according to such favorable judgment can the insured's "actual loss" be made up. Therefore, the favorable judgment itself can not lead to any change of the insured's "actual loss", and can not prevent the insured from claiming for insurance indemnities for its "actual loss" against the insurer. After paying insurance indemnities, the insurer can then, in accordance with Article 93 of the *PRC Maritime Procedure Law*, "continue" to exercise the insured's right of requiring the third party to compensate for the insured's actual loss, till the liable third party "actually shoulders" its civil responsibility. Such insurance subrogation has both the connotation of substantive right and the connotation of procedural right, and shall exist not only before the insured sues the liable third party or before the court's judgment, but also during the enforcement phase.

4.3 *Negative effects of the "Negation view"*

If the insured is not permitted to make insurance claim against the insurer after obtaining the favorable judgment against the liable third party, it not only goes against the legal principles, but also may cause following negative effects as confusion and unbalanced interests.

4.4 *Goes against the intention of insurance laws*

As mentioned above, obtaining the favorable judgment against the liable third party does not mean the insured's actual loss has been made up.

So long as there is actual loss and such actual loss is covered in the insurance contract, the insured should have the right to claim for insurance indemnities against the insurer. Prohibition of insurance claim against the insurer in spite of the fact that the liable third party fails to actually perform its compensation responsibility goes against the principles of insurance indemnities.

Scholars even propose that "insurance laws should and must reflect and safeguard the insured's interests. Though the insurance subrogation system cannot provide double compensations to the insured, the original intention of establishing such a system is to provide the insured with double guarantee."¹⁵

Under the "Negation view", the insured will not be permitted to make insurance claim against the insurer for its actual loss. This result clearly goes against the purpose of insurance laws.

4.5 *Urge the insured to only choose insurance claim*

The "negation view" urges the insured to choose insurance claim only. Not permitting the insured to claim against the insurer after obtaining a favorable judgment against the liable third party is virtually requiring the insured to choose between suing the liable third party and suing the insurer.

In the practice, sometimes the insured is unable to obtain compensations in full amount even if it has obtained the favorable judgment against the liable third party for such reasons as the insufficient executive capacity of the liable third party etc.

In order to avoid such risk, the insured will choose to sue the insurer instead of the liable third party, which is not good for ascertaining the final compensation responsibility of the liable third party.

4.6 *The insured is placed in a dilemma*

The "negation view" places the insured in a dilemma.

On the one hand, according to the "negation view", if the insured chooses to sue the liable third party and even if it obtains a favorable judgment, though the limitation of action can be protected accordingly, which is good for the insurer to exercise subrogation, the insured will not be able to claim against the insurer for

¹⁵ Huang Yu: *On Disadvantages of Insurance Subrogation System*, Journal of Minjiang University, 6th Issue, 2005, pages 40-45.

insurance indemnity when the insured “actual loss” cannot be made up in full amount due to the liable third party’s reason.

On the other hand, will only suing the insurer but not suing the liable third party constitutes the waiver of “its right to claim compensation from the third party” stipulated in Article 253 of the *PRC Maritime Law*¹⁶ and Article 61 of the *PRC Insurance Law*¹⁷? If such a waiver is constituted, the insurer will not shoulder the responsibility of paying insurance indemnities, the insured will gain nothing as a result.

Not bringing a lawsuit or applying for arbitration against the liable third party cannot protect the limitation of action of the claim against the liable third party. Once the lawsuit of insurance claim lasts for a long time, which exceeds the limitation of action of the lawsuit against the liable third party, this will make the insurer unable to exercise subrogation. Can it be confirmed that “the insurer cannot exercise its right to claim compensation by subrogation due to a deliberate act or gross negligence by the insured” stated in above articles, and thus enables the insurer to “deduct, or demand reimbursement of, the corresponding portion of the indemnities”, or even refuse to shoulder the responsibility of paying insurance indemnities? If “a deliberate act or gross negligence” is confirmed, the insured will gain nothing. If the insured is not confirmed to have “a deliberate act or gross negligence”, the liable third party will be enabled to “avoid” the responsibility of paying damages because the insurer is unable to subrogate the insured.

4.7 *In contradiction with the principle of litigation benefit*

According to the “negation view”, the insured’s claim against the insurer will be directly rejected just because the insured get a favorable judgment against the liable third party. On purpose of avoiding such result, the insured must separately sue the insurer and the liable third party so as to protect the limitation of action and avoid suing the insurer after obtaining a favorable judgment. At the same time, the insured should be better to “pray” that the lawsuit against the liable third party would proceed “slowly” and “last” till the lawsuit against the insurer is concluded, which is apparently in contradiction with the principle of litigation effectiveness.

4.8 *Judicial authority will be fundamentally affected*

If the insured has brought a lawsuit on insurance indemnities and has gone through all hearings, but finally his claim against the insurer being directly rejected only because the insured obtained the favorable judgment against the liable third party, the judicial authority will be fundamentally affected.

4.9 *Goes against the stability and foreseeability of the laws and justice*

Further, when the insured can get an effective judgment on the lawsuit against the liable third party is related to the legal proceedings of the court, and the relevant parties can not forecast or ascertain the time going. According to the “negation view”, the settlement of claim by the insurer before the favorable judgment is obtained and the settlement of claim after the favorable judgment is obtained will have completely different legal consequences, which apparently goes against the stability and foreseeability of the laws and justice.

4.10 *Problem of coordination among different courts*

Problems of coordination will arise if different courts separately try the lawsuit against the liable third party and the lawsuit against the insurer.

¹⁶ Article 253 of the *PRC Maritime Law* stipulate: “Where the insured waives his right of claim against the third person without the consent of the insurer or the insurer is unable to exercise the right of recourse due to the fault of the insured, the insurer may make a corresponding reduction from the amount of indemnity.”

¹⁷ Article 61 of the *RPC Insurance Law* provides that:

“Where the insured waives its right to claim compensation from the third party after the occurrence of an insured event and before the insurer pays indemnities, the insurer shall not be liable for the payment of indemnities.

If after the insurer has paid indemnities to the insured, the insured, without the consent of the insurer, waives its/his/her right to claim compensation from the third party, such waiver shall be deemed invalid.

If, due to a deliberate act or gross negligence by the insured, the insurer cannot exercise its right to claim compensation by subrogation, it may deduct, or demand reimbursement of, the corresponding portion of the indemnities.”

To sum up, the “negation view” is unacceptable.

5. Conclusion

We agree with the “affirmation view”.

It is the due right of the insured to independently decide the approaches and objects of litigation. On the basis of reasonably protecting the insured’s interests, we should have a correct understanding of the substantial meanings and procedural meanings of insurance subrogation, so that the insurer is able to, after making the actual payment of indemnities, immediately continue the insured’s claim against the liable third party. Thus, at the same time of protecting the insurer’s lawful rights and interests, the liable third party can be urged to shoulder the responsibility of paying damages, and the social fairness and justice can be maintained.

The Study on Impacts of Market-based Measures for Greenhouse Gas Emission Reduction on Maritime Transport Costs

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Abstract

Main market-based measures for greenhouse gas emission reduction from the international shipping discussed in International Maritime Organization have now been studied and divided into three categories: a maritime global emission trading system (METS), an international fund for greenhouse gases emissions from ships (GHG Fund) and the market measures based on energy efficiency of ships by taxes or carbon credit transactions (EIS and SECT). The results showed the implementation of METS or GHG Fund mechanism would directly cause the ship voyage costs increased, while implementation of the EIS and SECT mechanism will cause the capital and operating costs of shipping increased. The discipline of shipping costs changes with fuel prices and carbon prices of some typical types of ships, such as bulk carriers, oil tankers, container ships and ro-ro ships was studied. The results showed that the implementation of market mechanism based on the fuel consumption would cause transport costs increased, and the higher the carbon prices, the higher the carbon cost. The greatest impact of the shipping costs was on the type of the container ship because such type of the ship usually operated at a higher speed. With the rise of fuel prices, the proportion of carbon cost in the total costs decreased gradually, indicating that the main motivation of saving energy for ship owners come from the high marine oil price rather than the carbon tax (or GHG Contribution), especially under the circumstance of the high fuel price.

Keywords: Greenhouse gases, Emission reduction, Market measures, Impacts, Shipping costs

1. Introduction

Nowadays, emission reduction of greenhouse gas from international shipping has become one of the hot topics in the international society, it was discussed both under the framework of UNFCCC and IMO. According to IPCC (2006), the emission from the international water transport refers to one from the fuel combustion of all the ships engaged in the international water transport, which includes the whole emission from the country of departure to the country of destination occurred on the sea, inland lakes and coastal waters, but does not include the emission of the fishing vessels.

The emission from the international aviation or navigation was excluded from the emissions of a country as it was difficult to define the country's boundary when the emission occurred, which resulted that there was no relevant legally documents binding the international maritime greenhouse gas emissions under the Framework of UNFCCC available. The Kyoto Protocol provided in Article 2.2: "the parties included in Annex I shall pursue limitation or reduction of emission of greenhouse gases not controlled by the Montreal Protocol from aviation and marine bunker fuels, working through the International Civil Aviation Organization and the

International Maritime Organization (IMO), respectively.” Based on the above provisions, the International Maritime Organization has commenced the research and negotiations on emission of greenhouse gases from international shipping since 1998. Up to now, two studies have been finished by IMO, namely “Study of Greenhouse Gas Emissions from Ships” (IMO, 2000) and “Second IMO GHG Study” (IMO, 2009). According to the second study, the carbon dioxide occupied 96% of the total greenhouse gas emission from the marine transportation. In 2007, about 1,046 million tons of CO₂ were exhausted from the global shipping, accounting for 3.3% of the global emissions, of which, 870 million tons CO₂ were exhausted from the international shipping, accounting for 2.7% of the global emissions. IMO (2009) report further forecasted that, being considered the growth of marine transportation, the greenhouse gas from shipping in 2050 will possibly grow up 2-3 times as much as that in 2007 if special operational measures are untaken.

In such the context, IMO proposed a package of measures based on technology, operation and market to achieve global goals of greenhouse gases emission reduction from international shipping. Research has shown that technology and operational measures were not enough to reach a satisfactory target under the expectations of continued world trade growth. So the 60th session of the marine environment protection committee (MEPC 60) of IMO focused more on market-based mechanism. In this paper, three main categories of market-based measures discussed in IMO had been analysed and evaluated. Quantitative analysis was applied to study the discipline of cost changes with fuel oil prices, GHG Contribution or carbon quota prices.

2. Qualitative Analysis of the Impacts of Market Mechanisms on Shipping Cost

At present, 3 main categories of the market measures have been discussed in IMO. They are global emissions trading system for greenhouse gas emissions from international shipping (METS), which was proposed by Norway(2010), the United Kingdom(2009), France(2010) and Germany (2010), an International Fund for Greenhouse Gas emissions from ships (GHG Fund) submitted by Denmark (2009) and the tax or transaction mechanisms based on ship energy efficiency proposed by Japan, International Chamber of Shipping (2011) and the United States(2010) respectively.

The core of METS measure is to introduce a maritime greenhouse gas emissions limits and transaction mechanism. The emissions cap and target period are set by general assembly of the Convention Party or Convention parties. According to the industry’s emissions cap and the history data reported by ships, a certain amount of free quotas were allocated to each ship per year, or a ship get certain quotas by auction. At the end of a year, every ship included in the system has the obligation of submitting emission quotas according to their actually carbon dioxide exhausted. In the case of quota insufficient, the ships may purchase the carbon quota outside the system like the Clean Development Mechanism (CDM) or similar carbon credit.

The CO₂ emission from a ship can be measured as the fuel consumed in the defined period multiplied by the fuel carbon emission factor. As the merchant ships mainly use the heavy fuel oil (HFO) while sailing, the oil consumption becomes the main factor which influence the emissions. In the scenario of full auction of carbon credits in an METS mechanism, shipping companies calculate their carbon costs as Eq. 1.

$$C_{ETS} = Q_{fuel} * C_{factor} * P_{quota} \quad (1)$$

Where:

C_{ETS} -- carbon cost occurred in the measures of ETS;

Q_{fuel} -- fuel consumption of a ship in the defined period;

C_{factor} -- carbon dioxide emission factor of the fuel used in international shipping;

P_{quota} -- carbon quota price in a carbon transaction market or CDM price.

The proposal MEPC/59/4/5 submitted by Denmark (2009) suggested a greenhouse gas emissions levy (or GHG Contribution) on the fuel oil ship purchased for international shipping. Its core design mentality is: The International Fund for Greenhouse Gas Emissions from Ships (the Fund) would establish a global reduction target for international shipping. A target which limits on net emissions from international shipping has been

set and would be achieved largely by purchasing approved emission reduction credits. The quantity of credits purchased by the Fund would be calculated on the basis of the difference between the actual emissions from international shipping and the agreed target. The offsetting activities of the Fund would be financed by a contribution paid by ships on every tonne of bunker fuel purchased.

According to the mechanism of GHG Fund, the carbon costs paid by the shipping companies shall be calculated as Eq. 2.

$$C_{GHGFund} = Q_{fuel} * Contri_{GHG} \quad (2)$$

Where:

$C_{GHGFund}$ -- carbon cost occurred in the measure of GHG Fund;

Q_{fuel} -- ship fuel consumption in the defined period;

$Contri_{GHG}$ -- the GHG Contribution levied in the measure of GHG Fund for per ton fuel oil used for international shipping, which will be affected by the severity of emission reduction targets, the price of CDM or other regulated carbon credits.

Therefore, the common points of above two market mechanism are to limit the greenhouse gas emissions from the international shipping, which were mainly achieved by restricting fuel consumption at the present stage.

For the measure of EIS proposed by Japan and the International Chamber of Shipping (2011) and SECT proposed by the United States (2010), they are more likely the hybrid measures mixed tax or trading mechanism with the standards of ship energy efficiency. The mandatory phased-in energy efficiency standards for new building and existing ships respectively have been defined in those proposals. Non-compliance ships required to pay a fine or offset emission through buying carbon credits. Under those mechanisms, the ship owners are to take into account future requirements for energy efficiency when they plan to build new ships, which will obviously cause the cost of new buildings increased. For existing ships, the implementation of the energy conservation technological or the ship energy efficiency management plan will cause the operating costs of the ship increased.

The above study illustrated those different market-based measures for emission reduction will have different impacts on shipping costs. As we know, shipping costs mainly consisted of capital costs, operation costs and voyage costs. The EIS or SECT measures will cause the capital and operating costs of ships increased, while the METS and GHG Fund mechanism linked with fuel consumption closely mainly caused the voyage cost of ships increased.

3. Quantitative Analysis of the Impact of Market Mechanism on Shipping Costs

Typical types of ships, such as bulk carriers, oil tankers, container ships and ro-ro ships have been selected to evaluate the impacts of market-based mechanisms on shipping costs. In this section, the proportion of the carbon cost among the total transportation costs has been quantified first. Then, the discipline of the transportation cost changing with the fluctuations of carbon price and fuel price is illustrated.

In case of an ETS or GHG Fund mechanism implemented, total shipping costs are to be composed by four categories as Eq. 3 showed below.

$$TC = NP + OC + FC + CC \quad (3)$$

where: TC means total annual cost of a ship, NP means annual capital cost of a new coming ship, OC means annual operating cost, FC means annual fuel cost and CC means annual carbon cost.

Carbon cost occurred in the implementation of ETS or GHG Fund mechanism is closely related to the total fuel consumption, carbon emission factors, carbon quota prices, GHG Contribution and fuel price, as the Eqs. 1-2

showed above.

3.1. Parameter setting

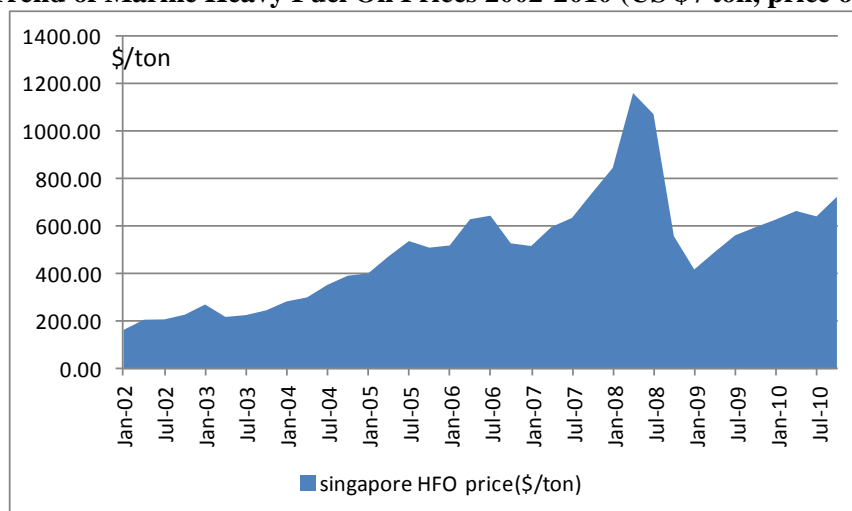
Some relative factors used in the quantitative analysis have been settled as follows:

The factor of the carbon dioxide emissions is determined by the carbon content of fuel and the share of non-oxidation of carbon in fuels. International ships are mainly driven by high-power low-speed diesel engine, consuming residual fuel oil (HFO) on sailing and marine diesel oil (MDO) at ports. The factor of CO₂ emissions of residual fuel oil and marine diesel oil is 3130 and 3190 kilograms per ton fuel oil respectively according to the newest massive test by the Lloyd's register (IPCC, 2006).

The price of carbon dioxide quota on European carbon trading market is mostly fluctuated from \$ 10 to \$ 50 per ton in recent years. Thus, the median carbon quota prices of \$15 and \$30/ton have been chosen in this quantitative analysis. With the reference to Eq. 1 and Eq. 2, we know that the carbon quota price of 15 or 30 dollars for per ton carbon dioxide will result the same impacts on shipping cost as the fuel levy of \$ 47 or \$ 94 per ton fuel oil does.

The marine fuel price was fluctuated much in the last decade. Figure 1 showed that shipping residual fuel oil price rose from \$ 165 per ton in 2002 to \$ 1,100 / ton in 2008, and then fell to \$ 400 / ton because of the financial crisis in 2009, and back to \$ 700 again in 2010. If we take the factors like economy growth, inflation and the use of low sulphur fuel oil and etc. into account, future marine fuel oil price is in a trend of rise, therefore, this article considers a fluctuation range from \$300 to \$900 per ton HFO for the quantitative investigation.

Figure 1: Trend of Marine Heavy Fuel Oil Prices 2002-2010 (US \$ / ton, price of Singapore)



Source: Clarkson Research Service

The parameters of costs for typical types of ships, including bulk carriers, oil tankers, container ships and ro-ro ships, were obtained from the study of CE Delft et al. (2010)(see table 1). No harbor expense is considered in this case, because the harbor expense is affected by the specific voyages and the charge level of every berth port, the big difference of each voyage made the harbor cost is difficult to be measured. If port expenses are covered, the fuel cost share in total cost is to drop.

Table 1: Sample Ships' Operational and Financial Parameters

Ship Types	Bulk		Tanker		Container ship	Ro-ro ship
	Handysize	Capesize	Handysize	VLCC		
	10,000-	1000,000-	20,000-	200,000+		
					4000~6000	2000+

	34,999	199,999	59,999		TEU	lane
Fuel consumption per day (ton)	22	60	32	90	135	39
Annual Operating days (d)	258	279	275	274	250	219
New building price (\$10 thousand)	2200	5000	3400	9200	4720	5450
Annual Capital cost (\$10 thousand)	225	506	347	937	481	225
Annual Operating cost (\$10 thousand)	170.6	268.1	276.2	381.3	292.8	213.2

Source: data based on CE Delft et al. (2010), reorganized by author

3.2. Impacts of Market-based Measures on Total Transportation Costs

According to the above data and Eq. 3, the study of impacts of ETS or GHG Fund measure on shipping costs showed that, with fuel prices of \$ 600 per ton, carbon quota prices 15 \$ per CO₂ ton, or an equivalent greenhouse gas emissions tax \$ 47 per fuel ton, the total cost of ro-ro ship is to be increased by 3.1%, VLCC tanker by 4.1%, the Capesize bulk carrier by 4.4% and 4000-6000TEU container ship by 5.74%. While in the scenario of carbon quota price of \$ 30 per CO₂ ton or equivalent to \$94 carbon tax per fuel ton, the implementation of market-based mechanism will cause the shipping cost increased by 6.3% -11.3% differently (see table 2).

Table 2: The Impact of Market-Based Measures on Maritime Transport Costs with Fuel Price \$ 600 / ton and Carbon Quota Price \$ 30 /CO₂ ton

Ship Type	Bulk		Tanker		Containership 4000~6000TEU	RoRo ships
	Handysize	Capesize	Handysize	VLCC		
Annual Capital Cost	2,250,000	5,060,000	3,470,000	9,370,000	4,810,000	5,550,000
Annual Operating Cost	1,705,970	2,680,896	2,762,116	3,813,054	2,927,538	2,132,487
Annual Fuel Cost	3,405,600	10,044,000	5,280,000	14,796,000	20,250,000	5,124,600
Annual Carbon Cost	532,976	1,571,886	826,320	2,315,574	3,169,125	802,000
Fuel Cost share in Total	46.3%	56.5%	45.9%	52.9%	72.4%	40.0%
Carbon Cost share in Total	6.8%	8.1%	6.7%	7.6%	10.2%	5.9%
Cost increase in percentage	7.2%	8.8%	7.2%	8.3%	11.3%	6.3%

3.3. The Discipline of Carbon Cost Changes with Different Fuel Oil Prices and Ship Types

The study further showed that the proportion of carbon costs also changed if the fuel price or carbon price changed. If a reasonable fuel price range of \$300-900 per ton and the carbon quota price of \$15 per ton CO₂ are set, the transport costs of handysize bulk carriers will rise by 2.90 - 4.65 %, capesize bulk carriers by 3.4 - 6.1% (see figure 2); handysize oil tanker by 2.88 - 4.60 %, VLCC by 3.23 - 5.55 % (see figure 3); 4000 – 6000TEU container ships by 4.1 - 8.76 % and ro-ro ships by 2.58 - 3.86 % (see figure 4).

The results showed that (see figures 2, 3 and 4) the higher the carbon quota prices, the greater the costs effected for all types of ships. Furthermore, with the rise of fuel prices, proportion of fuel cost in the total goes up while the carbon cost in the total costs reduced, for the fluctuations of fuel price was larger than that of the carbon price, the quantitative analysis illustrated clearly that stimulation of improving the energy efficiency for the shipowners of their ships is the fuel oil price itself instead of the fuel taxes or GHG Contribution. The stimulation works only if the greenhouse gas emission taxes or carbon quota price at a higher level, such as \$30 per ton CO₂ or more, which can cause the average shipping costs increased by more than 10 %.

Figure 2: The Impact of Implementation of ETS or GHG Fund on Bulker Transport Costs

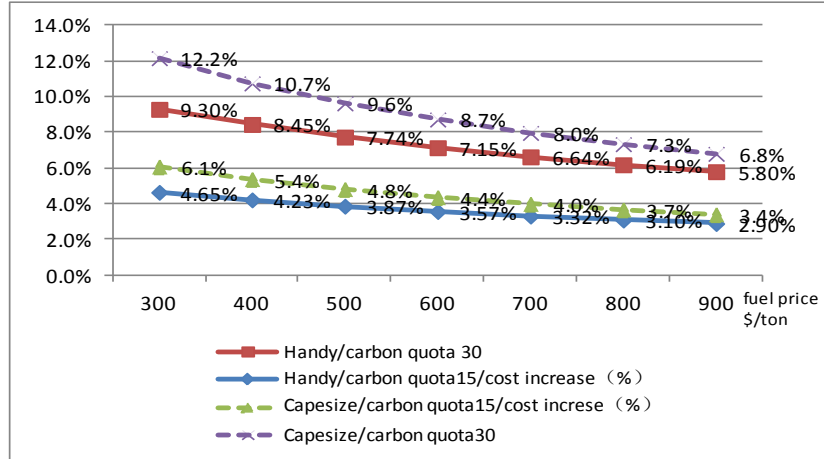


Figure 3: The Impact of Implementation of ETS or GHG Fund on Tanker Transport Costs

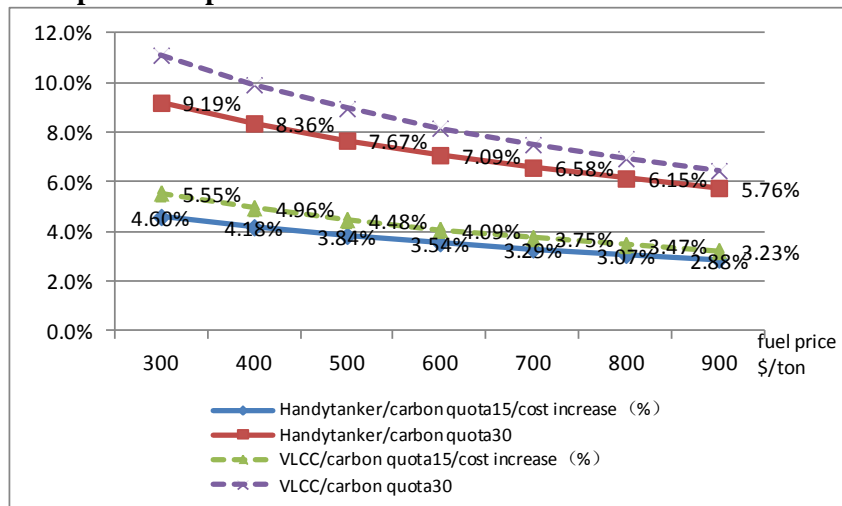
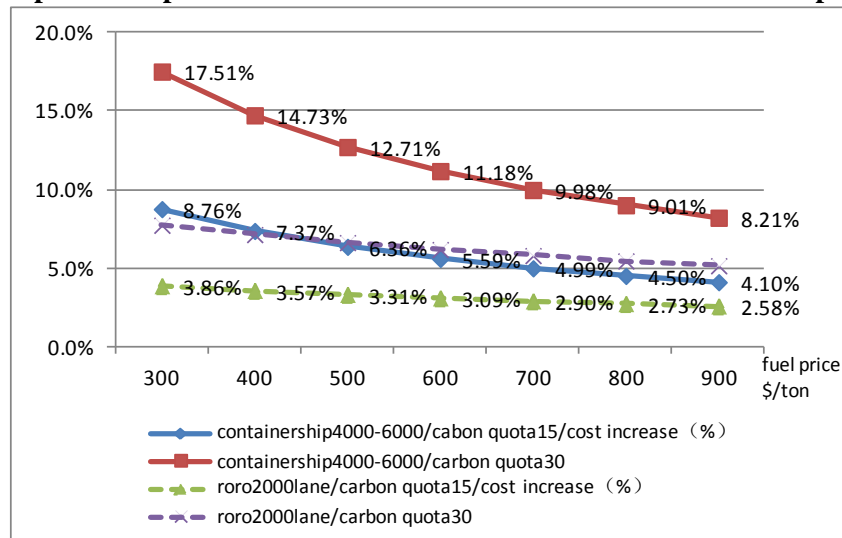


Figure 4: The Impact of Implementation of ETS or GHG Fund on Containership Transport Cost



4. Conclusion

The above studies showed that the implementation of the market-based mechanism relative to fuel

consumption will cause the transportation costs increased. The higher the carbon price, the greater the cost increased. The costs of container ships are impacted greatly because they are usually operated at relatively high speeds, while the costs of bulk carriers, oil tankers and ro-ro ships are impacted less.

The research concluded that the shipowners' inspiration of improving ship energy efficiency is mainly driven by the high fuel price itself rather than imposing the marine fuel carbon taxes. In fact, as the shipping transportation is an energy-hungry industry, contributions is to be made to the energy saving technology before introducing of the carbon taxes or other market-based measures. In a booming shipping market, the ship operator would not accept the low-speed operation but let the ship loaded with more cargoes and run fast as far as possible, for the increased fuel cost can be offset by additional freight revenue at this moment. In the point of view of stimulating the ship's energy efficiency, the higher fuel price is more effective than the market-based measures.

The harsh rules of setting a carbon dioxide emissions cap or net emission target for international shipping through an METS or GHG Fund mechanism may cause the cargoes to be transported by other ways in which there is no such kind of measures.

In the opinion of this article's authors, it is necessary to make a comprehensive assessment on such the market-based measures, and find more appropriate and effective solutions for the emission reduction of greenhouse gas from international shipping rather than with more burdens on the shipping industry, which is the greenest model in the global transportation.

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Regional Port Pollution Management - An Economic Investigation

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Abstract

This paper aims at studying the market-based policy on in-port air emission. Although the fraction of in-port air emissions is modest compared to at-sea air emission, in-port emissions generally occur near populated areas and have a higher impact on public health. Most previous studies on port pollution control have focused on technical designs and operating issues. In addition, while air emission from a port's operation may spread out and has influence over a wider region, few studies have analyzed emission control across ports. This study aims to complement this stream of research by examining the behaviours of ports and port users (shippers, shipping lines, etc.) if certain incentive or disincentive economic policy is implemented. Our investigation reveals that absent of inter-port coordination, pollution spill-over and inter-port competition can lead to distorted pollution taxation. This will lead to excessive pollution and sub-optimal social welfare. Therefore, despite the potential competition among the ports in a region, it is important for them to coordinate their pollution control efforts. Our study recommends a regional approach in pollution control, and suggests areas where inter-port cooperation is needed among competing ports.

Keywords: Air Pollution, Port Environment, Emission Reduction, Game Theory, Regional Governance

1. Introduction

The expansion of international trade and global economy has fuelled continued growth of the maritime industry. Port development and expansion bring about significant economic benefits to local industries as well as local consumers. However, port activities also generate negative environmental impacts and pollution emissions to the local community. Absent of explicit regulation in the forms of emission standard or pollution tax, such negative externalities and resulting social costs will not be considered in the production process of the marine industry. As a result, the market price and output level will deviate from social optimum, leading to reduced social welfare.

As discussed by Talley (2003), port operations and shipping activities often lead to certain negative environmental impacts such as vessel oil spills, ballast water disposal, air pollution, anti-fouling pollution, dredging, vessel scrapping, and waste disposal at sea. Alternative economic and regulatory tools may be used in environmental control. For instance, regulators may require shipping firms to adopt certain abatement technologies to reduce pollution effluent before discharge. The Port of Los Angeles has required ships to switch from cheap bunker oil to relatively clean diesel when approaching the port. In other cases, regulators may set the maximum allowable emission level so as to control the total amount released.

In addition to technical restrictions, policy makers may introduce economic regulations such as taxes on and/or subsidies to the polluters, so that to induce shipping outputs to an appropriate level. Among all these instruments, pollution tax has been extensively used not only in transport sectors such as aviation and road transport, but also other public utilities such as electricity generation, water supply and waste processing. One major advantage of pollution tax is that it reduces the effluent at minimum cost by equating the marginal costs to all the polluters, even if there is a large variation in pollution abatement costs and significant heterogeneity among the producing firms (Calthrop and Proost, 2003). In recent years, regional and/or national carbon taxes have been introduced in countries such as the United States (some states), South Korea, Australia, UK, and Switzerland. Several OECD countries have introduced green tax system reforms since the early 1990s, including Sweden in 1991, the Netherlands between 1971 and 1996, Finland in 1997, Denmark during 1994-1998, and Norway between 1991 and 1998 (OECD, 1999). Ecological tax for energy saving has been implemented in Germany since 1999 and the entire European Union since 2003 (Bellido-Arregui, 2003).

In the marine and port sector, many kinds of financial incentives and disincentives have already been introduced (IAPH, 2007). Sweden ports posted incentives (Fairway Dues) for low emission in 1997, and Norway ports imposed tax on NO_x emission in 2007. The Port of Los Angeles and the Port of Long Beach have jointly developed Clean Air Action Plan in 2006. The ports provide financial incentives (dockage rate reduction) to vessel operators for slowing down to 12 knots or less within 40 nautical miles from the harbour entrance. The Port Authority of New York and New Jersey developed a Clean Air Strategy in 2009 in which an incentive program is established for switching to low sulphur fuel and to fund the cost differential between the use of low sulphur fuel and conventional bunker fuel.

The port authorities have offered important considerations on the pollution tax and environmental incentives. However, most of these policies have considered pollution tax either at port level or national level. That is, there is only one decision maker involved (i.e., a local port authority or a central government). Such an assumption does not always hold in practice, as pollution at a port may have some spill-over effects on its neighbours. That is, if two ports are located near to each other, the effluent of one port may generate negative spill-over effects or inter-port externalities to the others. Unless the two local governments or port authorities behave like one single decision maker, the conclusions obtained in previous studies may not hold. For example, pollutants released at Shenzhen Port may cause some damages in the adjacent port of Hong Kong, and vice versa. Another example of possible spill-over effects is among neighbouring ports in Norway and Sweden. The US Environmental Protection Agency (2009) estimated ship emission inventory on Category 3 (C3) vessels using C3 engines for propulsion with data in calendar year 2002¹. As summarized in Table 1, interport emissions often accounted for over 80 percent of the total inventory. The data are presented in total and thus spill-over emission from a particular port to other ports cannot be directly identified. Still, the magnitudes of interport emissions suggest that they shall be recognized when regulators design pollution and environmental related policies.

**Table 1: Contribution of Near Port and Interport Emissions to the Total C3 Inventory
(Calendar Year 2002)**

Region	Metric Tonnes								
	NO _x			PM ₁₀			PM ₂₅		
	Port	Interport	Total	Port	Interport	Total	Port	Interport	Total
Alaska East (AE)	833	17,218	18,051	80	1,345	1,425	74	1,237	1,311
Alaska West (AW)	0	60,019	60,019	0	4,689	4,689	0	4,313	4,313
East Coast (EC)	48,313	171,247	219,560	4,126	13,375	17,501	3,796	12,305	16,101
Gulf Coast (GC)	33,637	139,260	172,897	3,169	10,874	14,043	2,916	10,004	12,920
Hawaii East (HE)	2,916	19,684	22,600	251	1,524	1,775	231	1,402	1,633
Hawaii West (HW)	0	31,799	31,799	0	2,498	2,498	0	2,297	2,297
North Pacific (NP)	14,015	12,022	26,037	1,216	938	2,154	1,119	863	1,982

¹ Category 3 engines are specified as having displacement above 30 liters per cylinder (L/cyl).

South Pacific (SP)	20,079	84,076	104,155	1,525	6,569	8,094	1,403	6,044	7,447
Great Lakes (GL)	491	14,528	15,019	44	1,135	1,179	41	1,044	1,085
<i>Total Metric Tonnes</i>	<i>120,285</i>	<i>549,852</i>	<i>670,137</i>	<i>10,413</i>	<i>42,945</i>	<i>53,358</i>	<i>9,580</i>	<i>39,510</i>	<i>49,089</i>
Region	HC			CO			SO ₂		
	Port	Interport	Total	Port	Interport	Total	Port	Interport	Total
Alaska East (AE)	27	570	597	66	1,344	1,410	641	9,977	10,618
Alaska West (AW)	0	1,989	1,989	0	4,685	4,685	0	34,786	34,786
East Coast (EC)	1,603	5,674	7,277	3,864	13,367	17,231	45,952	99,072	145,024
Gulf Coast (GC)	1,142	4,615	5,757	3,305	10,864	14,169	24,187	80,665	104,852
Hawaii East (HE)	96	653	749	230	1,535	1,765	1,891	11,291	13,182
Hawaii West (HW)	0	1,053	1,053	0	2,484	2,484	0	18,546	18,546
North Pacific (NP)	540	398	938	1,152	938	2,090	8,329	6,966	15,295
South Pacific (SP)	678	2,786	3,464	1,876	6,561	8,437	11,715	48,728	60,443
Great Lakes (GL)	17	481	498	40	1,134	1,174	346	8,420	8,766
<i>Total Metric Tonnes</i>	<i>4,103</i>	<i>18,219</i>	<i>22,322</i>	<i>10,533</i>	<i>42,912</i>	<i>53,445</i>	<i>93,062</i>	<i>318,450</i>	<i>411,512</i>

Note: 1) PM₂₅ is estimated from PM₁₀ using a multiplicative adjustment factor of 0.92.

2) Port or near port inventories were estimated based on the emissions associated with ship movements when entering or exiting the major US ports, while interport inventories were calculated from vessels used in travelling between ports which extended from the US coastline to a 200 nautical mile boundary.

Therefore, joint decision by adjacent ports or their respective local governments may be desired when pollution control policies are designed. Such regional or inter-city cooperation could be important yet has not been fully recognized in previous studies. One exception is Yin (2003), which considers the corrective taxes under oligopoly market structure. However, that study mainly focused on firm level at a specific market without considering overall market outcome. Possible regional cooperation among adjacent regulators is not considered either.

While it has been well recognized that the market structure in the marine industry plays an important role in determining the price and output levels (e.g., Ferrari and Benacchio (2000), Lam and Yap (2006), Luo *et al.* (2010), and Ducruet *et al.* (2011)), few studies have explicitly considered their implications on the choice of pollution tax level. In order to fill this research gap, this paper investigates the effects of pollution tax taking into account of (possible) regional port cooperation as well as competition among shipping lines and marine ports. While we have explicitly modelled the case of two adjacent ports, the model can be easily extended to other cases such as two airports in adjacent cities, or even the case of two power generation plants in adjacent cities.

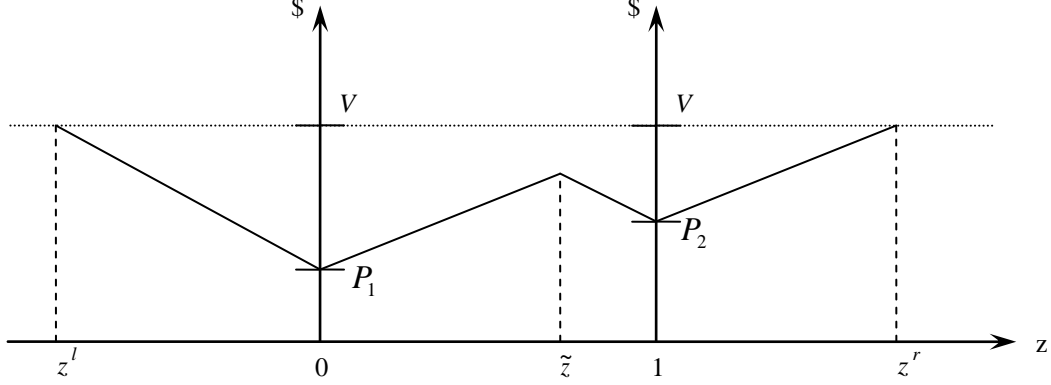
The structure of this paper is laid out as follows. Section 2 describes the basic economic model. Optimal pollution tax derivation is given in Section 3. The analytical results on market equilibria are presented in Section 4. The last section provides concluding remarks.

2. The Basic Economic Model

Following a similar approach as used by Zhang *et al.* (2010) and Basso and Zhang (2007), we consider an infinite linear region or port catchment areas where potential shippers (also referred as consumers hereafter) are distributed uniformly with a density of one shipper per unit of length. Two competing ports are located at 0 (Port 1 in city 1) and 1 (Port 2 in city 2), each is served with n_i ($i = 1, 2$) symmetric shipping lines (see Figure 1). The shipping lines are symmetric in the sense that they produce homogeneous output with constant marginal cost c . At each port, the total output is defined as $Q_i = \sum_{k=1}^{n_i} q_{ik}$, where q_{ik} is the output of liner k .

Market price at port i is denoted as P_i . For mathematical tractability, we consider a symmetric case where shipping lines have the same cost function $C(q_{ik}) = cq_{ik}$, where c is the constant marginal cost per unit of output.

Figure 1: Consumer Distribution and Ports' Catchment Areas



The total cost for a consumer located at $0 \leq z \leq 1$ and going to Port 1 is given by $P_1 + (4t)z$, where $4t$ (> 0) represents the consumer's transportation cost per unit of distance in going to and from a port. Such a cost specification may reflect real transportation cost or simply consumers' preference to a particular port. By choosing either Port 1 or Port 2 (but not both) the consumer derives the following respective net utilities:

$$U_1 = V - P_1 - 4tz, \quad U_2 = V - P_2 - 4t(1 - z), \quad (1)$$

where V denotes (gross) benefit from marine shipping. Assuming all consumers in the $[0,1]$ interval consume, then the indifferent consumer $\tilde{z} \in (0,1)$ is determined by setting $U_1 = U_2$, or:

$$\tilde{z} = \frac{1}{2} + \frac{P_2 - P_1}{8t}. \quad (2)$$

Given that port 1 also captures consumers at its immediate left side, define z^l as the last shipper on the left side of the region who utilizes port 1. Similarly, define z^r as the last shipper on the right side of the city who goes to port 2. With the uniform distribution of shippers, z^l and z^r are computed as:

$$z^l = -\frac{V - P_1}{4t}, \quad z^r = 1 + \frac{V - P_2}{4t}. \quad (3)$$

Each port's demand is computed as:

$$Q_1 = \tilde{z} + |z^l| = \frac{1}{2} + \frac{P_2 - P_1}{8t} + \frac{V - P_1}{4t}, \quad (4)$$

$$Q_2 = (1 - \tilde{z}) + (z^r - 1) = \frac{1}{2} - \frac{P_2 - P_1}{8t} + \frac{V - P_2}{4t}. \quad (5)$$

From (4)-(5) the inverse demands of the ports are given by:

$$P_i(Q_1, Q_2) = (2t + V) - 3tQ_i - tQ_j, \quad i, j = 1, 2, \quad (6)$$

which take the linear functional forms. Since the market demands depends on both Q_i and Q_j , there are intra and inter port competitions simultaneously.

The shipping and port terminal operations at port i lead to pollution to the residents in city i (local pollution) as well as to the residents in the adjacent city j (spill-over). The pollution cost to city i is defined as in (7), where α is the pollution costs associated with per unit shipping volume at its own city and β represents inter-city externalities. When the two ports are close to each other, thus there are significant spill-over effects, β approaches α . Otherwise, if two ports are far from each other and thus there is not much spill over, β approaches 0.

$$PC_i = \alpha Q_i + \beta Q_j, \quad \alpha > \beta > 0. \quad (7)$$

The ports' and shipping lines' behaviour is modelled as the following two-stage game: In the First Stage, each port chooses its respective port service charge w_i to maximize its profit. In Stage Two, shipping lines compete in Cournot to maximize their individual profits. Without loss of generality, it is assumed that the two ports have constant marginal costs which are normalized to zero. A port's profit function is specified as below, where $Q_i^* = \sum_{k=1}^{n_i} q_{ik}^*(w_1, w_2)$ denotes the total outputs of shipping lines at port i .

$$\Pi_i(w_1, w_2) = w_i Q_i^*. \quad (8)$$

The profit maximization problem for shipping line k ($k = 1, 2, \dots, n_i$) at port i ($i = 1, 2$) is specified as:

$$\text{Max}_{q_{ik}} \pi_{ik} = (P_i - c - w_i) q_{ik}. \quad (9)$$

This game can be solved in reverse. Shipping lines' output in stage two is obtained by solving the system of first-order conditions derived from equation (9), thus that:

$$q_{ik}^*(w_1, w_2) = \frac{(2n_j + 3)(2t + V - c - w_i) + n_j(w_j - w_i)}{(8n_i n_j + 9n_i + 9n_j + 9)t}. \quad (10)$$

Substitute (10) into (8), optimal port charges can be obtained by jointly solving two ports' best response functions. We thus obtain the port charges and liner outputs at equilibrium as follows:

$$w_i^*(n_1, n_2) = \frac{(14n_i n_j + 18n_i + 15n_j + 18)(2t + V - c)}{35n_i n_j + 36n_i + 36n_j + 36}, \quad (11.1)$$

$$q_{ik}^*(n_1, n_2) = \frac{3(n_j + 1)(14n_i n_j + 18n_i + 15n_j + 18)(2t + V - c)}{(8n_i n_j + 9n_i + 9n_j + 9)(35n_i n_j + 36n_i + 36n_j + 36)t}. \quad (11.2)$$

The pollution cost at each port is therefore calculated as:

$$PC_i = \frac{1}{t} [(\lambda_i \alpha + \lambda_j \beta)(2t + V - c)], \quad (12)$$

where $\lambda_i = \frac{3n_i(n_j+1)(14n_in_j+18n_i+15n_j+18)}{(8n_in_j+9n_i+9n_j+9)(35n_in_j+36n_i+36n_j+36)}$, $i, j = 1, 2$.

Clearly $\lambda_i > 0$ and so $\partial PC_i / \partial t = -(\lambda_i \alpha + \lambda_j \beta)(V - c) / t^2 < 0$. That is, when transportation cost is increased, outputs of shipping services will be reduced and thus pollution costs will be lower. “Local” social welfare at city i can be derived, which is the sum of consumer surplus at the city, total profits of shipping lines serving its port, tax revenue of the local government, and the (negative) pollution cost. The social welfare is therefore specified as²:

$$SW_i \equiv \varphi_i = \frac{t}{4} (7Q_i^2 - Q_j^2 + 2Q_i Q_j) + t(Q_j - Q_i - 1) + (P_i - c)Q_i - PC_i. \quad (13)$$

Thus, at equilibrium the local social welfare is:

$$\varphi_i = \frac{(2t+V-c)}{4t} \left[(2t+V-c)(4\lambda_i - 2\lambda_i \lambda_j - 5\lambda_i^2 - \lambda_j^2) - 4t(\lambda_i - \lambda_j) - 4(\alpha \lambda_i + \beta \lambda_j) \right] - t. \quad (14)$$

Define the regional welfare as the sum of the local social welfare in the two ports as $\Phi = \varphi_1 + \varphi_2$, it can be derived that at equilibrium:

$$\Phi = \frac{(2t+V-c)}{2t} \left[(2t+V-c)(2\lambda_1 + 2\lambda_2 - 2\lambda_1 \lambda_2 - 3\lambda_1^2 - 3\lambda_2^2) - 2(\alpha + \beta)(\lambda_1 + \lambda_2) \right] - 2t. \quad (15)$$

Without government intervention, pollution costs will not be considered in private firm’s output decision. Therefore, output and pollution levels are usually above social optimal level. Pollution tax may be introduced to force firms to take into account of the negative effects caused by pollution. However, as discussed in previous sections, most of previous studies only considered the case of single regulator / decision maker. In the following sections we will analyze the cases where competition among shipping lines and ports are present.

3. Market Equilibria with Alternative Forms of Pollution Tax

Consider the case where regulators in the two cities (hereafter “city”) impose pollution tax s_i ($i = 1, 2$) on shipping lines for each unit of shipping volume. Clearly this will influence equilibrium outputs and thus pollution cost, which is denoted as $PC_i = \alpha Q_i(s_1, s_2) + \beta Q_j(s_1, s_2)$ for clarity. In the absence of inter-city coordination, the two cities will independently choose tax levels in order to maximize their respective local welfare. If there is coordination, the two cities will behave like one single identity such that the regional welfare is maximized. The general taxation process is modelled as a three-stage game: In the First Stage, local city governments decide their tax charge s_i , either independently or with coordination. In the Second Stage, each port decides its service charge w_i . In the Third Stage, shipping lines compete in Cournot.

Note with pollution tax, the profit maximization problem of shipping lines is defined as:

$$Max_{q_{ik}} \pi_{ik} = (P_i - c - w_i - s_i) q_{ik}. \quad (16)$$

The outputs and port service charges at equilibrium given pollution tax at each port are, respectively:

² For details of social welfare derivation, please refer to the Appendix.

$$q_{ik}^*(s_1, s_2) = 3(n_j + 1) \left[\frac{(14n_i n_j + 18n_i + 15n_j + 18)(2t + V - c - s_i) + 3n_j(n_i + 1)(s_j - s_i)}{(8n_i n_j + 9n_i + 9n_j + 9)(35n_i n_j + 36n_i + 36n_j + 36)t} \right], \quad (17.1)$$

$$w_i^*(s_1, s_2) = \frac{(14n_i n_j + 18n_i + 15n_j + 18)(2t + V - c - s_i) + 3n_j(n_i + 1)(s_j - s_i)}{(35n_i n_j + 36n_i + 36n_j + 36)}. \quad (17.2)$$

Clearly, pollution tax s_i imposed by port i would reduce the outputs of shipping lines serving its own port but increase the outputs of shipping lines serving the rival port j . The intuition is clear: *ceteris paribus*, imposing pollution tax would increase the production costs of shipping lines serving the port, which reduces their competitiveness against liners in the rival port. Such a feature has not been considered in previous studies. Note where there is an identical increase in pollution tax in the two ports, i.e. $ds_1 = ds_2 = ds$, we have:

$$dq_{ik}^* = \left(\frac{\partial q_{ik}^*}{\partial s_1} + \frac{\partial q_{ik}^*}{\partial s_2} \right) ds = - \left(\frac{3(n_j + 1)(14n_i n_j + 18n_i + 15n_j + 18)}{(8n_i n_j + 9n_i + 9n_j + 9)(35n_i n_j + 36n_i + 36n_j + 36)t} \right) ds < 0. \quad (18)$$

That is, if pollution tax is introduced in both ports, shipping lines' outputs will be all reduced. In the following sections we consider the ports' decisions on pollution with and without coordination.

3.1 Local Pollution Taxation without Regional Coordination

If there is no coordination / cooperation between the two cities, each city will set pollution tax in order to maximize its local welfare φ_i as specified in (13). With the new market equilibrium outputs and port service charges as defined in (17.1) and (17.2), the first-order conditions for ports' local welfare optimization problem can be obtained by solving $[\partial \varphi_i(s_1, s_2) / \partial s_i] = 0$. This leads to the following optimal taxes:

$$s_i^{LO*} = 4te_i - (V - c)d_i + \alpha a_i - 3\beta b_i, \quad (19)$$

where
$$e_i = \frac{8n_i^2 n_j^2 - 246n_j^2 n_i - 42n_j n_i^2 - 54n_i^2 - 378n_i - 594n_j - 621n_i n_j - 270n_j^2 - 324}{18n_i(n_j + 1)(32n_i n_j + 35n_i + 35n_j + 36)},$$

$$d_i = \frac{2076n_j^2 n_i + 1620n_j n_i^2 + 837n_i^2 + 2106n_i + 2646n_j + 784n_i^2 n_j^2 + 1350n_j^2 + 4185n_i n_j + 1296}{18n_i(n_j + 1)(32n_i n_j + 35n_i + 35n_j + 36)} > 0,$$

$$a_i = \frac{1467n_i^2 + 2754n_i + 2826n_i^2 n_j + 5463n_i n_j + 1360n_i^2 n_j^2 + 2706n_i n_j^2 + 1350n_j^2 + 2646n_j + 1296}{18n_i(n_j + 1)(32n_i n_j + 35n_i + 35n_j + 36)} > 0,$$

$$b_i = \frac{80n_i^2 n_j^2 + 154n_i n_j^2 + 82n_i^2 n_j + 90n_j^2 + 141n_i n_j + 90n_j - 18n_i - 3n_i^2}{18n_i(n_j + 1)(32n_i n_j + 35n_i + 35n_j + 36)} > 0.$$

A somewhat unexpected result is that, without regional coordination, pollution tax s_i^{LO*} can be negative. That is, instead of reducing output to social optimal level so that pollution level is controlled, without regional coordination the cities may instead subsidize shipping lines so that to encourage a higher shipping volume. This new insight is due to the fact that market structure in the liner and port markets are explicitly considered

in our study. Note the competition between the two ports may be limited if their catchments are sufficiently separated (i.e., large t in our model). When there is only a small number of competing liners serving the ports (i.e., small n_i), the liner market is best characterized as oligopoly instead of perfectly competitive. Therefore, the output may be lower than social optimal level due to insufficient competition. More importantly, in the absence of regional coordination, the two city governments only value the size of local economy and care only local pollution. Spill-over pollution to their neighbours is not considered. As a result the two cities have strong incentive to help their local marine sector in the competition against the adjacent port. Consequently, they may want to subsidize rather than charge the local marine sector, leading to a negative pollution tax s_i^{LO*} . A positive tax will only be introduced when a port's desire to control pollution outweighs the possible incentive of subsidy.

The determination process of pollution tax can be further clarified by checking the comparative statics. It can be shown that:

$$\frac{\partial s_i^{LO*}}{\partial \alpha} = a_i > 0 \quad \text{and} \quad \frac{\partial s_i^{LO*}}{\partial \beta} = -3b_i < 0 . \quad (20)$$

That is, as the pollution cost / damage to the local resident gets larger, the city government would increase pollution tax thus to control local pollution ($\partial s_i^{LO*} / \partial \alpha > 0$). On the other hand, *ceteris paribus*, an increase in spill-over damage but not the local pollution damage will actually prompt the government to reduce pollution tax ($\partial s_i^{LO*} / \partial \beta < 0$). Intuitively, if pollution only harms the neighbour city without creating local damage, there is no incentive for a city government to charge its local marine sector a pollution tax. Instead, increased pollution to the neighbour will reduce rival's competitiveness thus indirectly help its own marine sector. Of course, in practice with moral pressure local governments are unlikely to do so. But it is clear that absent of regional coordination local governments have no economic incentive to control its own marine sector for the benefit of rival port.

In reality, a change in shipping technology usually affects local and spill-over pollution damage simultaneously. If there is an identical change in pollution damage, i.e., an identical change in both α and β so that $d\alpha = d\beta = dP$, the overall effect on pollution is:

$$ds_i^{LO*} = \left(\frac{\partial s_i^{LO*}}{\partial \alpha} + \frac{\partial s_i^{LO*}}{\partial \beta} \right) dP = (a_i - 3b_i) dP . \quad (21)$$

It can be shown that $(a_i - 3b_i) > 0$. That is, if local and spill-over pollution per unit shipping volume increases (decreases) simultaneously, local government will increase (decrease) pollution tax.

We further examine the effect of market size and competition as measured by the number of the shipping lines. It can be shown that:

$$\frac{\partial s_i^{LO*}}{\partial n_i} > 0 . \quad (22)$$

That is, an increase in the number of shipping firms would raise the market output and consequently pollution cost. In order to control an effluent emission, the local government would set a higher tax rate so as to restrict market outputs to an appropriate level. However, the sign of $\partial s_i^{LO*} / \partial n_j$ cannot be determined because it is dependent on many parameters related to pollution spill-over, inter-port competition and competition in the liner market.

3.2 Pollution Taxation with Regional Coordination

If the two city governments cooperate thus that they behave as if there is a central government coordinating the pollution taxes, the objective is best specified as in equation (23), thus that pollution taxes s_1 and s_2 are chosen jointly to maximize the regional social welfare $\Phi = \varphi_1 + \varphi_2$, which is the sum of local social welfare in the two cities.

$$\begin{aligned} & \text{Max}_{s_1, s_2} \Phi, \\ & \text{where } \Phi = \varphi_1 + \varphi_2 = \frac{3t}{2}(Q_1^2 + Q_2^2) + t(Q_1 Q_2 - 2) + \sum_i [(P_i - c_i)Q_i - PC_i]. \end{aligned} \quad (23)$$

Solving (23) one can obtain the coordinated pollution tax as:

$$s_i^{CO*} = (\alpha + \beta) - \frac{(8n_i n_j + 9n_i + 18n_j + 18)(2t + V - c - \alpha - \beta)}{12n_i(n_j + 1)}. \quad (24)$$

Note this total social welfare maximizing tax is lower than a standard Pigouvian tax (Pigou, 1932). A standard Pigouvian tax equals to marginal externality damage, which in our model is $(\alpha + \beta)$. Again, this is due to the fact that we have explicitly modelled the competition in the port and liner markets. When there is insufficient competition (e.g., small number of competing liners as measured by n_i , or the two ports are not easily substitutable as measured by a larger transportation cost t), the market output will be below social optimal. Thus the coordinated ports, or a hypothetical central government, will have an incentive to subsidize shipping lines by charging tax lower than marginal environmental cost. Such a result is consistent with Buchanan (1969), Barnett (1980), and Baumol and Oates (1988), who also considered taxation in markets which are not perfectly competitive³.

In comparison to the case of pollution tax without coordination, note:

$$\frac{\partial s_i^{CO*}}{\partial \alpha} = \frac{\partial s_i^{CO*}}{\partial \beta} = \frac{20n_i n_j + 21n_i + 18n_j + 18}{12n_i(n_j + 1)} > 0. \quad (25)$$

That is, with coordination, damages caused to either port, as measured by parameters α and β , will be compensated in the pollution tax. That is the main benefits from regional cooperation / coordination. The effects of intra and inter port competition on pollution tax are definite as evidenced by the following comparative statics:

$$\frac{\partial s_i^{CO*}}{\partial n_i} = \frac{3}{2n_i^2}(2t + V - c - \alpha - \beta) > 0, \text{ and } \frac{\partial s_i^{CO*}}{\partial n_j} = \frac{1}{12(n_j + 1)^2}(2t + V - c - \alpha - \beta) > 0. \quad (26)$$

The interpretation is straightforward, as there are more shipping lines competing in the markets thus output will be larger, the coordinated pollution tax shall always increase to compensate the increased pollution level.

4. The Effects of Pollution Tax

After solving the optimal pollution tax with and without regional coordination, we investigate the effects of pollution tax at market equilibrium by comparing key results across different scenarios as modelled in

³ Under different theoretical model settings, some scholars found that an imperfect competition does not necessarily imply that the optimal tax should be lower than marginal damages, for example, Yin (2003) and Simpson (1995).

previous sections.

4.1 Comparison of Pollution Tax with and without Regional Coordination

When two cities coordinate to maximize total regional welfare, the optimal “coordinated pollution tax” imposed will be higher than the “local tax” charged by independent local governments if $(2t + V - c - \alpha - \beta) > (4t - 4\beta)$. Otherwise, coordinated pollution tax will be equal to or lower than local tax. To see this, note by (19) and (24), the difference between coordinated tax and the local tax is calculated as:

$$s_i^{CO*} - s_i^{LO*} = \zeta(-2t + V - c - \alpha + 3\beta), \quad (27)$$

$$\text{where } \zeta = \frac{(648 + 810n_j^2 + 1536n_i^2n_j + 1584n_j^2n_i + 2943n_in_j + 800n_i^2n_j^2 + 1350n_i + 1458n_j + 729n_i^2)}{36n_i(n_j + 1)(32n_in_j + 35n_i + 35n_j + 36)} > 0.$$

Therefore, s_i^{CO*} is greater than s_i^{LO*} if $(V - c) - \alpha + 3\beta - 2t > 0$. Such a condition is more likely to hold as: (a) the two ports are more substitutable to each other (i.e., lower transportation cost t), (b) the shipping service has a high net value ($V - c$) thus shipping demand is high, (c) shipping pollution is less harmful to local residents (i.e. a smaller α), but (d) spill-over effect β is larger. Intuitively, as two ports are more substitutable so that there is increased inter-port competition, a local government’s incentive to help its local marine industry will be stronger. Similarly, if shipping services bring greater benefits to the economy, local government’s incentive to help its own marine sector in the competition with rival port will be stronger. Such considerations (competitive externalities) will not be present in the case of coordinated case. Therefore, pollution tax in the coordinated case will be higher than local tax, so that traffic volume and pollution level in the coordinated case will be reduced to regional optimal level.

The effects of local pollution cost α and spill-over pollution cost β are more straightforward: with regional coordination the spill-over effects will be fully addressed, while independent local government will only take care of local pollution damage. In general, coordinated pollution tax is more likely to be higher than independent local pollution tax as the marine service is of greater economic value, and the two ports are more related to each other in terms of increased inter-port competition and higher spill-over effects.

4.2 Market Outputs and Prices

With independent local pollution tax, the output of firm k at port i is:

$$q_{ik}^{LO*} = \frac{1}{6tn_i} [(V - c - \alpha)\kappa_i + 4tf_i + 3\beta g_i], \quad (28)$$

$$\text{where } \kappa_i = \frac{(68n_in_j + 69n_i + 75n_j + 72)}{(32n_in_j + 35n_i + 35n_j + 36)} > 0, \quad f_i = \frac{(14n_in_j + 18n_i + 15n_j + 18)}{(32n_in_j + 35n_i + 35n_j + 36)} > 0, \text{ and}$$

$$g_i = \frac{(4n_in_j - n_i + 5n_j)}{(32n_in_j + 35n_i + 35n_j + 36)} > 0.$$

With coordinated pollution tax, a shipping line’s output is:

$$q_{ik}^{CO*} = \frac{1}{4tn_i} (2t + V - c - \alpha - \beta). \quad (29)$$

The difference of outputs in the two cases is therefore:

$$q_{ik}^{CO*} - q_{ik}^{LO*} = -\frac{(40n_i n_j + 33n_i + 45n_j + 36)(-2t + V - c - \alpha + 3\beta)}{12n_i(32n_i n_j + 35n_i + 35n_j + 36)}. \quad (30)$$

Again, the relative size of outputs depends on the sign of $(-2t + V - c - \alpha + 3\beta)$. The result is consistent with the findings in Section 4.1. *Ceteris paribus*, higher pollution tax will lead to lower output, or $s_i^{CO*} > s_i^{LO*}$ implies $q_{ik}^{CO*} < q_{ik}^{LO*}$.

It can be shown that with coordinated pollution tax, the market price of liner services precisely reflects social cost so that $P_i^{CO*} = c + \alpha + \beta$. In addition, the relative size of liner service prices under the two pollution taxes again depends on the sign of $(-2t + V - c - \alpha + 3\beta)$ since:

$$P_i^{CO*} - P_i^{LO*} = \frac{2(20n_i n_j + 18n_i + 21n_j + 18)(-2t + V - c - \alpha + 3\beta)}{3(32n_i n_j + 35n_i + 35n_j + 36)}, \quad (31)$$

which again states that if $s_i^{CO*} > s_i^{LO*}$ then $P_i^{CO*} > P_i^{LO*}$.

5. Concluding Remarks

This paper has examined the managerial and policy implications of pollution tax (or negative incentive) on the environmental protection and social welfare improvement. With the set up of two competing ports, shipping lines need to face not only direct competition within the port, but also indirect competition from the other adjacent port. Such a theoretical model allows us to consider the effects of port competition and coordination with respect to taxation implications, a feature not present in previous studies on port pollution. Within this constructed conceptual framework, the inter-relationship between the quantities of air emissions from two adjacent ports and alternative regulatory scenarios are analyzed, allowing alternative pollution control policies to be evaluated.

This paper contributes to the development of future government policy on low carbon shipping and provides guidance to shippers on the measurement and reduction of air emissions across their supply chains. In our study, a regulatory instrument discussed is to impose the effluent fees (or negative incentive) to the polluters. Furthermore, the cooperative manner of local governments is explicitly considered in the investigation in order to explore possible improvements on social welfare from the traditional cases.

Our investigation reveals that absent of inter-port coordination, pollution spill-over and inter-port competition can lead to distorted pollution taxation. The “coordinating tax” can be either higher or lower than the “local tax” depends on market responses to the emission fees, i.e., changes in consumption and production. Without regional coordination, there are two conflicting forces determining pollution tax. Cities have incentive to control local pollution which calls for pollution tax. However, there are also incentives for the ports to subsidize its marine sector in the competition with rival port. Whether governments would introduce subsidy or pollution tax is therefore dependent on the joint effects of pollution and competition. Local tax does not truly reflect marginal social damage / cost.

Our study suggests that there is room for social welfare improvement when two local governments cooperate in the decision of (coordinated) tax rate. Inter-port externalities will be considered in such a case, and social optimality can be reached with market price signals equal to total social cost. That is, despite potential competition among the ports in a region, it is important for them to coordinate their pollution control efforts.

Overall, this study provides some new and important insights for regulators with respect to environmental

policy. In particular, our investigation results call for cooperation between local governments, which improves the effectiveness of pollution tax in the presence of adverse externalities between the ports. While this study brings about many useful policy recommendations, the theoretical model used are subject to possible limitations due to the simplifying assumptions used, such as the assumptions of constant marginal operating and pollution costs, unchanged production technology in response to pollution tax, and homogeneous shipping services. While such simplifications are unlikely to change our results qualitatively, there may be quantitative changes if one would like to precisely estimate the effects of alternative taxation schemes. After all, theoretical models can only complement, but not totally substitute empirical studies. Estimation with real market data on this issue will be of great value. Numerical examples can also be constructed with our model if rich data are available with respect to port specific demand and cost function, liner competition, pollution cost on adjacent ports and product differentiation between adjacent ports. In addition, as discussed earlier in this study there could be other instruments for environment protection. Comparative analysis of alternative instruments in practical implementation, although beyond the scope of the current study, will surely bring significant value to the marine industry.

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Appendix

Social welfare at each port is defined as a summation of net consumer surplus, producer surplus (or shipping lines' profits), port profit, and tax revenue of the local government. Then, the pollution cost will be subtracted from the total value of social welfare. With reference to Figure 1 consumer surplus is specified as:

$$\begin{aligned}
 cs_1 &= \int_0^{\left|z^l\right|} [V - P_1(Q_1, Q_2) - 4tz] dz + \int_0^{\tilde{z}} [V - P_1(Q_1, Q_2) - 4tz] dz, \text{ and} \\
 cs_2 &= \int_0^{(1-\tilde{z})} [V - P_2(Q_1, Q_2) - 4tz] dz + \int_0^{(z^r-1)} [V - P_2(Q_1, Q_2) - 4tz] dz,
 \end{aligned} \tag{A.1}$$

where $\tilde{z} = \frac{1}{2} + \frac{P_2 - P_1}{8t}$, $z^l = -\frac{V - P_1}{4t}$, and $z^r = 1 + \frac{V - P_2}{4t}$. Note Q_1 and Q_2 do not depend on z , whereas \tilde{z} , z^l , and z^r depend on Q_1 and Q_2 . Substitute $P_i(Q_1, Q_2)$ from (6) into (A.1), then consumer surplus for each port can be written as:

$$cs_i = \frac{t}{4} (7Q_i^2 - Q_j^2 + 2Q_i Q_j) + t(Q_j - Q_i - 1). \tag{A.2}$$

Note that total net consumer surplus for these two local cities is:

$$CS = cs_1 + cs_2 = \frac{3t}{2} (Q_1^2 + Q_2^2) + t(Q_1 Q_2 - 2). \tag{A.3}$$

Then, the respective total shipping line profits, port profits, tax revenues, and total pollution costs can be expressed as follows:

$$\begin{aligned}
 \sum_{k=1}^{n_i} \pi_{ik} &= \sum_{k=1}^{n_i} (P_i - c - w_i - s_i) q_{ik}, & \Pi_i &= w_i Q_i, \\
 GovtRev_i &= s_i Q_i, \text{ and} & PC_i &= \alpha Q_i + \beta Q_j.
 \end{aligned} \tag{A.4}$$

Therefore, the local social welfare and regional welfare are expressed respectively as follows:

$$SW_i \equiv \varphi_i = \frac{t}{4} (7Q_i^2 - Q_j^2 + 2Q_i Q_j) + t(Q_j - Q_i - 1) + (P_i - c)Q_i - PC_i, \tag{A.5}$$

$$\Phi = \varphi_1 + \varphi_2 = \frac{3t}{2} (Q_1^2 + Q_2^2) + t(Q_1 Q_2 - 2) + \sum_i [(P_i - c)Q_i - PC_i]. \tag{A.6}$$

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